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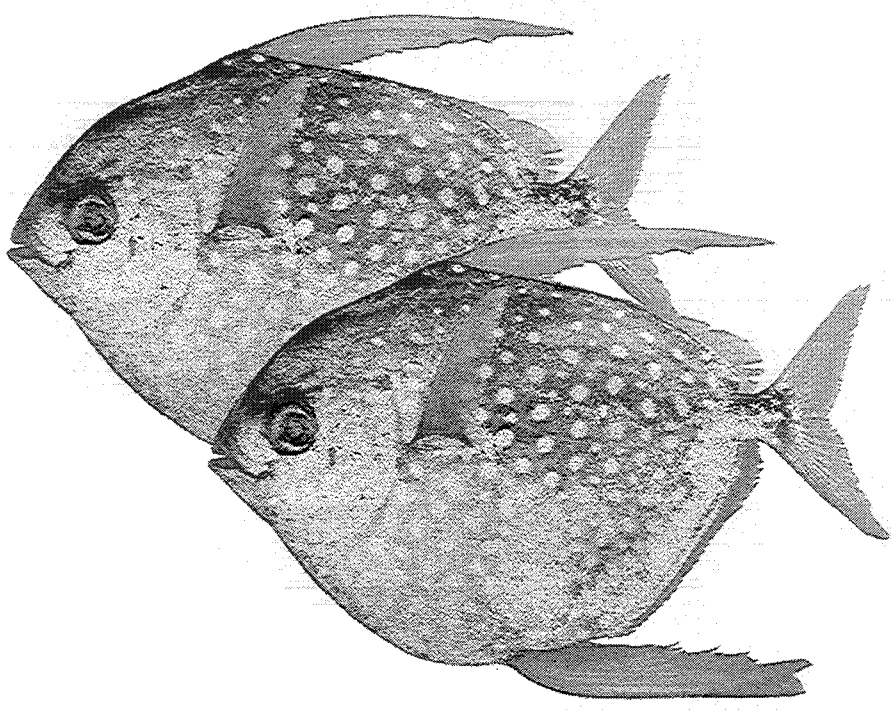

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Abstract

Francis, M. P., Griggs, L. H., Baird, S. J., Murray, T. E., & Dean, H. A. 1999: Fish bycatch in New Zealand tuna longline fisheries. ***NIWA Technical Report 55.*** **70 p.**

Tuna longlines are often regarded as environmentally benign, but for some target species, areas, and seasons, bycatch levels are high, leading to concerns about stock sustainability. The objectives of the present study were (a) to determine the species, and estimate the total numbers, of non-target fish species taken in New Zealand's tuna longline fisheries; and (b) to estimate the total catch and discard rate of marlin species. We used scientific observer data to determine which fish species were caught, and to estimate the amount of fish taken, by observed vessels. These estimates were then scaled up to provide estimates of the total fish bycatch. Bootstrap procedures were used to produce 95% confidence limits on our estimates. Marlin discard rates were also determined from the observer data.

The number of hooks set by tuna longline vessels in the New Zealand Exclusive Economic Zone (EEZ) declined by about 90% from a maximum of 24–27 million hooks per year in 1980–82 to 2–4 million hooks in 1994–97. Overall observer coverage was low (6.7%), but increased through time. Coverage was considered too low in 1986–87 and 1987–88 to be representative of the catch, so our analyses apply to the nine-year period 1988–89 to 1996–97. Coverage of the domestic fleet was low before 1994–95.

More than 165 000 fish and 67 species of fishes were observed on tuna longlines. Most species were rare: the commonest 17 species made up 97% of the observed catch. During the period 1988–89 to 1996–97, blue shark (*Prionace glauca*) and albacore (*Thunnus alalunga*) dominated the catch (32% and 29% respectively). Southern bluefin tuna (*Thunnus maccoyii*), Ray's bream (*Brama brama*), porbeagle shark (*Lamna nasus*), and mako shark (*Isurus oxyrinchus*) formed a second tier of species, contributing 6–8% of the catch each. Oilfish (*Ruvettus pretiosus*), moonfish (*Lampris guttatus*), broadbill swordfish (*Xiphias gladius*), lancetfish (*Alepisaurus* spp.), butterfly tuna (*Gasterochisma melampus*), dealfish (*Trachipterus trachypterus*), and yellowfin tuna (*Thunnus albacares*) each made up 1.2–3.3% of the catch. The remaining species (bigeye tuna, *Thunnus obesus*, school shark, *Galeorhinus galeus*, deepwater dogfish, Squaliformes, and rudderfish, *Centrolophus niger*) made up less than 1% each. Only 152 striped marlin (*Tetrapturus audax*) were observed over the nine-year period, and other marlin species were very rare. In recent years (1994–97), the changing fleet composition (from mainly foreign and charter vessels to mainly domestic vessels) has resulted in a shift in species composition: the proportion of albacore has increased (42%) and the proportion of blue shark has decreased (23%).

Blue shark was the main non-target species caught throughout the EEZ. Around North Island, porbeagle shark, oilfish, moonfish, lancetfish, mako shark, and butterfly tuna were the next commonest non-target species, and around South Island, Ray's bream, dealfish, porbeagle shark, and in some years butterfly tuna, moonfish, and rudderfish were important. Since 1988–89, catches of blue shark, southern bluefin tuna, broadbill swordfish, butterfly tuna, bigeye tuna, and oilfish have declined substantially, but catches of albacore tuna, yellowfin tuna, lancetfish, and rudderfish have increased. Other species showed no clear trends. For most species, there were large differences in catch per unit effort between the domestic and foreign and charter fleets, and/or between northern and southern New Zealand.

In 1996–97, 301 striped marlin were reported on Tuna Longlining Catch Effort Returns (TLCERs). If vessels completing TLCERs and Catch Effort Landing Returns (CELRs) had similar striped marlin CPUE, and similar reporting rates, the number of striped marlin caught in 1996–97 would have been about 380. Analysis of observer data produced a total catch estimate of 570 striped marlin (range 370–792) for the same year. Both estimates suffer biases, and the observer coverage was low. About 72% of striped marlin were alive when landed, and all observed vessels released their catch.

Introduction

Tuna longline fishing is often considered a highly specific, environmentally sound fishing technique compared with, for example, trawling and pelagic driftnet fishing. However, for some target species, areas, and seasons, bycatch levels are high, leading to concerns about stock sustainability. Oceanic sharks are an important bycatch throughout the Pacific Ocean (Bailey *et al.* 1996, He & Laurs 1998, Heberer in press, Stevens in press), and the demand for shark fins in Asia has led to increased catches over the last few decades (Bonfil 1994, Hayes 1996). Some oceanic sharks have low reproductive rates, long life spans, and possibly slow growth, and they segregate by size and sex. These features make them vulnerable to overfishing (Compagno 1990, Hoenig & Gruber 1990).

Billfish species are also caught in tuna longline fisheries. Blue marlin (*Makaira mazara*) is the most common bycatch species in the western tropical Pacific longline fishery, whereas broadbill swordfish (*Xiphias gladius*) and striped marlin (*Tetrapturus audax*) predominate in Australia (Bailey *et al.* 1996, Government of Australia 1998). In New Zealand, broadbill swordfish and striped marlin are commonly caught, and blue and black marlin (*M. indica*) are occasionally taken (Ross & Bailey 1986). These species are targeted by recreational big game fishers during summer with much of the catch being tagged and released (Saul & Holdsworth 1992). The only commercial fishery with a regular catch of marlins, albeit as bycatch, is the tuna longline fishery.

Since October 1987, foreign licensed vessels have been required to release all billfish caught in the New Zealand EEZ. Domestic fishers may retain broadbill swordfish but must return other billfish species to the water alive or dead. Commercial fishers view the practice of discarding dead marlin as a waste of a valuable resource, and sought a change in regulations to allow them to retain dead marlin, especially striped marlin which have high commercial value overseas. Recreational fishers, on the other hand, are concerned about any potential impact on the recreational fishery from increased domestic tuna longline activity, especially fishing effort which might target striped marlin. This longline effort was perceived by recreational fishers as the cause of low abundance of striped marlin off east Northland from 1983 to 1987. Both commercial and recreational sector groups have requested information on the numbers of marlin caught and on the discard rate before changes to the current regulations are considered.

Studies of tuna longline bycatch in the temperate Pacific Ocean are limited: general reviews were recently provided by Heberer (in press) and Stevens (in press). Preliminary assessments of bycatch composition and quantity are available for tuna longlines in Australian waters (Stevens 1992, Government of Australia 1998). Vessel logbook data and limited scientific observer data on catches in the New Zealand EEZ were presented by Ross & Bailey (1986), Stevens (1992) and Bailey *et al.* (1996). Michael *et al.* (1987, 1989) reported on the catches of five Japanese tuna longliners off the east coast of North Island in 1987 and 1988.

The Ministry of Fisheries is responsible for determining the impacts of fishing on associated or dependent species, including non-target fish species, taken as bycatch during normal fishing operations. New Zealand also has an obligation to provide estimates of the numbers of non-target fish species taken in the tuna longline fishery as part of its contribution to the Ecologically Related Species Working Group under the Convention for the Conservation of Southern Bluefin Tuna. The present study, carried out in 1997–98, was funded by the Ministry of Fisheries (Project ENV9702) in order to meet these obligations. The objectives addressed in this report were:

1. To determine the species and estimate the total numbers of non-target fish species, particularly sharks, taken as bycatch in tuna longline fisheries during the period 1988–89 to 1996–97.
2. To estimate the total catch and discard rate of marlin species taken as bycatch in the domestic tuna longline fishery during 1996–97.

Methods

Tuna longline vessels submit information on their fish bycatch to the Ministry of Fisheries on Tuna Longlining Catch Effort Returns (TLCERs). However, these returns probably underestimate bycatch because much of it is discarded at sea (Michael *et al.* 1987, 1989, Stevens 1992). More reliable data on the amount of fish bycatch are available from the Ministry's Scientific Observer Programme, in which observers aboard commercial vessels identify, count, and sometimes weigh, measure and sex the bycatch. Only a small proportion of the tuna longline fishing effort in the New Zealand EEZ has been observed, and this is the only independent source of information available on the scale of bycatch and discarding in the fishery. We used scientific observer data to determine which non-target fish species are caught, and to estimate the amount of fish taken, by observed vessels. These estimates were then scaled up to provide estimates of the total fish bycatch.

The New Zealand tuna longline fishery comprises three separate sectors: foreign licensed, foreign chartered, and domestic vessels. The fishery was initiated by foreign licensed vessels (mainly Japanese, but also Taiwanese and Korean) in the early 1950s, and licensing of this fishery began in 1979. New Zealand fishing companies first chartered foreign vessels in the 1988–89 fishing year (1 October–30 September), and domestic vessels entered the fishery in 1990–91. Foreign licensed vessels ceased fishing in New Zealand at the end of 1994–95. Only one New Zealand company has chartered foreign vessels, and for confidentiality reasons we cannot present catch and effort data separately for the charter fleet. We therefore combined the data for foreign licensed and chartered vessels in this report, because both fleets generally fish the same areas and use the same fishing gear and methods. Another reason for combining the two fleets was that observer coverage rates were low in some years and some geographical strata (*see* below), resulting in some unobserved strata; combining the fleets overcame this difficulty. In the rest of this report, we refer to the foreign licensed and foreign charter vessels as the "foreign and charter" fleet, and New Zealand owned and operated vessels as the "domestic" fleet.

Southern bluefin tuna is the usual target species of tuna longline vessels (78% of sets recorded on TLCERs), with bigeye tuna a distant second (16%). Albacore tuna, which is the tuna species caught most frequently on longlines, was listed as the target for only 5% of sets. Northern bluefin tuna, broadbill swordfish, and yellowfin tuna were each targeted by less than 1% of sets. In this study, we defined non-target species to be all other species caught on the longlines. Nevertheless, we also included information and analyses for the six target species where relevant.

Data on the number of hooks set, and the numbers of each species caught, were extracted from the scientific observer database managed by NIWA for the Ministry of Fisheries (*l_line*) for all observed longline sets. The numbers of hooks set by all vessels in the fishery were extracted from the groomed version of the TLCER database maintained by NIWA (*tuna*). Further grooming of both data sets was necessary. The main error checks and corrections are described below.

1. Some species identifications during the early years of the observer programme were unreliable. Some observers did not differentiate between porbeagle and mako sharks, so we report data for both species combined since 1988–89, and for the two species separately since 1992–93. One observer in 1994–95 was also uncertain about distinguishing the species, so data for the two species collected on those two trips were combined. Other groups of closely related or difficult to identify species were also combined (e.g., deepwater dogfishes of the Order Squaliformes). Unidentified fishes were classified as teleosts, sharks, or rays. Records of uncommon species were checked for accuracy where possible by examining photographs taken by observers. Species reported by only one observer were regarded as misidentifications (unless the number of records was very low, or they could be verified by photographs) and were treated as unidentified.
2. Some domestic vessels filled out Catch Effort Landing Returns (CELRs) instead of TLCERs. It was beyond the scope of the present study to extract and error check all such records from the CELR database. However, CELR data were extracted for one large vessel which carried observers for two trips and returned a mixture of TLCER or CELR forms; this achieved a more complete coverage of that effort. Where observed effort was recorded for a vessel, but there was no equivalent effort on the TLCER or CELR databases, the observed effort was added to the total

effort. Comparison of the hook numbers for the same sets in the observer and TLCER databases revealed some minor discrepancies (often the result of rounding by the skipper) which were corrected. Data for one abandoned set and one set for which there was no haul record were omitted.

3. Inspection of CPUE by trip revealed that one observer consistently under-reported non-target species (K. Richardson, NIWA, pers. comm.). The five trips completed by this observer were deleted from the data set.

The distributions of each of the commonest non-target species were determined from plots of the start positions of observed sets on which each species was caught. Start-of-set positions are not ideal, because tuna longlines may span up to 180 km of ocean, but in the absence of more precise information on the capture location, they provide a general indication of the area inhabited by a species.

CPUE was expressed as the number of fish caught per 1000 hooks set. Preliminary analyses showed that CPUE often varied significantly between the domestic and foreign and charter fleets, and also among different parts of the EEZ. To provide precise estimates of the numbers of fish caught, it was necessary to stratify the data to reduce the within-stratum variation in CPUE. We assumed that water temperature would be a major factor influencing CPUE, and initially divided the EEZ into three latitudinal bands: north of 38° S, between 38 and 43° S, and south of 43° S. Results from those analyses were presented by Baird *et al.* (1998). Detailed inspection of the data indicated that this stratification was inappropriate. Observer coverage was greatest in the northern and southern zones (*see* Results), with only sparse coverage (none in some years) of the central zone. Furthermore, the CPUE of a number of species was markedly different between the eastern and western parts of the central zone. We therefore reduced the geographical stratification to two regions – north and south – which were separated at 37° S on the west coast and 43° 50' S on the east coast (*see* Figure 5). The north region corresponds with seabird bycatch assessment areas 1, 2, and 5, and the south region with seabird areas 3 and 4 (Murray *et al.* 1992).

Catch rates of oceanic pelagic species are strongly seasonal, so temporal stratification of the data would be desirable. Foreign and charter vessels fished only a short season, mainly between April and July. Domestic vessels operated for much of the year, with effort peaking in January–July, but observer coverage was mostly limited to the period April–June (*see* Results). This made seasonal stratification of the data impractical. Caution is therefore required in the interpretation of the domestic data, because the available observer coverage may not be representative of all seasons. The final data stratification therefore involved two regions (north and south), and two fleets (foreign and charter, and domestic).

The numbers of fish caught by observed vessels were scaled up to the total fishing effort deployed in the fishery in two ways. First, the number of fish observed in each stratum in a fishing year was multiplied by the ratio of the number of hooks set to the number of hooks observed in that stratum. This is equivalent to multiplying the raw observed CPUE (number per 1000 hooks) by the stratum fishing effort. Scaled totals were then summed across strata to provide an estimate of the annual catch.

Second, bootstrap estimates (Efron & Tibshirani 1993) of CPUE and numbers of fish caught were derived for the 17 commonest species (or species groups; *see* Table 6), and for porbeagle and mako sharks combined. Two separate sets of bootstraps were carried out for each species and each of the fishing years 1988–89 to 1996–97:

1. *Stratum CPUE*: 1000 bootstraps were run on the observed CPUEs for each longline set within the four region and fleet strata described above to produce mean stratum CPUEs and lower and upper 95% confidence limits. These CPUE estimates were plotted against fishing year to determine whether there were any trends over the nine-year period.
2. *Total numbers*: Bootstrap samples were taken from the observed CPUEs for each longline set within each stratum and scaled to the total stratum effort to give an estimated stratum catch. The estimated stratum catches were then summed across all four strata to give a total catch. This procedure was repeated 1000 times to produce a total estimated catch with 95% confidence limits.

Results from the two methods of estimating total numbers were almost identical. The big advantage of the bootstrap method is that it enables the estimation of standard errors and 95% confidence limits around the total catch estimates. In this report, we present only the bootstrap estimates. An attempt was made to validate observer-based estimates of bycatch by comparing them with catches reported in TLCERs. The latter are likely to be most reliable for the highly valued commercial species (especially southern bluefin tuna, bigeye tuna, and albacore), so we also estimated the numbers of target species caught. Poor correspondence might indicate biased observer coverage, biased reporting by vessel skippers, or both.

The approach used to estimate the numbers of striped marlin caught on longlines was similar to that for the other species described above, but with some important modifications. The focus was on 1996–97, so foreign licensed vessels do not feature in the main analysis. Because of the few marlin observed, data for domestic and chartered vessels were combined. Marlins reported on CELRs were not used in our estimates because most were reported as weights rather than numbers. The possibility of using these data should be more thoroughly investigated in future, but for this analysis catch estimates were limited to longline sets reported on TLCERs, and effort was determined from both TLCERs and CELRs. The abundance of marlin in New Zealand is highly seasonal, so we stratified the data by season (summer: December–March; autumn: April–July). Therefore our analysis included only a single fleet stratum (charter and domestic combined), a single geographical stratum (north; marlin do not occur in the south stratum), and two seasonal strata. Catch rates were bootstrapped as described above to estimate the total numbers of striped marlin caught. The catch of other marlin species was not estimated because only striped marlin were observed caught in 1996–97 (although one black marlin was recorded on TLCERs by fishers during this period). Scientific observer data were also used to determine the proportion of striped marlin still alive when landed.

Results

Fishing effort and observer coverage

The number of hooks set by tuna longline vessels in the New Zealand EEZ has declined from a maximum of 24–27 million hooks per year (mean 25.8 million) in 1980–82 to 2–4 million hooks in 1994–97 (mean 2.7) (Figure 1, Table 1). This decline of about 90% in fishing effort resulted from a reduction in foreign licensed vessels fishing in New Zealand. Foreign chartered and domestic vessels began operating in 1988–89 and 1990–91 respectively. The effort of the former has remained steady (except for 1995–96 when no foreign licensed or chartered vessels fished New Zealand waters), and the domestic effort increased initially and then stabilised. Fishing effort by fleet and fishing year (1 October–30 September) is shown in Figure 2 and Table 2.

The first observer trips on tuna longliners were in June–July 1987 (Michael *et al.* 1987). Two trips were completed, but only one trip collected sufficient data to warrant inclusion in the database. Observer coverage since then has been low, with only 6.7% of hooks being observed overall (Figure 2, Tables 2 and 3). The percentage coverage was similar for both foreign and charter and domestic fleets. Up to the end of 1996–97, observers had completed 84 trips and observed 2167 sets. However the pattern of observer coverage varied annually, with an increase in recent years. In 1986–87 and 1987–88, coverage was less than 1% of the hooks set. It increased to a mean of 4.3% (range 2.6–6.0%) during the next four years, and then to a mean of 23.6% (range 7.7–33.4%) for the last five years.

Coverage of foreign and charter vessels was 2.6–6.0% from 1988–89 to 1991–92, and then increased rapidly to include more than half of the fleet from 1993–94 onwards. Observer coverage of the domestic fleet began in 1991–92 with 6.4% of the hooks being observed. There was no coverage in 1992–93, and only three sets (0.2% of hooks) were observed in 1993–94. Coverage of the domestic fleet was 7.1–11.9% for the period 1994–95 to 1996–97. Coverage of both fleets was higher overall in the south region (11.8%) than the north region (8.1%).

Observer coverage was considered too low in 1986–87 and 1987–88 to be representative of the catch. Similarly, coverage of the domestic fleet was low or non-existent before 1994–95. We therefore

restricted our analyses to the period since 1988–89 for foreign and charter vessels and since 1994–95 for domestic vessels. This means that the five trips observed by Michael *et al.* (1987, 1989) were not included. The numbers of observed and set hooks used in our analyses are given in Tables 4 and 5.

Our estimates of the numbers of non-target fish caught by the tuna longline fishery represent only the catches of

1. the foreign and charter fleet from 1988–89 to 1996–97
2. domestic vessels that filled out TLCERs from 1994–95 to 1996–97
3. domestic vessels that filled out CELRs from 1994–95 to 1996–97, and were observed by scientific observers.

Catches of the following sectors of the fishery were not represented in our estimates.

1. Foreign licensed vessels before 1988–89.
2. Domestic vessels before 1994–95.
3. Unobserved domestic vessels filling out CELRs.
4. Korean vessels fishing for albacore tuna north of 35° S in 1988–89: six vessels made 108 sets. No observers were placed on Korean vessels, and their fishing methods differed significantly from those of the Japanese vessels, so the observer coverage of Japanese vessels is unlikely to be representative of the catches of Korean vessels.

Most fishing by the foreign and charter fleet occurred between April and July (Figure 3). Observer coverage of this fleet shows the same seasonal pattern. Domestic vessels operated during a longer season (mainly December–July), but most observer coverage was in April–June.

The geographical distribution of longline start-of-set positions from 1988–89 to 1996–97 shows concentrations of effort off northeast North Island (particularly Bay of Plenty–East Cape), western South Island (particularly Fiordland), and southeast South Island (Figure 4). Observer coverage over the same period was concentrated in the first two locations, with little coverage of southeast South Island (Figure 5). The geographical pattern of observer coverage varied annually (Appendix 1). In the southern fishery, the observed domestic and foreign and charter fleets fished similar areas, but in the northern fishery, the two fleets were largely segregated.

Species composition and distribution

More than 165 000 fish and 67 species of fishes, and a few invertebrates, were observed on tuna longlines (Table 6). Most species were rarely observed, with only 28 species (treating porbeagle and mako sharks separately) exceeding 100 observations. The commonest 17 species constituted 97% of the observed catch (Figure 6).

Blue shark was the species most commonly caught (Table 6, Figure 6). The next most important non-target species were Ray's bream and porbeagle and mako sharks, followed by smaller numbers of oilfish, moonfish, lancetfish, butterfly tuna, dealfish, school shark, deepwater dogfish, and rudderfish. Lancetfish consists of two species (*Alepisaurus ferox* and *A. brevirostris*) that were not distinguished in the catches, and deepwater dogfish consists of a number of squaloid dogfish species including *Centroscymnus squamosus, C. owstoni, Dalatias licha*, and *Zameus squamulosus*. Only 152 striped marlin were observed; other marlin species were very rare (9 shortbill spearfish and 3 blue marlin).

Blue shark, Ray's bream, porbeagle shark, moonfish, butterfly tuna, mako shark, and rudderfish occurred throughout the area covered by observers (Appendix 2). Dealfish, deepwater dogfish, and school shark were mainly recorded around the South Island, and oilfish and lancetfish were mainly recorded around the North Island.

Log CPUE was plotted against start-of-set latitude for the commonest 17 species, and porbeagle and mako sharks combined (Figure 7). For convenience, the plots are grouped into three categories: sharks; tunas and broadbill swordfish; and other species. Zero catch rates were plotted at 0.2 fish per 1000 hooks (because the log of zero is undefined). Blue, porbeagle, and mako sharks showed no clear

latitudinal trends in abundance, although there was a tendency for CPUE to be slightly higher in the north, especially around 36–38° S (northeast of East Cape). Deepwater dogfish and school shark showed no latitudinal trend within the southern region. Albacore tuna were clearly more abundant in the north, and bigeye and yellowfin tuna were absent south of about 38° S (East Cape). Broadbill swordfish extended into southern latitudes but were less abundant south of 38° S. Southern bluefin tuna and butterfly tuna showed no latitudinal patterns. The abundance of Ray's bream increased with increasing latitude, and dealfish were rare north of 40° S. Oilfish, moonfish, and lancetfish were most abundant in the north. Rudderfish showed no latitudinal trend, but were rarely caught north of 35° S.

Catch per unit effort

Bootstrap estimates of mean CPUE for the target and main non-target species are shown by stratum and fishing year in Figure 8 and Appendix 3. The 95% confidence limits were frequently asymmetrical, with the upper limit being further from the mean than the lower limit. This is typical of CPUE data, which are often skewed to the right as a result of having a few very large values. The 95% confidence limits were mostly reasonable, apart from two estimates of school shark mean CPUE, where one very large CPUE in each stratum resulted in broad 95% limits.

The two time series of domestic CPUE were too short (3 years) to identify temporal trends. For the foreign and charter fleet, most non-target and target species showed significant inter-annual variation in CPUE in at least one of the two regions. Many of these fluctuations appeared to be random, with no apparent temporal trends, but there were some exceptions.

- Blue shark CPUE was low up to 1991–92 in both regions, and then increased rapidly in north region to 1994–95, followed by a decline again in 1996–97. However, the estimates for north region from 1993–94 onwards were based on small numbers of hooks (*see* Table 5).
- CPUE of porbeagle and mako sharks combined increased in both north and south regions. However, inspection of the shorter time series for the individual species showed no obvious trends, indicating that the result for the combined species may have been spurious.
- Southern bluefin tuna and broadbill swordfish CPUE declined in north region from 1990–91 to 1994–95, but increased to their highest values in 1996–97.
- Dealfish CPUE increased in south region.

For most species, there were large differences in CPUE between the two fleets and/or between the two regions. This suggests that the stratification scheme was effective in reducing within-stratum variation relative to between-stratum variation. The following patterns were apparent.

- In some years, blue shark CPUE was much higher for the foreign and charter fleet in north region than for the same fleet in south region, but in other years the two regions had similar CPUE. Domestic north CPUE was much lower than foreign and charter north CPUE.
- CPUE of porbeagle and mako sharks (separately and combined) was higher in north region than south region. In north region, the foreign and charter fleet caught more porbeagles and fewer makos than the domestic fleet.
- Deepwater dogfish CPUE was higher in south region than in north region.
- Greatest catch rates of albacore, bigeye tuna, yellowfin tuna, and lancetfish were made by the domestic fleet in north region. Catch rates were higher in north region than in south region. The foreign and charter fleet had very low catch rates of yellowfin tuna.
- CPUE of southern bluefin tuna was higher in south region than in north region (except for the foreign and charter fleet in north region in 1996–97).
- Broadbill swordfish catch rates were highest in north region.
- CPUE of Ray's bream and dealfish was greatest in south region.
- Oilfish and moonfish CPUE was greatest in north region. Oilfish CPUE in north region was greater for the foreign and charter fleet than for the domestic fleet.

Numbers of fish caught

The estimated numbers of target and non-target fish caught by the vessels represented in our study (all strata combined), and a comparison with the numbers reported on TLCERs, are presented in Figure 9 and Appendix 4. When interpreting these results, it must be remembered that some sectors of the tuna longline fishery are not represented in the estimates. Korean vessels set 340 685 hooks in 1988–89, or 3.5% of the total effort for that year. They did not fish in New Zealand's EEZ in subsequent years.

Most of the domestic effort recorded on CELRs is not covered by our estimates, and its magnitude is unknown. Similarly, domestic effort reported on TLCERs is not covered by our observer estimates before 1994–95 because of low observer coverage. In 1991–92 to 1993–94, domestic TLCER effort comprised 3%, 15%, and 60% respectively of the total reported TLCER effort (*see* Table 2). Therefore the observer estimates of the numbers of fish caught in 1991–92 and 1992–93 will be slightly underestimated and those in 1993–94 will be grossly underestimated. This is apparent for mako shark, albacore tuna, broadbill swordfish, bigeye tuna, yellowfin tuna, and moonfish (Figure 9). For those species and years, the TLCERs probably provide more reliable estimates of the numbers of fish caught than the observer estimates.

There was reasonable agreement (Figure 9) between observer estimates and TLCER data for:

- blue shark in 1988–89 and 1989–90 (TLCERs were lower than observer estimates in other years)
- albacore tuna up to 1991–92
- southern bluefin tuna (except 1989–90 and 1990–91 when TLCERs were lower)
- butterfly tuna
- moonfish (except 1990–91, 1992–93 and 1993–94)

The discrepancies for 1992–93 and 1993–94 were expected, as discussed above. Most of the discrepancies in other years can also be explained. In early 1991, Australia introduced a ban on the finning of sharks if the carcasses were not also retained (J. D. Stevens, CSIRO Marine Research, Tasmania, Australia, pers. comm.). New Zealand also considered, but did not introduce, a ban on finning. At about the same time, conservation groups were raising concern about the sustainability of shark fisheries world-wide, because of the vulnerability of many shark species to overfishing. It is likely that these events led to gross under-reporting of blue sharks on TLCERs by foreign fishing vessels.

The discrepancies for albacore tuna between 1992–93 and 1994–95 appear larger than would be expected to result from exclusion of much of the domestic fleet effort from our observer estimates. However, this is probably due to domestic vessels having much higher catch rates of albacore than foreign and charter vessels (*see* Figure 8).

Southern bluefin tuna was probably under-reported by foreign vessel skippers in 1989–90 and 1990–91 following the introduction of a quota for the New Zealand zone in 1989. Australian fisheries authorities uncovered gross under-reporting of southern bluefin tuna in their zone during 1990–91, resulting in several successful prosecutions (M. Gleeson, Australian Fisheries Management Authority, Canberra, Australia, pers. comm.).

We cannot explain the big discrepancy for moonfish in 1990–91, but it may have been a result of moonfish being discarded in favour of the more highly valued southern bluefin tuna, which was caught in large numbers that year.

Surprisingly, there appears to have been some over-reporting of bigeye tuna and yellowfin tuna on TLCERs. For both species, this may have been an attempt to disguise southern bluefin tuna as less valuable, non-quota species. This would serve a double purpose of increasing the southern bluefin catch beyond the quota, and reducing the payment of licence fees, which are based on catch composition and value. Alternatively, some observers may have confused small bigeye and southern bluefin tuna, which are difficult to distinguish. The discrepancies for bigeye tuna in 1992–93 and 1993–94 are due to the exclusion of domestic vessels which tend to have higher catch rates than foreign and charter vessels (*see* Figure 8).

For five species, the reasonable agreement between TLCER and observer estimates, except where otherwise explained, gives us confidence that the observer estimates are reasonably accurate for the vessels represented in our analysis. There is also evidence that the low observer coverage rates in 1988–89 to 1991–92 (*see* Table 3) produced acceptable estimates of numbers caught and 95% confidence limits. It is therefore safe to use our estimates to infer general trends in numbers of fish caught, and on the level of reporting on TLCERs. Except for southern bluefin tuna and school shark, which are both subject to quotas, vessels are required to report only the portion of their catch that is kept for sale. Therefore under-reporting is expected for species that are usually discarded, and also for species that are normally retained but which are subject to high-grading (e.g., fish may be discarded because they are too small or are damaged by sharks while on the line).

The following general patterns are apparent in Figure 9.

- Blue shark catches declined from 60 000–75 000 per year from 1988–89 to 1990–91 to about 25 000–45 000 from 1991–92 onwards, despite increased CPUE (*see* Figure 8). Most blue sharks are discarded after finning. Catches have been under-reported on TLCERs since 1990–91.
- Porbeagle and mako shark catches have been relatively stable. Reporting rates were high for mako shark, the larger individuals of which are retained, but low for porbeagle shark which is usually discarded after finning.
- Catches of deepwater dogfish were small, and fluctuated markedly. Dogfish are not retained and were not reported.
- School shark catches averaged about 1000 per year, which at a mean weight of 14 kg would represent 14 tonnes. School shark has been part of the Quota Management System since October 1986, but has apparently been discarded by foreign vessels and not reported. Reporting rates have improved in recent years with the increase in domestic effort, but are still low.
- Albacore catches have increased as a result of the increased effort and high CPUE of domestic vessels. Reporting rates were high, but there was probably some under-reporting in 1995–97.
- Southern bluefin tuna catches declined with the reduction in foreign and charter effort (*see* Figure 2). The species appears to have been under-reported in 1989–90 and 1990–91.
- Broadbill swordfish catches declined with the reduction in foreign and charter effort. It was under-reported up to 1991–92, but has been well reported since then. This is because it has been illegal for foreign licensed vessels to retain swordfish since October 1987, whereas domestic and foreign chartered vessels are allowed to retain it.
- Butterfly tuna catches have declined with the reduction in foreign and charter effort. Butterfly tuna are usually retained, and catches were well reported.
- Bigeye tuna catches have declined with the reduction in foreign and charter effort.
- Yellowfin tuna catches have increased as a result of increased domestic effort and high domestic north CPUE. Reporting rates have been low in recent years.
- Catches of Ray's bream have been consistently high, typically about 10 000–12 000 per year. This species is usually discarded, and under-reported.
- Dealfish catches have been variable, and were not reported.
- Oilfish catches have declined dramatically with the reduction of foreign and charter effort. Oilfish has been under-reported.
- Moonfish catches have been stable at about 2 000–4 000 per year. Moonfish are retained and have been well reported.
- Lancetfish catches have increased in recent years as a result of increased domestic effort and high domestic north CPUE. Lancetfish are not retained or reported.
- Rudderfish catches have increased recently, and so has the reporting rate.

For the period 1988–89 to 1996–97, the relative proportions of the catch contributed by each species, based on the scaled total observer estimates, are shown in Figure 6. The proportions, and for some species the rankings, differ from those indicated by the raw observer counts (*see* Table 6) because observer coverage was greater in south region (11.8%) than north region (8.1%). Consequently, the scaled total estimates are higher than expected from raw counts for northern species and lower for southern species. Blue shark and albacore dominated the tuna longline catch (32% and 29% respectively). Southern bluefin tuna, Ray's bream, and porbeagle and mako sharks, formed a second

tier of species, contributing 6–8% of the catch each. (Porbeagle sharks made up 74% of the combined porbeagle and mako shark catch for the period during which the two species were reliably identified, suggesting that porbeagles were about 4.5% of the total catch and makos about 1.6%). Oilfish, moonfish, broadbill swordfish, lancetfish, butterfly tuna, dealfish, and yellowfin tuna each constituted 1.2–3.3% of the catch, and the remaining species (bigeye tuna, school shark, deepwater dogfish, and rudderfish) less than 1%.

The reduction in foreign and charter fishing effort, and increase in domestic effort, resulted in a change in the species composition of the catch (*see* Figure 6). In the three-year period 1994–95 to 1996–97, albacore tuna was the most frequently caught species (42% of catch), followed by blue sharks (23%). Second tier species (2–7%) were Ray's bream, lancetfish, porbeagle and mako sharks, yellowfin tuna, southern bluefin tuna, dealfish, and moonfish. The remaining species (oilfish, broadbill swordfish, butterfly tuna, bigeye tuna, school shark, deepwater dogfish, and rudderfish) each made up less than 1.1%.

Marlin catches and life status

Marlin catches reported on TLCERs declined dramatically from 1988, following the moratorium on the landing of billfish by foreign and charter vessels, and the exclusion of foreign licensed vessels from FMAs 1 and 9 before June (when marlin are most common) (Table 7). Reported catches (in numbers) of striped marlin, blue and black marlin combined, and sailfish and spearfish combined, declined by 90%, 87%, and 89% respectively between 1980–87 and 1988–97. Fishing effort declined by only 63% during the same period. The number of striped marlin reported has increased in recent years (Table 7) as a result of increased voluntary recording of caught and released marlins from as early as 1993–94. From 1996–97, Ministry of Fisheries regulations required that such marlin be reported.

To determine the level of reporting by longline vessels, we compared the numbers of striped marlin reported by the vessel skipper and by the observer on observed domestic and charter vessels between June 1994 and March 1997. A total of 71 observed domestic longline sets caught striped marlin. TLCERs and CELRs reported 12 fish while observers reported 104 fish from the same sets. Reporting was not compulsory during most of the period considered.

Inspection of reported longline catches of striped marlin between 1980 and 1997 indicated that they can be caught north of 38° S on the west coast and north of 40° S on the east coast of the North Island. Most striped marlin are caught between the 1000 m and 4000 m depth contours off Bay of Plenty, east Northland, Three Kings Ridge, and Norfolk Ridge. Striped marlin reported on TLCERs in 1996–97 reflected this historic pattern (Figure 10), whereas those reported by observers were largely limited to the eastern Bay of Plenty (Figure 11). The limited distribution of observed marlins reflects the low and spatially restricted observer coverage: in 1996–97 longlining occurred over the area 33–39° S and 171° E to 175° W, while observed effort covered the area 35–39° S and 175–180°. Observer effort was limited to January–June in this area, with monthly coverage of 4–11% (Table 8).

In 1996–97, 301 striped marlin were reported on TLCERs in all months except July, August, and October. While it is possible to catch striped marlin throughout the year, observer data since 1994 indicated that 98% of catches occurred during December–July. This period was therefore used to estimate the marlin catch in the area where longlining occurred and where marlin could be expected to be caught.

Although observer coverage was limited temporally and spatially in 1996–97, it covered the period when over 90% of striped marlin are expected to be caught by longline. Of greater concern is that observer coverage during the period when about 80% of marlin should be caught (December–March) was concentrated in the southeast quadrant of the area fished (i.e., off East Cape). During the remainder of the time observer effort was in the centre of unobserved effort. Despite the potential biases that can arise with low observer coverage, we assumed that the observed longline effort was representative of the whole fleet. We therefore extrapolated spatially from an observed geographical area of less than 30% of the area fished by the entire fleet, and assumed that catch rates in December were the same as in January–March, and that catch rates in July were the same as in April–June.

Thirty-four striped marlin were observed caught in 1996–97 (Table 9). Bootstrap estimates of striped marlin CPUE were twice as high in summer as in autumn. Total fishing effort in the two periods was similar (less than 6% difference). Scaling the bootstrap CPUE estimates to the total effort yielded an estimated catch of 570 (range 370–792) striped marlin (Table 10). Only 301 striped marlin were reported on TLCERs in 1996–97. However, some striped marlin would also have been caught and reported by longline vessels that completed CELRs. About 20% of sets (471 out of 2284) in 1996–97 were reported on CELRs. If vessels completing TLCERs and CELRs had similar striped marlin CPUE, and similar reporting rates, the number of striped marlin caught in 1996–97 would have been about 380, which is just above the lower 95% confidence interval of the bootstrap estimate.

The status of marlins at the time of landing has been recorded by observers since 1992–93 (Table 11). Only three of the five marlin species (blue marlin, shortbill spearfish, and striped marlin) have been observed; striped marlin accounted for 94% of these. Since 1992–93, all marlins caught on observed longliners have been released as required by regulations, and 72% of striped marlin were alive when released. There was no significant difference in the proportion landed alive by domestic, and by foreign and charter vessels (Table 12; $\chi^2 = 0.20$, df = 1, $p > 0.5$).

Discussion

Observer data showed that a wide range of fish species is taken as incidental bycatch in the tuna longline fishery, but few are caught in large numbers. The main bycatch species are similar to those reported previously in the New Zealand fishery (Michael *et al.* 1987, 1989), and many are also taken by longliners in Australia (Stevens 1992, Government of Australia 1998) and the subtropical Western Pacific (Bailey *et al.* 1996, Heberer in press).

Our observer-based estimates of the numbers of fish caught on tuna longlines are subject to two main negative biases. First, the effort of the domestic fleet before 1994–95 and an unknown number of domestic vessels filling out CELRs was not represented. Second, unwanted fish are often shaken or cut off the lines by the crew, and not all are seen by observers (Michael *et al.* 1987, 1989, Stevens 1992, Bailey *et al.* 1996). Actual catches therefore exceed the estimated numbers reported here.

From 1988–89 to 1996–97, the tuna longline fishery caught mainly blue shark (32% of the catch) and albacore tuna (29%). The main target species, southern bluefin and bigeye tuna, were relatively minor, making up only 8.7% of the catch by number. Northern bluefin tuna, broadbill swordfish, and yellowfin tuna were infrequent target species. Other fish species taken as significant bycatch were (in descending order) Ray's bream, porbeagle shark, oilfish, moonfish, lancetfish, butterfly tuna, mako shark, and dealfish. Smaller numbers of school shark, deepwater dogfish, and rudderfish were also caught. In recent years (1994–97), the changing fleet composition (from mainly foreign and charter vessels to mainly domestic vessels) has resulted in a shift in species composition: the proportion of albacore has increased (42%) and the proportion of blue shark has decreased (23%).

Blue shark was the main non-target species caught throughout the EEZ. Around North Island, porbeagle shark, oilfish, moonfish, lancetfish, mako shark, and butterfly tuna were the next commonest non-target species, and around South Island, Ray's bream, dealfish, porbeagle shark, and in some years butterfly tuna, moonfish, and rudderfish were important.

In the south region, both fleets had similar catch rates for most species, presumably because both fleets were targeting southern bluefin tuna and fishing in similar areas (*see* Appendix 1). In the north region, the catch rates of some target and non-target species differed markedly between the domestic and foreign and charter fleets. The domestic fleet had higher catch rates of albacore, bigeye, and yellowfin tunas, and of mako shark and lancetfish. Conversely, the foreign and charter fleet had higher catch rates of blue shark, porbeagle shark, oilfish, and southern bluefin tuna. Both fleets targeted the same species (almost exclusively southern bluefin tuna from 1994–95 to 1996–97). The differences probably reflect the greater amount of fishing and observer coverage during summer for the domestic fleet (*see* Figure 3), different fishing areas of the two fleets (*see* Appendix 1), different gear types, and possibly different hook depths. Foreign and charter vessels mostly used a kuralon mainline with about

2500–3000 hooks, whereas domestic vessels set shorter monofilament lines with 300–2700 hooks. The two fleets also used different hooks. Tuna longliners usually avoid areas with high blue shark abundance, or change the types of hooks and bait used, to reduce their catches of sharks and oilfish (Michael *et al.* 1987, 1989, Stevens 1992).

Tuna and non-target fish species tend to have different depth preferences (Michael *et al.* 1987, Nakano *et al.* 1997; P. G. Williams, Pacific Community, pers. comm.). The overall range of depths fished by tuna longliners is about 60–250 m (Michael *et al.* 1987, 1989, Stevens 1992), but the depths fished by the fleets in New Zealand waters have not been analysed. The shorter lines used by domestic vessels may enable them to fish highly productive convergence zones more effectively than the foreign and charter vessels, which tend to fish in groups and set their lines along a straight course (Michael *et al.* 1987).

For most species, mean CPUE varied markedly among strata, and among years within strata (*see* Figure 8). Blue shark mean CPUE was typically less than 15 per 1000 hooks, but reached a maximum of 114 per 1000 hooks for the foreign and charter north stratum in 1994–95. The latter value was based on only a small amount of observed effort (29 207 hooks). In Australian waters, blue shark CPUE averaged 10.4 per 1000 hooks, but occasionally exceeded 100 per 1000 hooks (Stevens 1992). This illustrates the potential dangers of inadequate stratification, and failure to obtain observer data from all strata and years. In this study, the two geographical regions and two fleets were identified as significant sources of variation in CPUE, and therefore in the estimates of the numbers of fish caught. Ongoing observer coverage of all the identified strata is therefore necessary in order to obtain unbiased estimates of the catch.

Low value and discarded species were either not reported or were under-reported in TLCERs. Comparison of observer data and TLCERs on an annual basis also revealed likely under-reporting of high value target species, including southern bluefin tuna, broadbill swordfish, and albacore in some years. By contrast, bigeye tuna and yellowfin tuna appeared to have been over-reported in some years, perhaps by inclusion of southern bluefin tuna, but observer mis-identification of bigeye as southern bluefin may have contributed to the discrepancies. Under-reporting of albacore, moonfish, and mako shark by foreign licensed vessels was detected by Michael *et al.* (1989) off East Cape in 1988. They also suggested that bigeye tuna and butterfly tuna were under-reported, but sample sizes were too small to be sure. Trip-by-trip comparison of TLCER and observer data would provide a clearer picture of the degree of under-reporting, but was beyond the scope of the present study. Under-reporting of both target and non-target species in vessel logbooks has also been detected in Australian waters (Stevens 1992, M. Gleeson pers. comm.) and elsewhere in the Pacific (Bailey *et al.* 1996, He & Laurs 1998).

The tuna longline fishery has changed dramatically during the last two decades, and this has been reflected in the catches of both the target and non-target species. The number of hooks set has declined by 90% since 1980, when effort statistics first became available, due to the disappearance of foreign licensed vessels from the New Zealand EEZ. The effort of the domestic fleet increased during the early 1990s but has remained stable for the last 3 years. In the period covered by our analyses (1988–89 onwards), the number of hooks declined by about 70%, but, surprisingly, the numbers of fish caught have not declined for all species. This is because domestic vessels did not simply replace the effort of foreign licensed vessels; instead they fished year-round in different parts of the north region using different gear, resulting in a different non-target catch composition. Since 1988–89, catches of blue shark, southern bluefin tuna, broadbill swordfish, butterfly tuna, bigeye tuna, and oilfish have declined substantially, but catches of albacore tuna, yellowfin tuna, lancetfish, and rudderfish have increased. Other species showed no clear trends.

TLCER data are available for foreign licensed vessels since 1980 (= 1979–80 fishing year), so for species that appear to have been well reported, it is possible to estimate the magnitude of catches between 1979–80 and 1987–88. Blue shark were well reported in 1988–89 and 1989–90, before the ban on finning was introduced (*see* Figure 9). TLCER records for Japanese and Korean vessels combined between 1979–80 and 1987–88 give a mean annual catch of 78 000 blue sharks (range

41 000–102 000). However, the numbers reported increased through the time period: the first four years had a mean of 54 000 (range 41 000–66 000) whereas the last 5 years had a mean of 97 000 (range 88 000–102 000), which is contrary to expectation given the large drop in hooks during that period (*see* Figure 1). If reporting rates were higher from 1983–84 to 1987–88 than in the earlier years, and catch rates in both periods were similar, then total catches may have been as high as 150 000–170 000 blue shark per year in the early 1980s.

From 1979–80 to 1987–88, the TLCERs reported mean numbers of 4200 mako sharks (range 2600–7400), 4 700 butterfly tuna (range 2500–7700) and 33 000 moonfish (range 11 000–68 000) caught per year. For butterfly tuna, the reported values were close to those estimated from observer data in the period 1988–89 to 1990–91, but for blue shark, mako shark, and moonfish, the catches in the early–mid 1980s were substantially higher than in the period covered by observer data.

Given the huge reduction in fishing effort since the early 1980s, it seems likely that the catches of most non-target (and target) species have declined during the last two decades. However, the development of a domestic longline fleet has increased the catches of some non-target species, and current catches of some non-target species may exceed those of the early 1980s.

Striped marlin is the main marlin species caught by tuna longlines and recreational fishers in the New Zealand EEZ. Longline vessels reported 301 striped marlin caught on TLCERs in 1996–97, but if allowance is made for longline sets reported on CELRs, the total reported catch may have been about 380 fish. Using observer data, we estimated that 570 striped marlin were caught by tuna longliners in 1996–97. Data problems prevented more precise estimation of the marlin catch. Catches reported on CELRs were found to be a mixture of numbers and weights which could not be easily separated, and the observer data suffered from low coverage, and potential spatial and temporal biases.

Most striped marlin caught in the EEZ are released alive. This is true for the recreational big game fishery, which often tags and releases the catch (Saul & Holdsworth 1992), and also for the longline fishery which by regulation is required to release all billfish whether dead or alive. Analysis of observer data showed that about 72% of marlins are released alive.

The sustainability of striped marlin catches has not yet been considered, largely because the availability of marlins in the New Zealand EEZ is influenced by climatic factors (T. E. Murray & P. R. Taylor, unpubl. data), and by interactions with fisheries outside New Zealand. While striped marlin stock structure is uncertain, the resource in the EEZ is part of a much larger stock which is commonly taken as longline bycatch in subtropical and equatorial waters. The area immediately north of New Zealand supports some of the highest catch rates in the western Pacific (Bailey *et al.* 1996), and is the likely source of New Zealand's striped marlin. While CPUE trends may be confounded by changes in fleet composition and targeting, raw CPUE has declined steadily in this area since the 1960s (Bailey *et al.* 1996). This raises sustainability concerns that may warrant a broader scale, standardised analysis of striped marlin CPUE.

Ongoing NIWA research funded by the Ministry of Fisheries in 1998–99 (project ENV9802) will:

1. extend the present study by estimating CPUE and total numbers of fish caught in 1997–98;
2. use observer data on length and weight of the main bycatch species to estimate the total weights of non-target species caught;
3. determine the effects of area, depth, season and gear parameters on CPUE;
4. assess the likely impact of the longline fishery on blue, mako and porbeagle sharks by:
   - determining the size composition and sex ratio of the catch;
   - reviewing world-wide geographic distributions and movement patterns of these species (to infer stock structure);
   - estimating the proportion of each species that is returned to the sea alive after capture;
   - determining the relative contribution of New Zealand catches to total stock catches;
   - comparing trends in CPUE in New Zealand waters with those reported from elsewhere in the stock range, and reviewing the status of fisheries for these species elsewhere in the world;
   - assessing the productivity of each species by reviewing available information on growth, size and age at maturity, fecundity, and natural mortality.

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Table 1: **Numbers of hooks set by tuna longline vessels in the New Zealand EEZ, classified by fleet. Hook numbers are presented by calendar year, so they are not directly comparable with the numbers of hooks given by fishing year in subsequent tables. Source: TLCERs**

Calendar year	Number of hooks		
	Domestic	Foreign + charter	Total
1980	0	25 898 663	25 898 663
1981	0	27 283 720	27 283 720
1982	0	24 101 065	24 101 065
1983	0	16 420 054	16 420 054
1984	0	14 019 984	14 019 984
1985	0	13 819 413	13 819 413
1986	0	13 759 643	13 759 643
1987	0	18 014 144	18 014 144
1988	0	14 782 512	14 782 512
1989	0	9 959 545	9 959 545
1990	0	8 553 288	8 553 288
1991	71 205	13 129 251	13 200 456
1992	260 683	8 599 951	8 860 634
1993	955 773	4 589 581	5 545 354
1994	1 442 525	966 985	2 409 510
1995	2 183 323	1 432 553	3 615 876
1996	1 777 456	0	1 777 456
1997	1 685 430	1 217 615	2 903 045

Table 2: **Numbers of trips, sets and hooks observed by scientific observers, and numbers of hooks set by tuna longline vessels, classified by fleet. Data exclude five trips made by an unreliable observer in 1991–92 and 1992–93. Sources: Scientific observer database, TLCERs and CELRs**

Fishing year	Observed trips	Observed sets	Observed hooks			Set hooks		
			Domestic	Foreign +charter	Total	Domestic	Foreign +charter	Total
1986–87	1	13	0	38 244	38 244	0	16 765 852	16 765 852
1987–88	3	41	0	116 880	116 880	0	12 942 901	12 942 901
1988–89	5	87	0	246 282	246 282	0	9 618 590	9 618 590
1989–90	6	154	0	447 454	447 454	0	8 553 288	8 553 288
1990–91	3	150	0	439 144	439 144	13 070	13 129 251	13 142 321
1991–92	8	193	19 525	518 849	538 374	304 998	8 600 071	8 905 069
1992–93	17	373	0	1 106 022	1 106 022	842 083	4 633 681	5 475 764
1993–94	9	246	2 418	739 146	741 564	1 428 040	966 985	2 395 025
1994–95	12	339	152 980	779 773	932 753	2 163 843	1 435 712	3 599 555
1995–96	5	147	162 953	0	162 953	2 103 553	0	2 103 553
1996–97	15	424	216 961	799 123	1 016 084	1 817 776	1 223 365	3 041 141
Total	84	2167	554 837	5 230 917	5 785 754	8 673 363	77 869 696	86 543 059

Table 3: **Percentage of hooks observed by scientific observers**

Fishing year	Percentage of hooks observed		
	Domestic	Foreign +charter	Total
1986–87	–	0.2	0.2
1987–88	–	0.9	0.9
1988–89	–	2.6	2.6
1989–90	–	5.2	5.2
1990–91	0.0	3.3	3.3
1991–92	6.4	6.0	6.0
1992–93	0.0	23.9	20.2
1993–94	0.2	76.4	31.0
1994–95	7.1	54.3	25.9
1995–96	7.7	–	7.7
1996–97	11.9	65.3	33.4
Total	6.4	6.7	6.7

Table 4: **Numbers of observed hooks used to estimate numbers of fish caught, classified by fleet and region**

Fishing year	Domestic			Foreign and charter			Total
	North	South	Total	North	South	Total	
1988–89	0	0	0	131 994	114 288	246 282	246 282
1989–90	0	0	0	226 010	221 444	447 454	447 454
1990–91	0	0	0	353 146	85 998	439 144	439 144
1991–92	0	0	0	243 646	275 203	518 849	518 849
1992–93	0	0	0	350 215	755 807	1 106 022	1 106 022
1993–94	0	0	0	91 452	647 694	739 146	739 146
1994–95	65 750	87 230	152 980	29 207	750 566	779 773	932 753
1995–96	64 512	98 441	162 953	0	0	0	162 953
1996–97	79 991	136 970	216 961	127 000	672 123	799 123	1 016 084
Total	210 253	322 641	532 894	1 552 670	3 523 123	5 075 793	5 608 687

Table 5: **Numbers of set hooks used to estimate numbers of fish caught, classified by fleet and region**

Fishing year	Domestic			Foreign and charter			Total
	North	South	Total	North	South	Total	
1988–89	0	0	0	3 360 154	6 258 436	9 618 590	9 618 590
1989–90	0	0	0	3 755 000	4 798 288	8 553 288	8 553 288
1990–91	0	0	0	5 203 141	7 926 110	13 129 251	13 129 251
1991–92	0	0	0	3 939 909	4 660 162	8 600 071	8 600 071
1992–93	0	0	0	826 371	3 807 310	4 633 681	4 633 681
1993–94	0	0	0	91 308	875 677	966 985	966 985
1994–95	1 345 083	818 760	2 163 843	45 187	1 390 525	1 435 712	3 599 555
1995–96	1 581 186	522 367	2 103 553	0	0	0	2 103 553
1996–97	1 475 229	342 547	1 817 776	135 820	1 087 545	1 223 365	3 041 141
Total	4 401 498	1 683 674	6 085 172	17 356 890	30 804 053	48 160 943	54 246 115

***Table 6*: Species and numbers of fish recorded by scientific observers aboard foreign and charter, and domestic tuna longline vessels, 1 October 1988 – 30 September 1997. Species are listed in descending order of total number observed. Source: Scientific Observer Database (includes all trips except those for one observer who did not record non-target fish species accurately)**

Common name	Scientific name	Number observed		
		Foreign +charter	Domestic	Total
Blue shark	*Prionace glauca*	57 251	9 065	66 316
Albacore tuna	*Thunnus alalunga*	15 731	9 433	25 164
Ray's bream	*Brama brama*	19 533	2 803	22 336
Southern bluefin tuna	*Thunnus maccoyii*	11 539	1 073	12 612
Porbeagle and mako shark	*Lamna nasus & Isurus oxyrinchus*	8 629	1 189	9 818
Dealfish	*Trachipterus trachypterus*	4 781	810	5 591
Oilfish	*Ruvettus pretiosus*	3 568	181	3 749
Moonfish	*Lampris guttatus*	2 298	523	2 821
Broadbill swordfish	*Xiphias gladius*	2 031	223	2 254
Butterfly tuna	*Gasterochisma melampus*	2 069	30	2 099
Lancetfish	*Alepisaurus ferox & A. brevirostris*	569	1 344	1 913
Deepwater dogfish	Squaliformes	1 679	177	1 856
Teleosts, unidentified	Teleostei	1 621	18	1 639
School shark	*Galeorhinus galeus*	1 326	233	1 559
Rudderfish	*Centrolophus niger*	525	371	896
Bigeye tuna	*Thunnus obesus*	562	280	842
Yellowfin tuna	*Thunnus albacares*	19	686	705
Sunfish	*Mola mola*	293	251	544
Big scale pomfret	*Taractichthys longipinnis*	461	42	503
Escolar	*Lepidocybium flavobrunneum*	91	305	396
Pelagic stingray	*Pteroplatytrygon violacea*	14	337	351
Hoki	*Macruronus novaezelandiae*	258	39	297
Thresher shark	*Alopias vulpinus*	263	29	292
Barracouta	*Thyrsites atun*	137	45	182
Striped marlin	*Tetrapturus audax*	33	119	152
Spiny dogfish	*Squalus acanthias*	130	13	143
Shark, unidentified	Selachii	38	96	134
Skipjack tuna	*Katsuwonus pelamis*	9	100	109
Northern bluefin tuna	*Thunnus thynnus*	79	22	101
Slender tuna	*Allothunnus fallai*	69	17	86
Ray, unidentified	Myliobatiformes	62	15	77
Black barracouta	*Nesiarchus nasutus*	8	21	29
Hapuku and bass	*Polyprion oxygeneios & P. americanus*	23	1	24
Bronze whaler shark	*Carcharhinus brachyurus*	13	11	24
Opah	*Lampris immaculatus*	18	0	18
Kingfish	*Seriola lalandi*	7	8	15
Taractes asper	*Taractes asper*	2	13	15
Wingfish	*Pteraclis velifera*	3	12	15
Snipe eel	Nemichthyidae	11	2	13
Bigeye thresher	*Alopias superciliosus*	9	3	12
Dolphinfish	*Coryphaena hippurus*	0	11	11
Shortbill spearfish	*Tetrapturus angustirostris*	1	8	9
Ragfish	*Icichthys australis*	5	2	7
Pilotfish	*Naucrates ductor*	4	3	7
Remora	Echeneidae	6	0	6
Gemfish	*Rexea solandri*	2	4	6

***Table 6 (continued)*:**

Common name	Scientific name	Number observed		
		Foreign +charter	Domestic	Total
Hake	*Merluccius australis*	3	3	6
Ribaldo	*Mora moro*	5	0	5
Hammerhead shark	*Sphyrna zygaena*	3	2	5
Unicornfish	*Lophotus capellei*	0	5	5
Bluenose	*Hyperoglyphe antarctica*	1	3	4
False frostfish	*Paradiplospinus gracilis*	0	4	4
Blue marlin	*Makaira mazara*	3	0	3
Oceanic whitetip shark	*Carcharhinus longimanus*	0	3	3
Great white shark	*Carcharodon carcharias*	3	0	3
Carpet shark	*Cephaloscyllium isabellum*	2	0	2
Frostfish	*Lepidopus caudatus*	0	2	2
Squid	Cephalopoda	0	2	2
Cubehead	*Cubiceps baxteri*	1	0	1
Manefish	*Caristius* spp.	1	0	1
Blue mackerel	*Scomber australasicus*	1	0	1
Frigate tuna	*Auxis thazard*	1	0	1
Sharpnose sevengill shark	*Heptranchias perlo*	0	1	1
Octopus	Cephalopoda	1	0	1
Red cod	*Pseudophycis bachus*	0	1	1
Salp	Thaliacea	1	0	1
Broadnose sevengill shark	*Notorynchus cepedianus*	1	0	1
Sea horse	*Hippocampus abdominalis*	0	1	1
Tiger shark	*Galeocerdo cuvier*	1	0	1
Tubbia tasmanica	*Tubbia tasmanica*	0	1	1
White warehou	*Seriolella caerulea*	0	1	1
Scalloped dealfish	*Zu elongatus*	1	0	1
All species		135 809	29 997	165 806

Table 7: **Marlin catches (weight in tonnes and numbers) by tuna longline vessels in the New Zealand EEZ, 1980–97 as reported on TLCERs. STM, striped marlin; BKM+BLM, blue and black marlin combined; SAI+SSF, sailfish and shortbill spearfish combined**

Calendar Year	Hooks (millions)	STM		BKM+BLM		SAI+SSF	
		Weight	Number	Weight	Number	Weight	Number
1980	25.9	42.1	678	2.4	23	0.8	26
1981	27.3	123.5	1 829	16.5	223	0.8	25
1982	24.1	197.4	2 856	18.2	190	1.1	78
1983	16.4	77.4	1 067	8.3	116	0.8	38
1984	14.0	92.3	1 444	9.5	151	1.6	103
1985	13.8	52.7	784	16.1	313	2.6	117
1986	13.8	121.4	1 608	9.7	129	1.0	78
1987	18.0	154.6	2 046	5.1	66	2.4	189
1988	14.8	17.0	315	6.5	131	0.6	51
1989	10.0	3.0	61	1.8	50	0.1	8
1990	8.6	9.7	141	0.4	5	0.1	9
1991	13.2	1.5	21	0.9	6	0.0	3
1992	8.9	0.7	17	0.0	0	0.0	0
1993	5.5	0.2	7	0.0	0	0.0	1
1994	2.4	2.7	63	0.0	0	0.1	6
1995	3.6	6.2	174	0.0	0	0.1	8
1996	1.8	11.0	455	0.0	0	0.2	7
1997	2.9	2.2	300	0.0	0	0.0	0
1980-87 mean	19.2	107.7	1539	10.7	151	1.4	82
1988-97 mean	7.2	5.4	155	1.0	19	0.1	9

Table 8: **Summary of tuna longline effort (number of hooks set reported on TLCERs and CELRs) used to estimate marlin catches in 1996–97 in the area 33– 39° S. The proportion of sets without position data was 3.8%**

Month	Position known	Total	Number observed	Percent observed
October	11 560	13 960	0	0.0
November	47 820	51 650	0	0.0
December	12 000	18 050	0	0.0
January	211 487	218 237	14 556	6.7
February	239 944	251 244	28 248	11.2
March	209 050	216 600	8 673	4.0
April	186 116	197 066	8 879	4.5
May	229 180	232 340	12 133	5.2
June	142 235	143 835	7 502	5.2
July	82 045	83 095	0	0.0
August	28 970	28 970	0	0.0
September	6 720	7 200	0	0.0
Total	1 407 127	1 462 247	79 991	5.5

Table 9: **Bootstrap estimates of striped marlin CPUE (number of fish per 1000 hooks) by season (summer, autumn) in 1996–97 with upper and lower 95% confidence intervals**

Period	No. of fish observed	CPUE		Number of sets	Lower 95% C.I.	Upper 95% C.I.
		Mean	Std. error			
December–March	29	0.531	0.108	65	0.335	0.752
April–July	5	0.203	0.083	31	0.078	0.367
Total	34	0.419	0.079	96	0.272	0.582

Table 10: **Bootstrap estimates of the numbers of striped marlin caught by season (summer, autumn) in 1996–97 with the upper and lower 95% confidence intervals**

Period	Number of hooks		Percent observed	Number caught		
	Set	Observed		Bootstrap estimate	Lower 95% C.I.	Upper 95% C.I.
December–March	704 131	51 477	7.3	374	236	530
April–July	656 336	28 514	4.3	133	51	241
Total	1 360 467	79 991	5.9	570	370	792

Table 11: **Summary of the life status of marlins released from observed tuna longliners by species and year**

Species	Year	Alive	Dead	Unknown	Total	Percent released alive[1]
Blue marlin	1992–93	0	1	0	1	0.0
Shortbill spearfish	1993–94	0	1	0	1	0.0
	1994–95	5	1	0	6	83.3
	1995–96	1	0	0	1	100.0
	All	**6**	**2**	**0**	**8**	**75.0**
Striped marlin	1992–93	7	2	0	9	77.8
	1993–94	4	3	4	11	57.1
	1994–95	30	10	0	40	75.0
	1995–96	33	11	0	44	75.0
	1996–97	22	12	0	34	64.7
	All	**96**	**38**	**4**	**138**	**71.6**

[1] Excludes fish with "Unknown" status

Table 12: **Comparison of the numbers of striped marlin landed alive by foreign and charter and domestic fleets, 1992–93 to 1996–97**

Fleet	Alive	Dead	Total
Foreign + charter	10	5	15
Domestic	86	33	119
Total	96	38	134

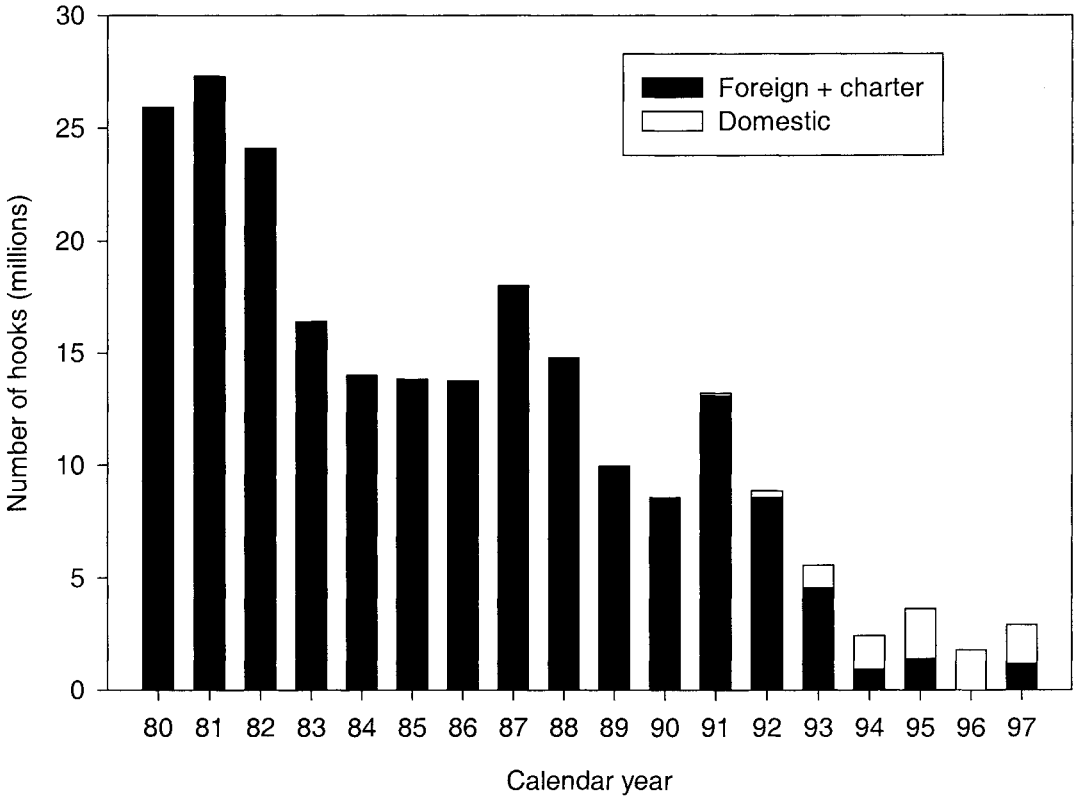


Figure 1: **Number of hooks set in the tuna longline fishery by fleet and calendar year.**

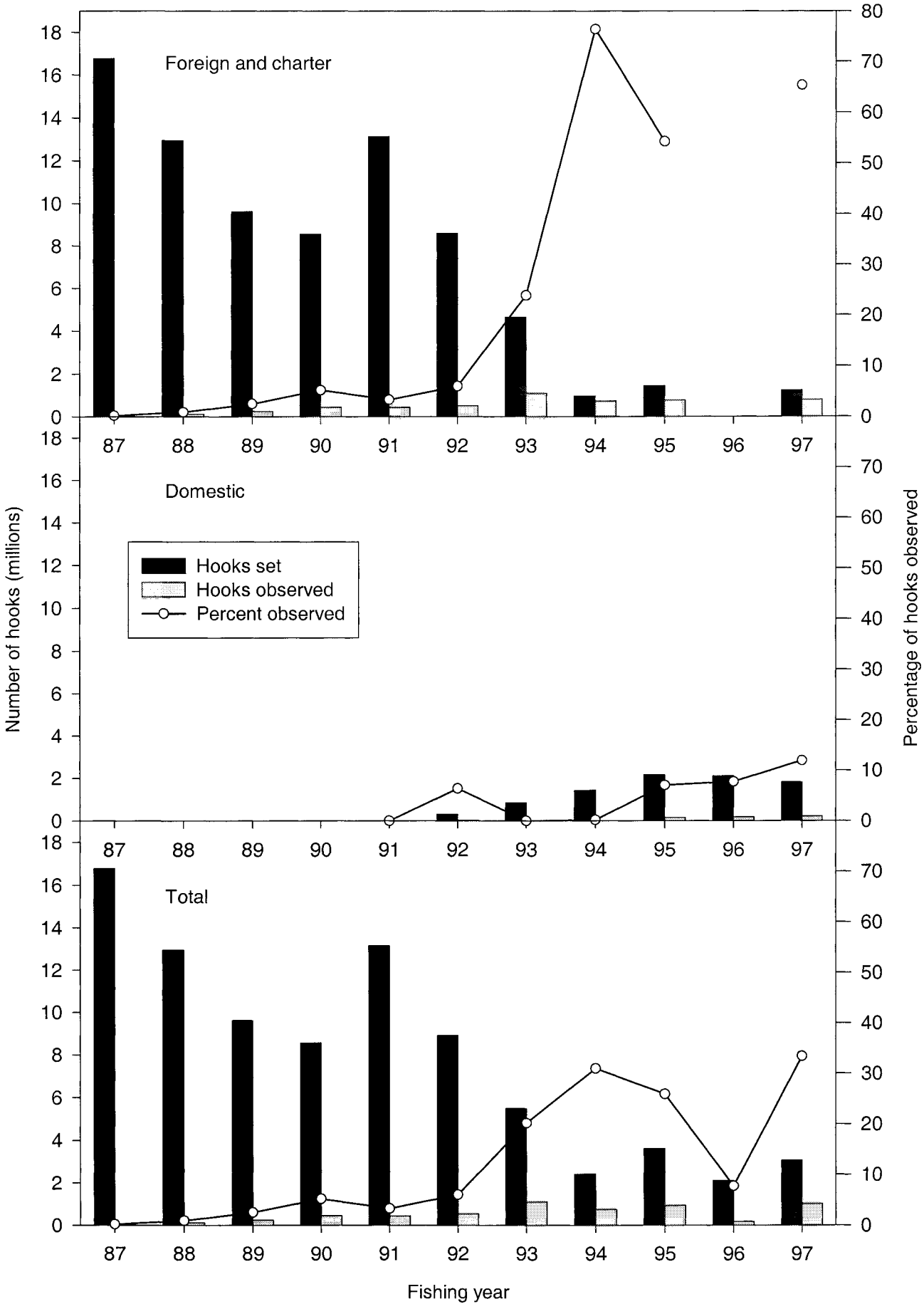


Figure 2: **Numbers of hooks set and observed, and percentage of hooks observed, by fleet and fishing year. Fishing year 87 = October 1986 to September 1987.**

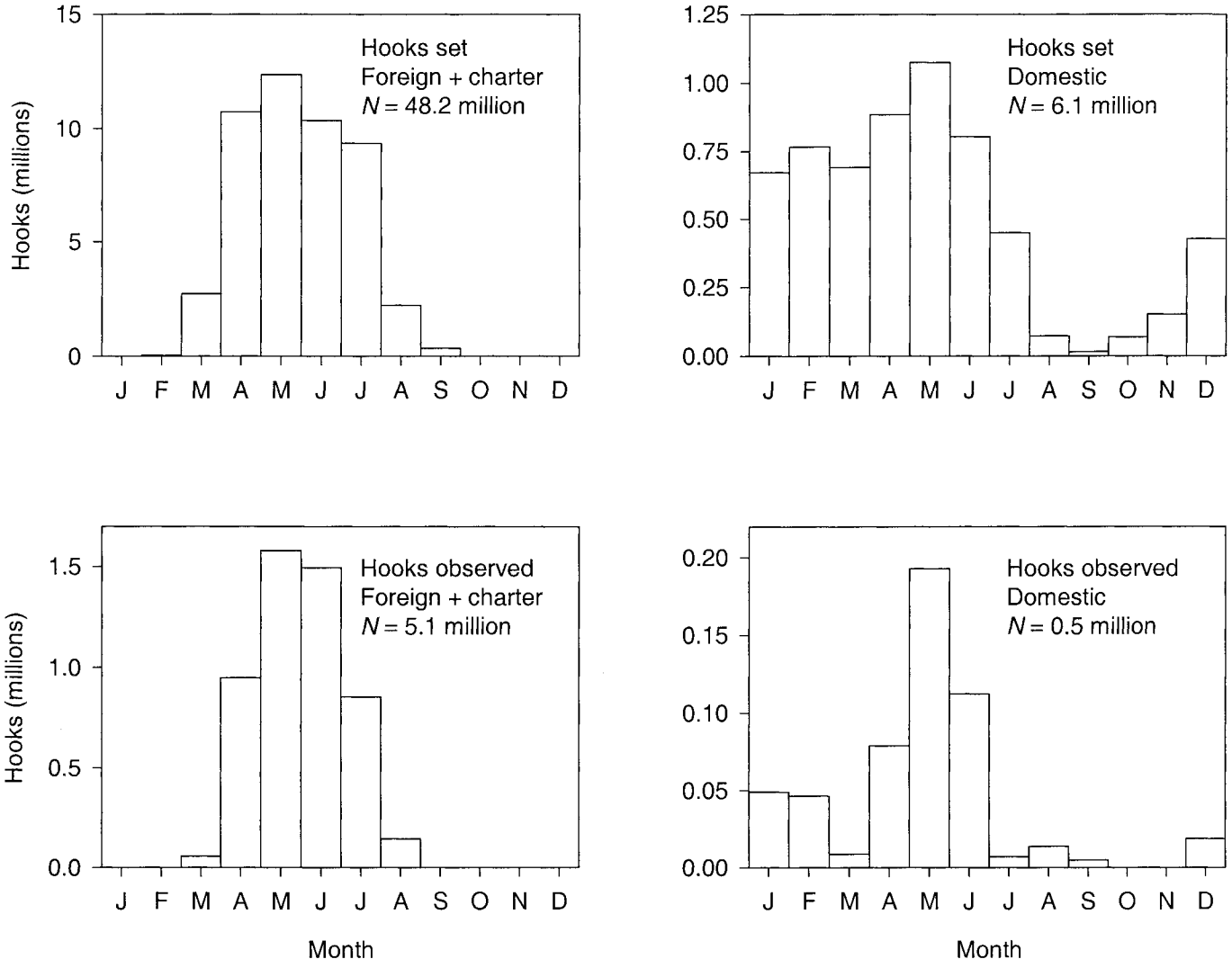


Figure 3: **Seasonal distribution of observed and set hooks, October 1988 to September 1997 (based on data shown in Tables 4 and 5).**

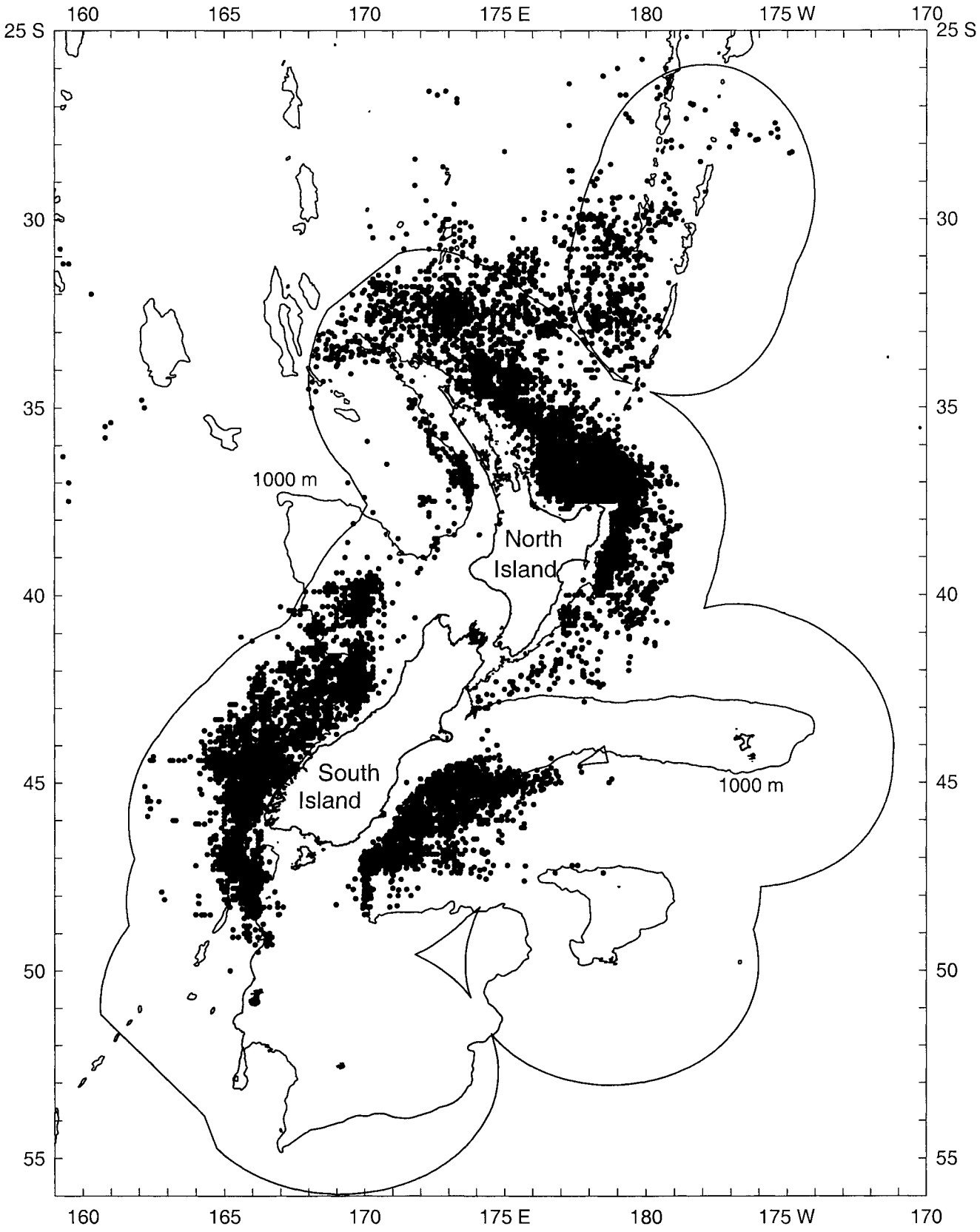


Figure 4: **Start positions for tuna longline sets, October 1988 to September 1997 (N = 25 829).**

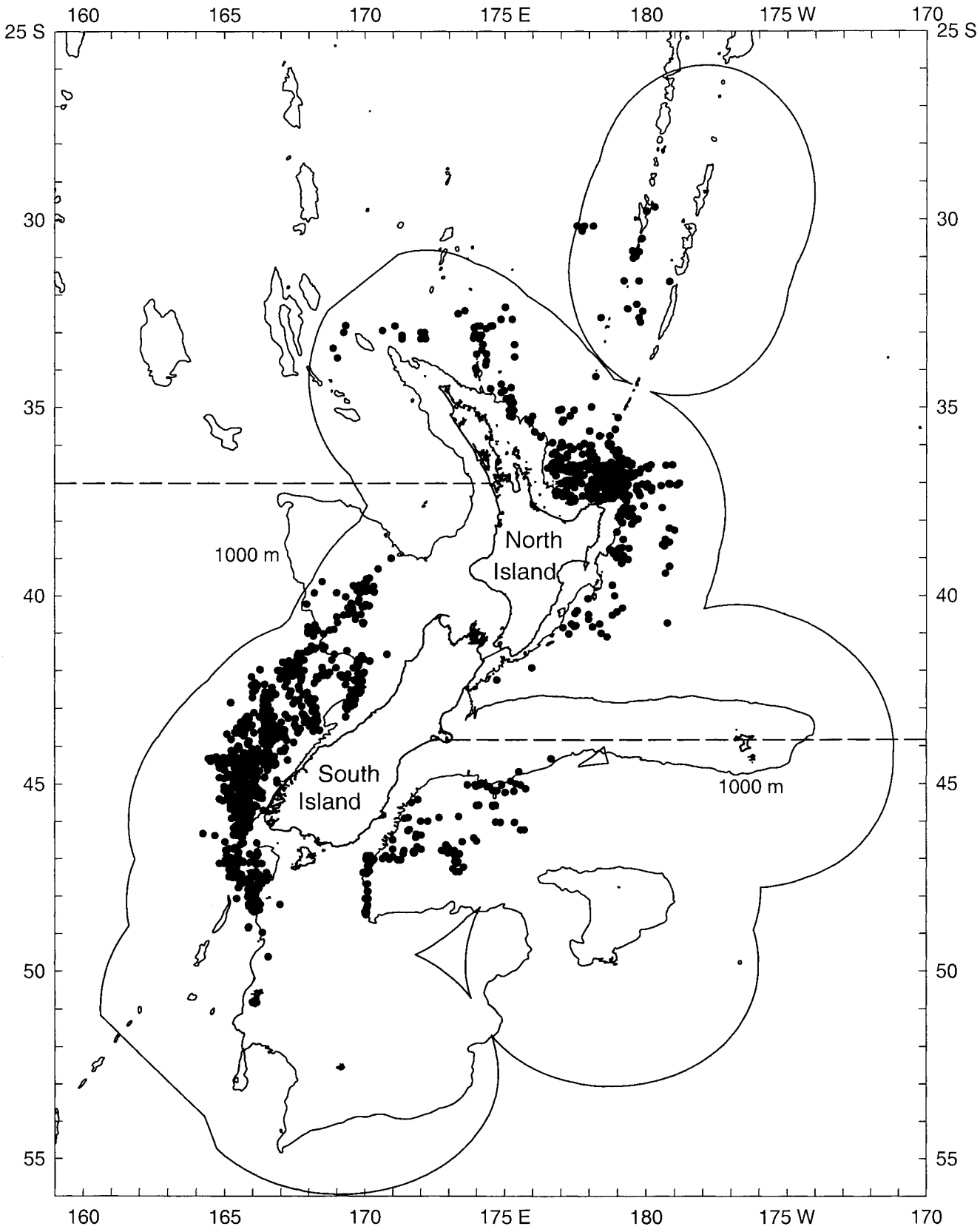


Figure 5: **Start positions for observed tuna longline sets, October 1988 to September 1997 (N = 2093). Dashed lines indicate boundaries used to separate North and South regions.**

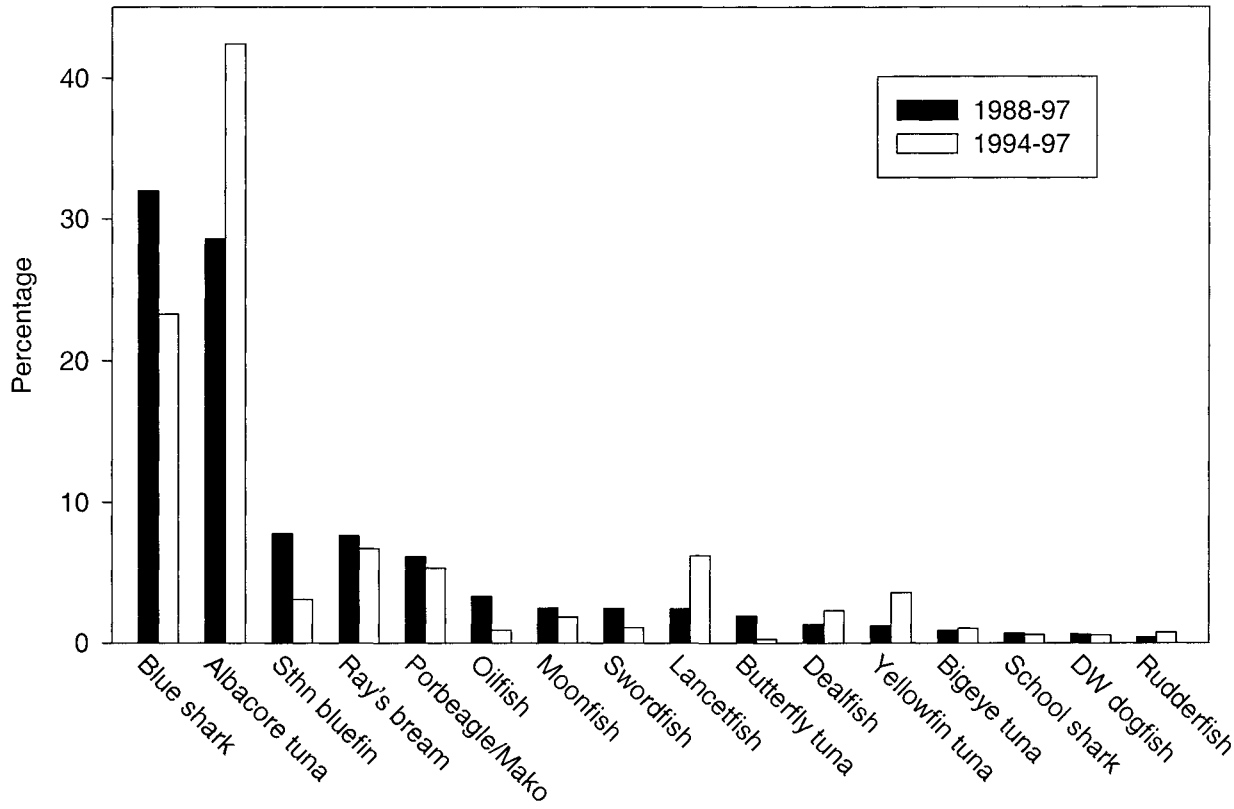


Figure 6: **Percentage species composition of scaled estimates of numbers of fish caught by the tuna longline fishery, 1988–97 and 1994–97.**

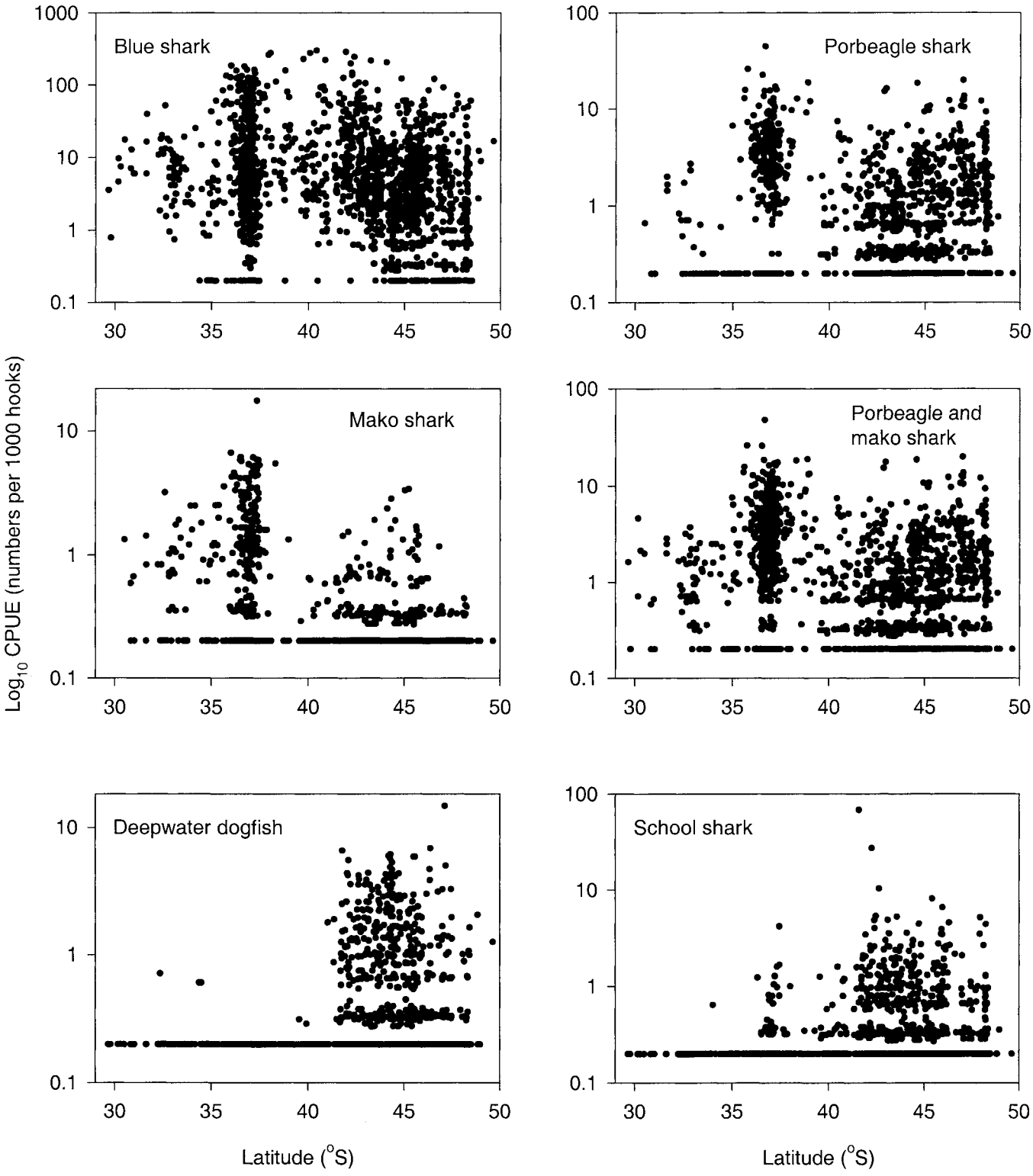


Figure 7: **Variation in catch per unit effort (CPUE) with latitude – Sharks. Zero CPUEs are plotted at 0.2 per 1000 hooks.**

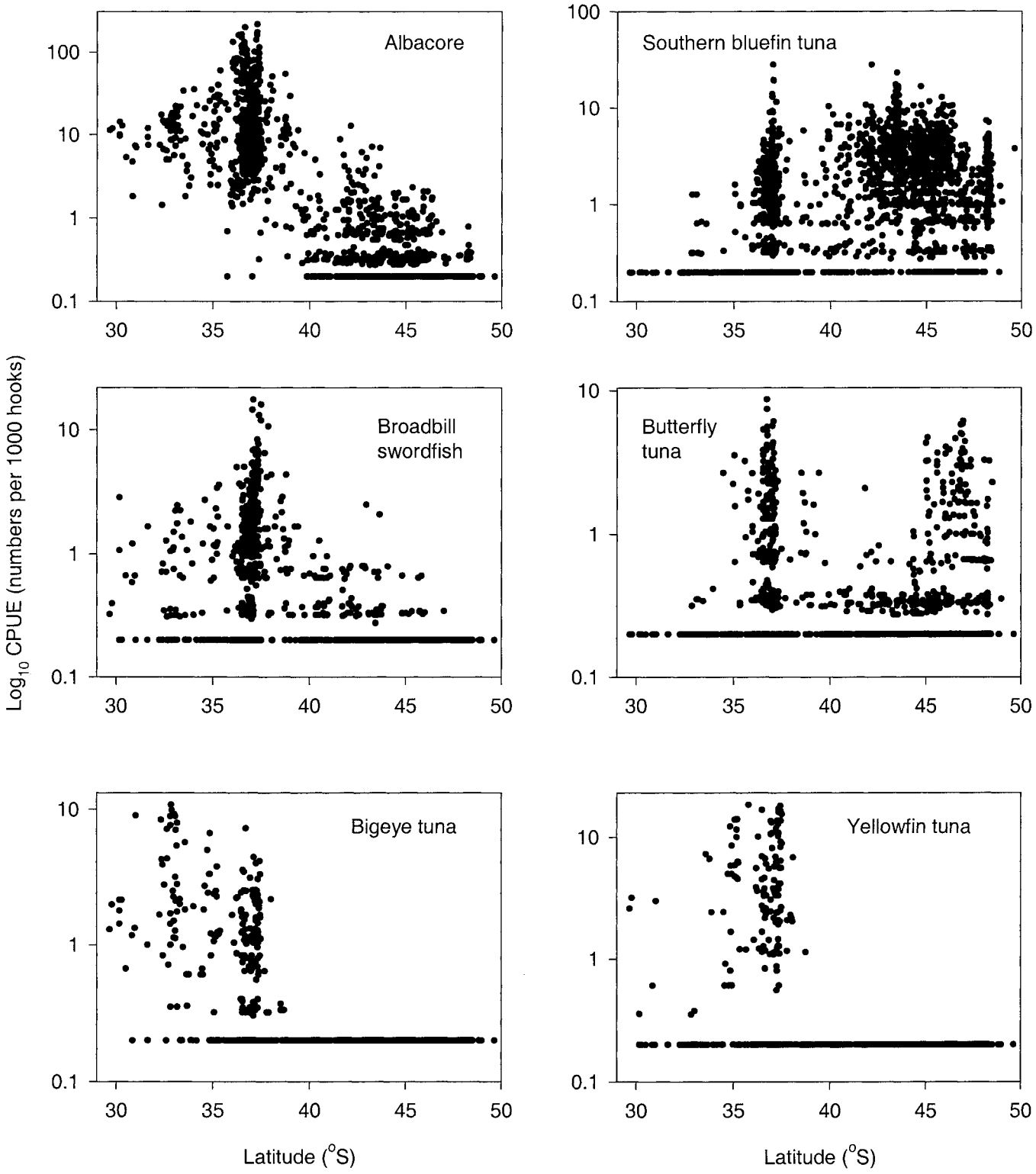


Figure 7 (continued): **Variation in catch per unit effort (CPUE) with latitude – Tunas and broadbill swordfish. Zero CPUEs are plotted at 0.2 per 1000 hooks.**

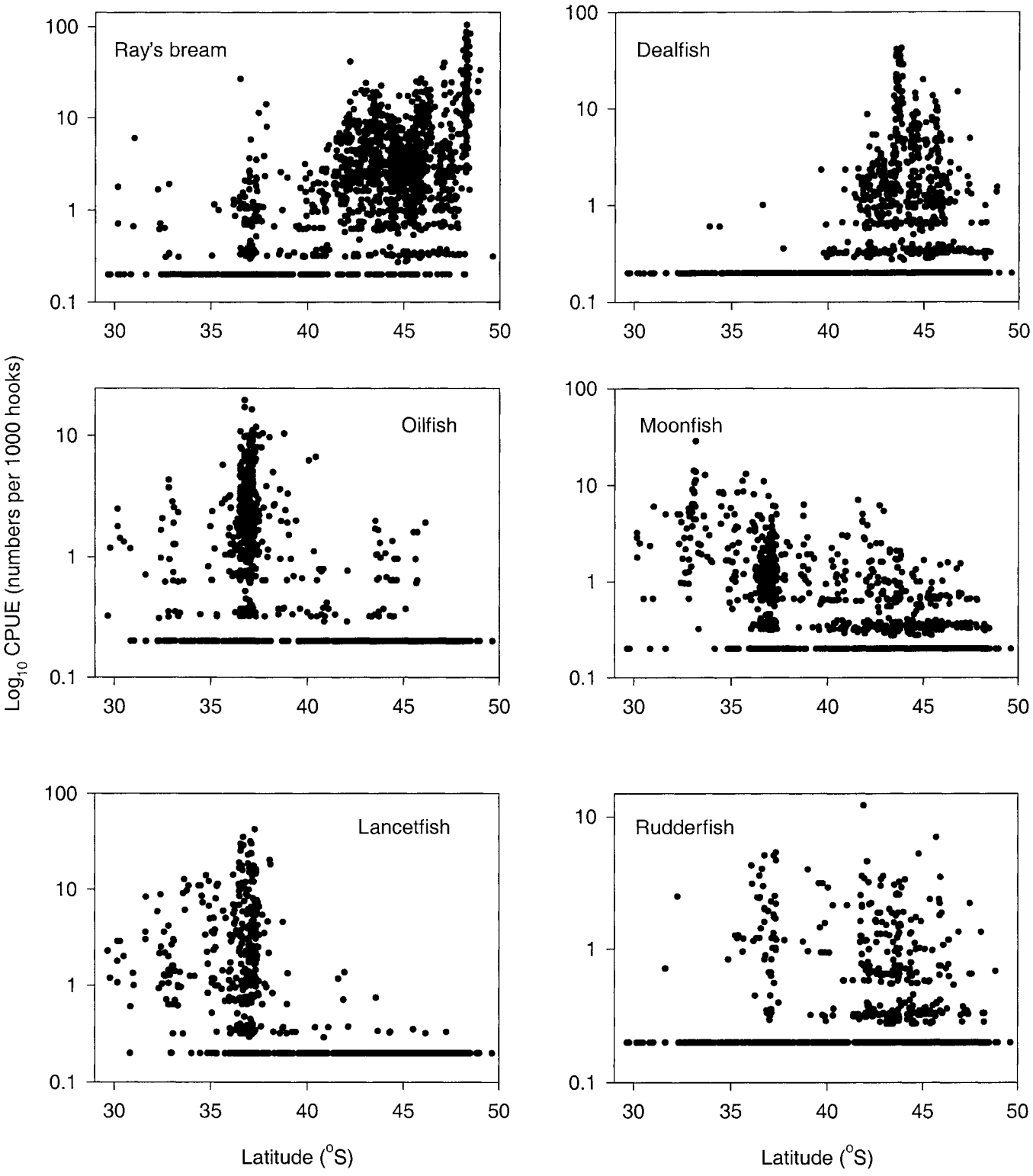


Figure 7 (continued): **Variation in catch per unit effort (CPUE) with latitude – Other species. Zero CPUEs are plotted at 0.2 per 1000 hooks.**

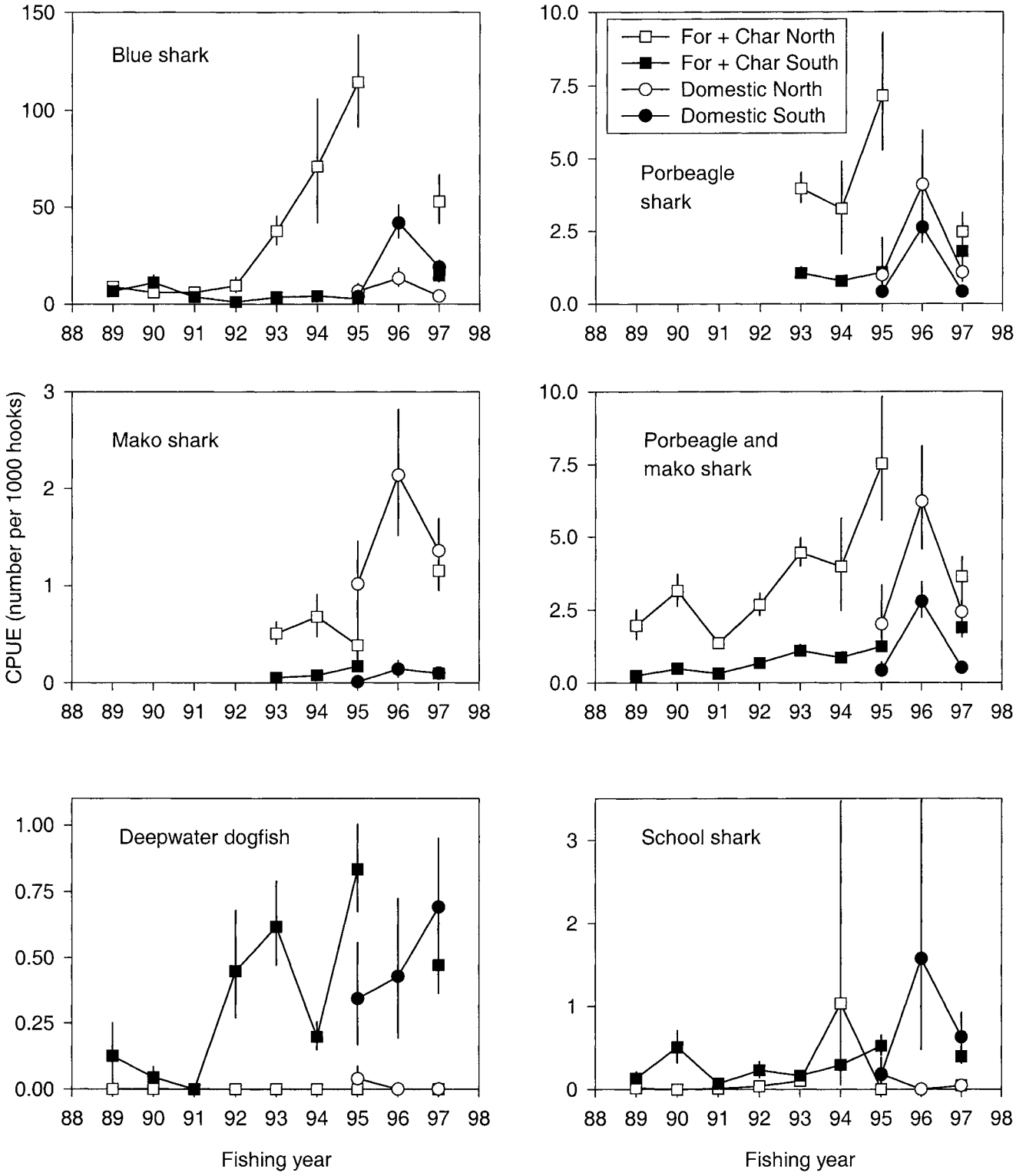


Figure 8: **Annual variation in catch per unit effort (CPUE) for the foreign and charter, and domestic fleets fishing in the north and south regions – Sharks. Plotted values are the bootstrap mean estimates with 95% confidence limits. Fishing year 89 = October 1988 to September 1989.**

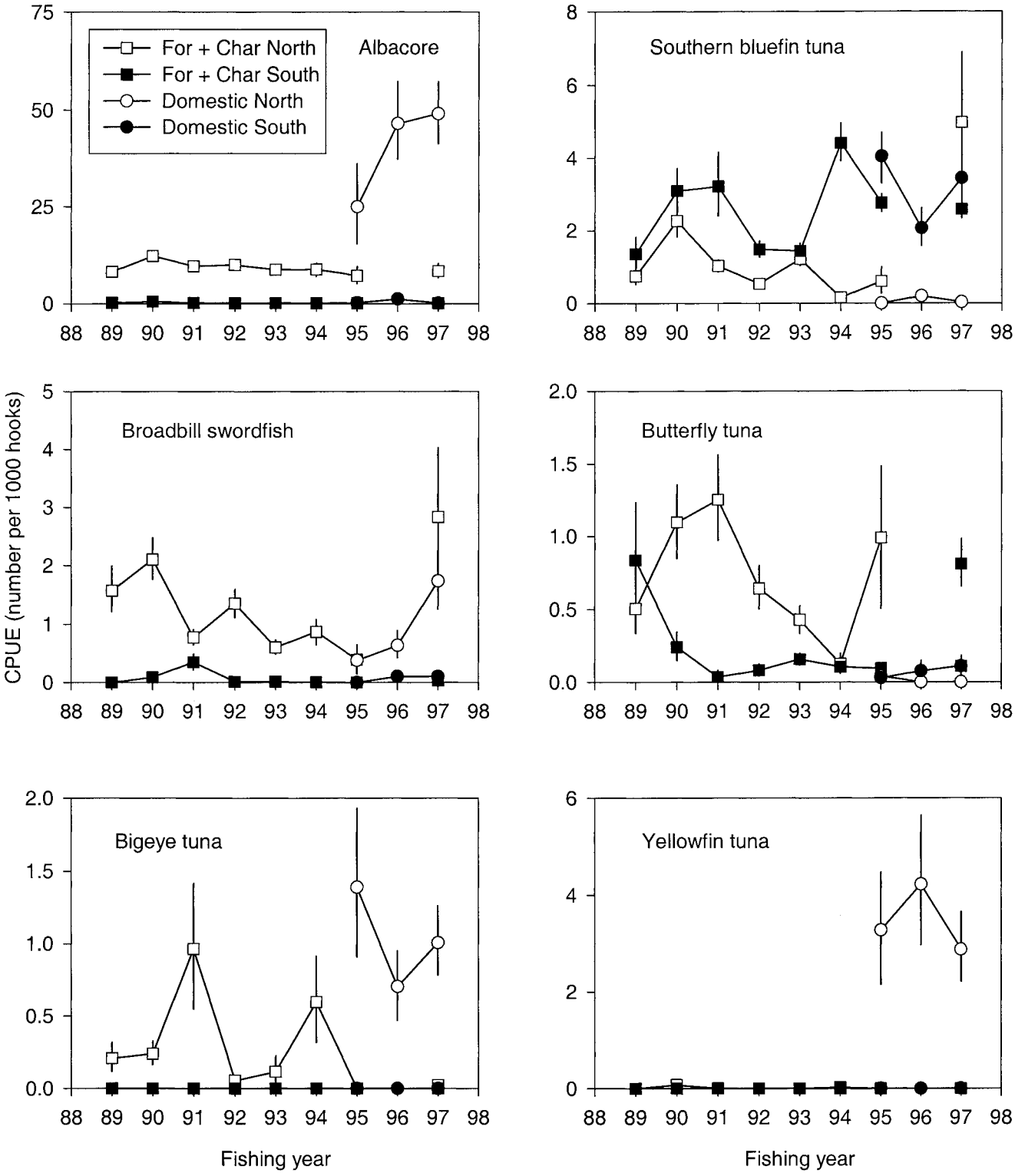


***Figure 8 (continued)*: Annual variation in catch per unit effort (CPUE) for the foreign and charter, and domestic fleets fishing in the north and south regions – Tunas and broadbill swordfish. Plotted values are the bootstrap mean estimates with 95% confidence limits. Fishing year 89 = October 1988 to September 1989.**

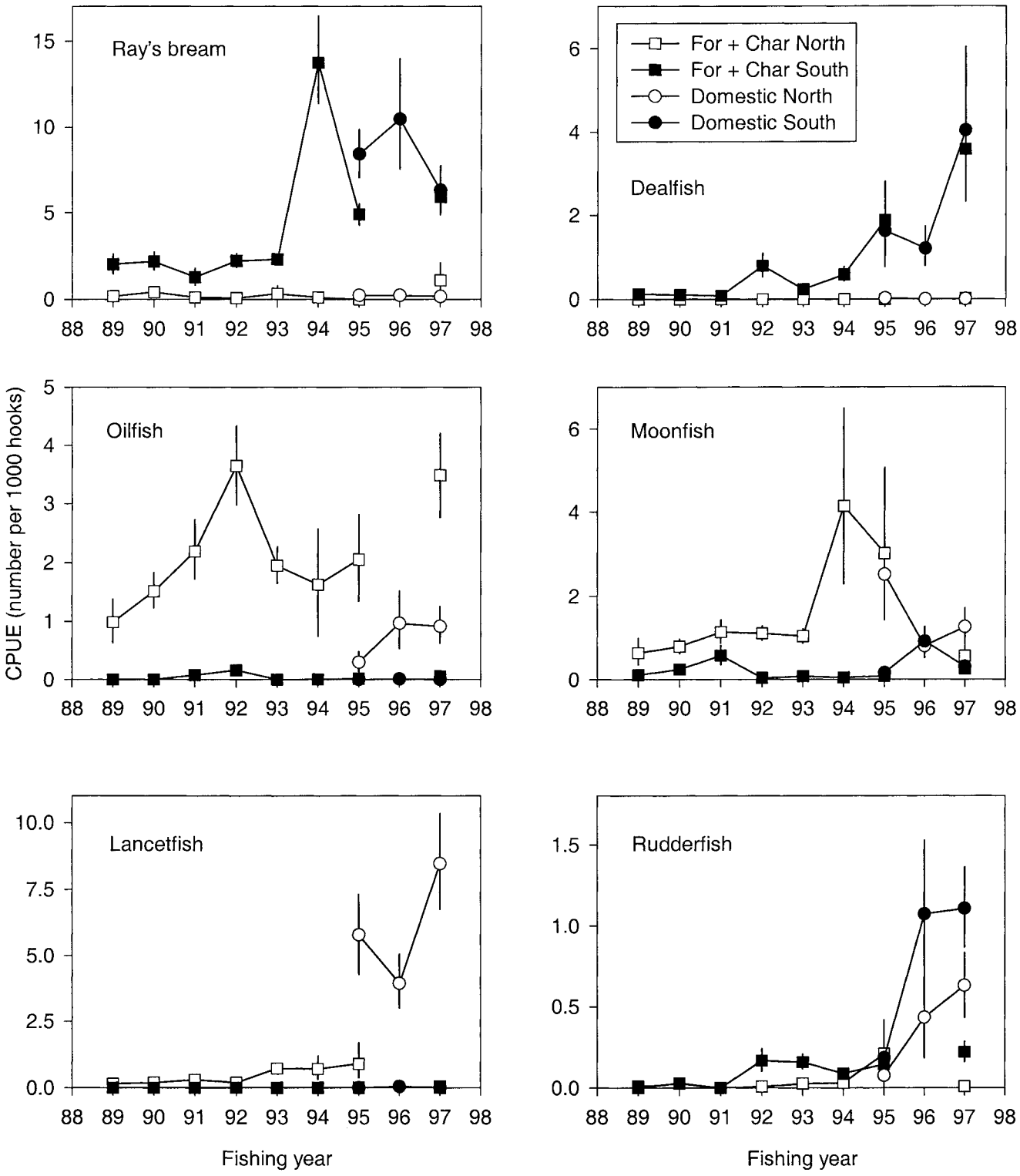


Figure 8 (continued): **Annual variation in catch per unit effort (CPUE) for the foreign and charter, and domestic fleets fishing in the north and south regions – Other species. Plotted values are the bootstrap mean estimates with 95% confidence limits. Fishing year 89 = October 1988 to September 1989.**

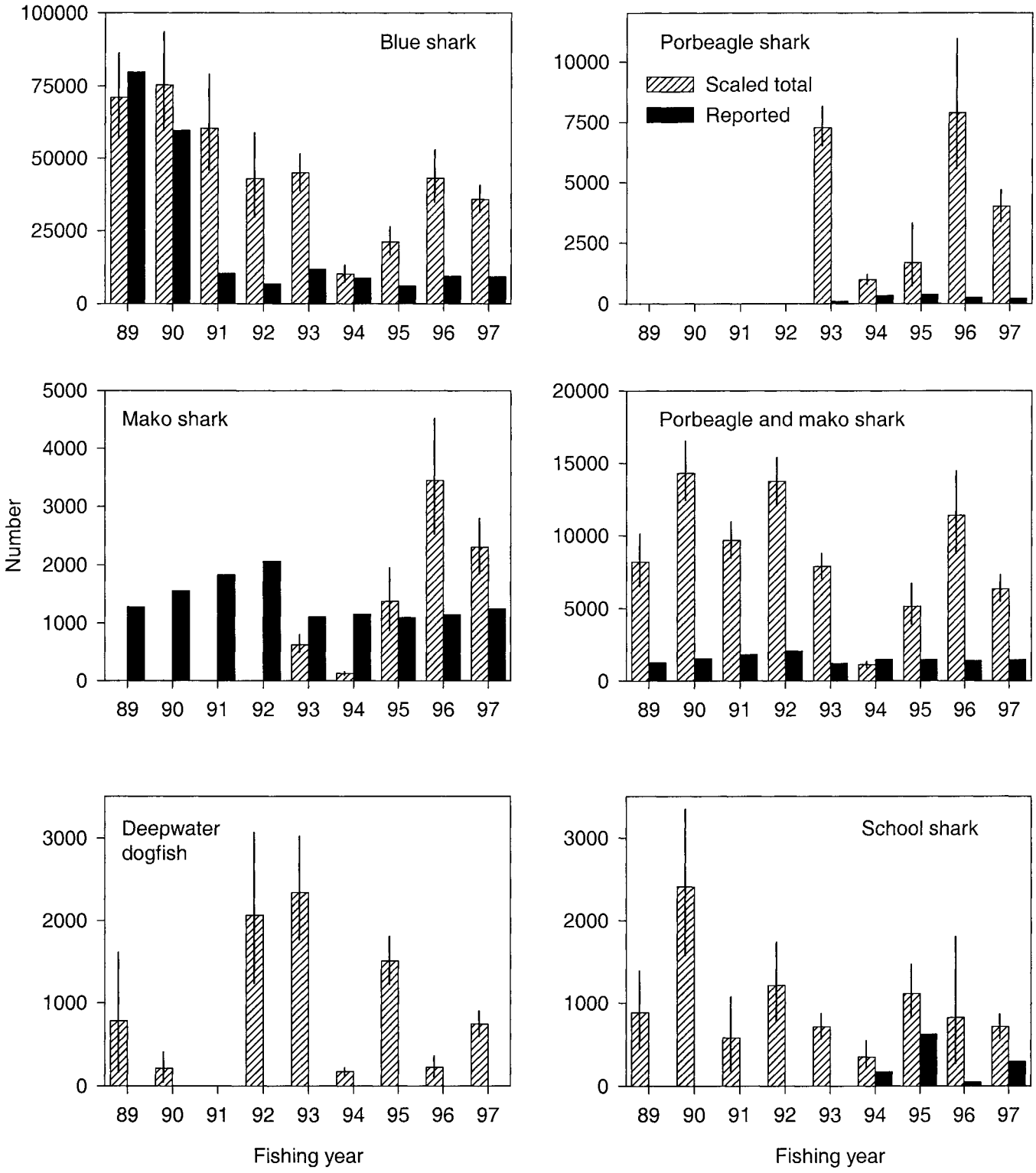


Figure 9: **Bootstrap estimates of scaled total numbers of fish caught (with 95% confidence limits) and numbers reported by vessel skippers on TLCERs – Sharks. The scaled totals underestimate actual catches in 1992–93 and 1993–94 because some domestic vessels were not included. Fishing year 89 = October 1988 to September 1989. See text for further details.**

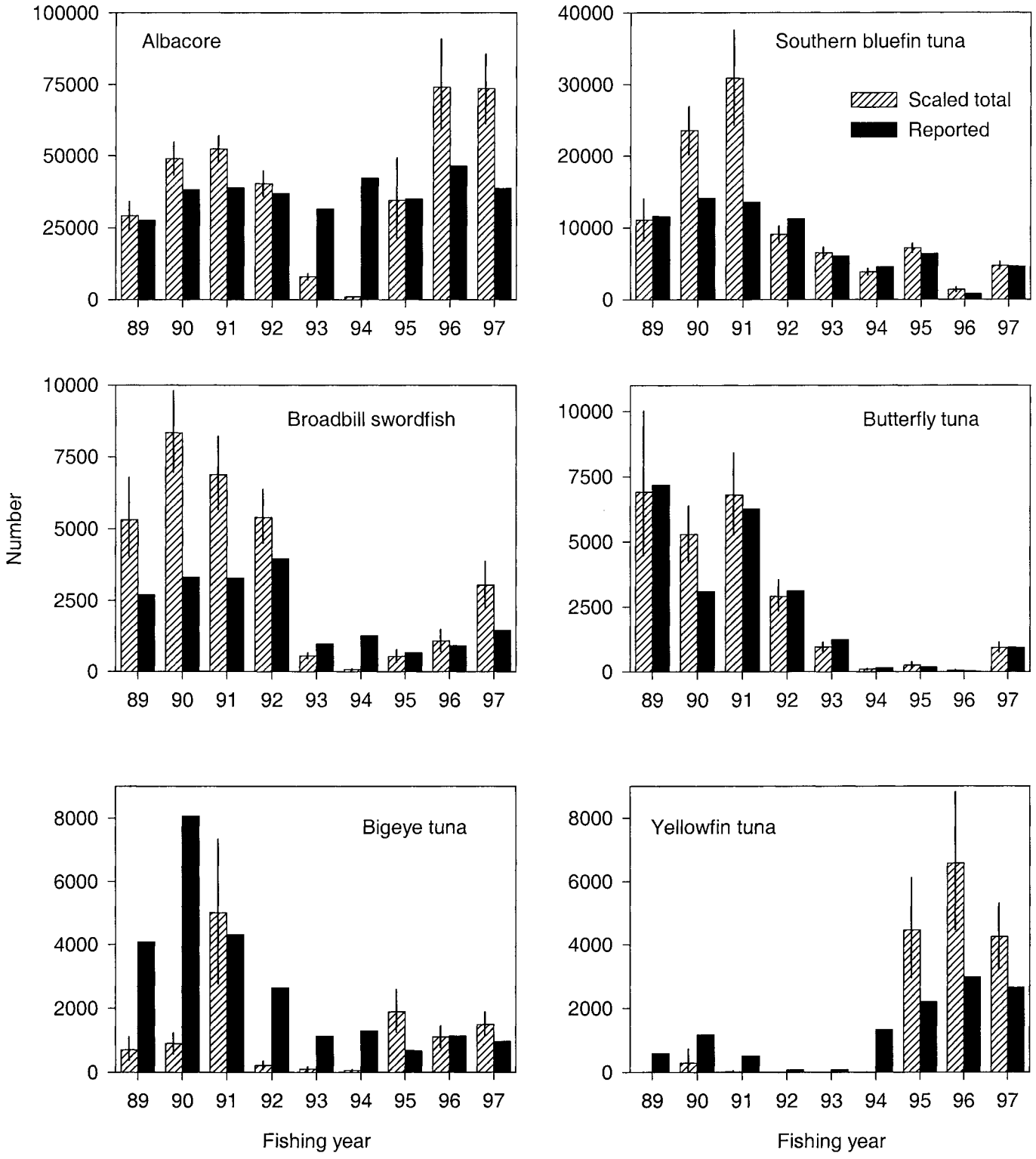


Figure 9 (continued): **Bootstrap estimates of scaled total numbers of fish caught (with 95% confidence limits) and numbers reported by vessel skippers on TLCERs – Tunas and broadbill swordfish. The scaled totals underestimate actual catches in 1992–93 and 1993–94 because some domestic vessels were not included. Fishing year 89 = October 1988 to September 1989. See text for further details.**

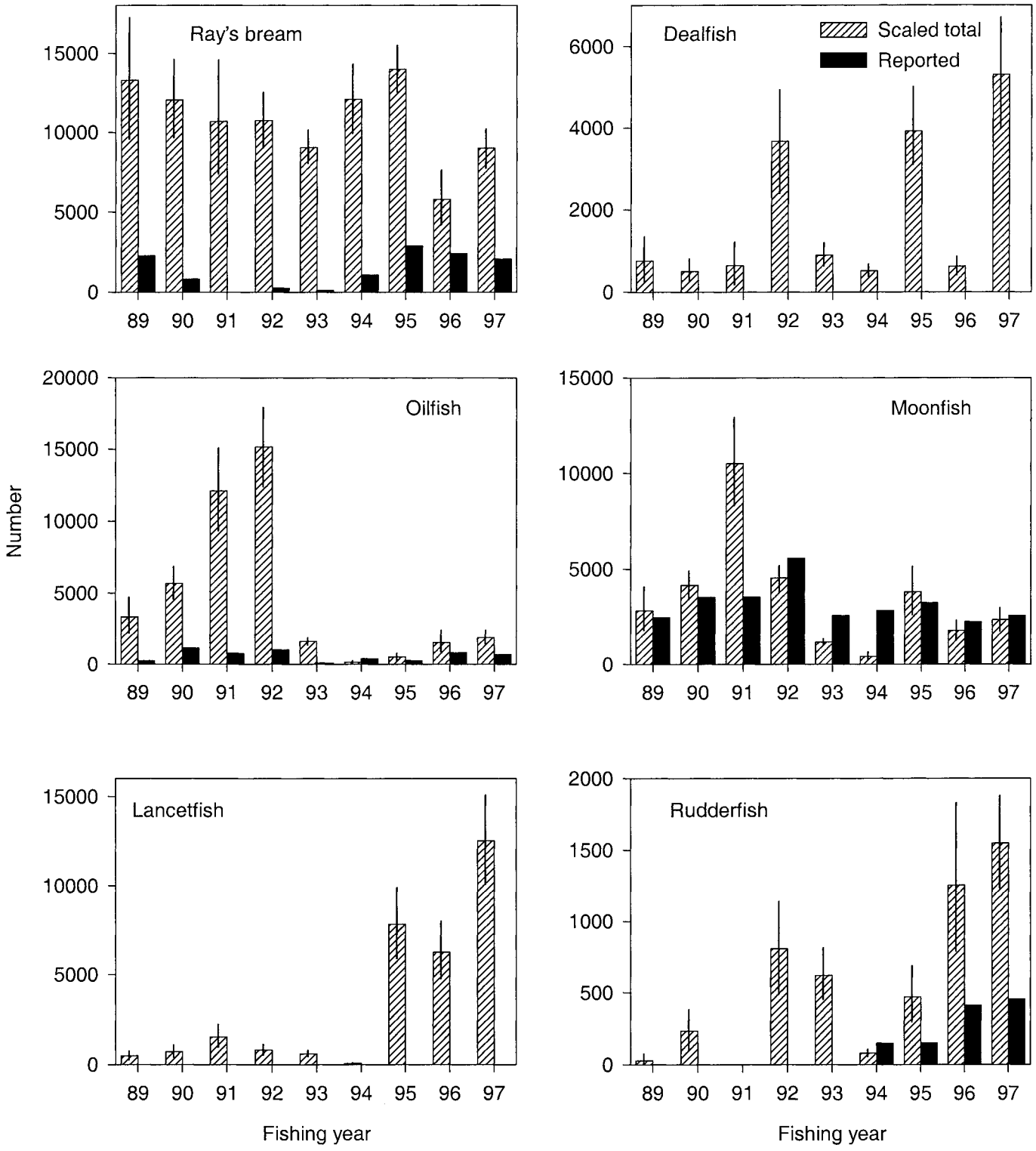


Figure 9 (continued): **Bootstrap estimates of scaled total numbers of fish caught (with 95% confidence limits) and numbers reported by vessel skippers on TLCERs – Other species. The scaled totals underestimate actual catches in 1992–93 and 1993–94 because some domestic vessels were not included. Fishing year 89 = October 1988 to September 1989. See text for further details.**

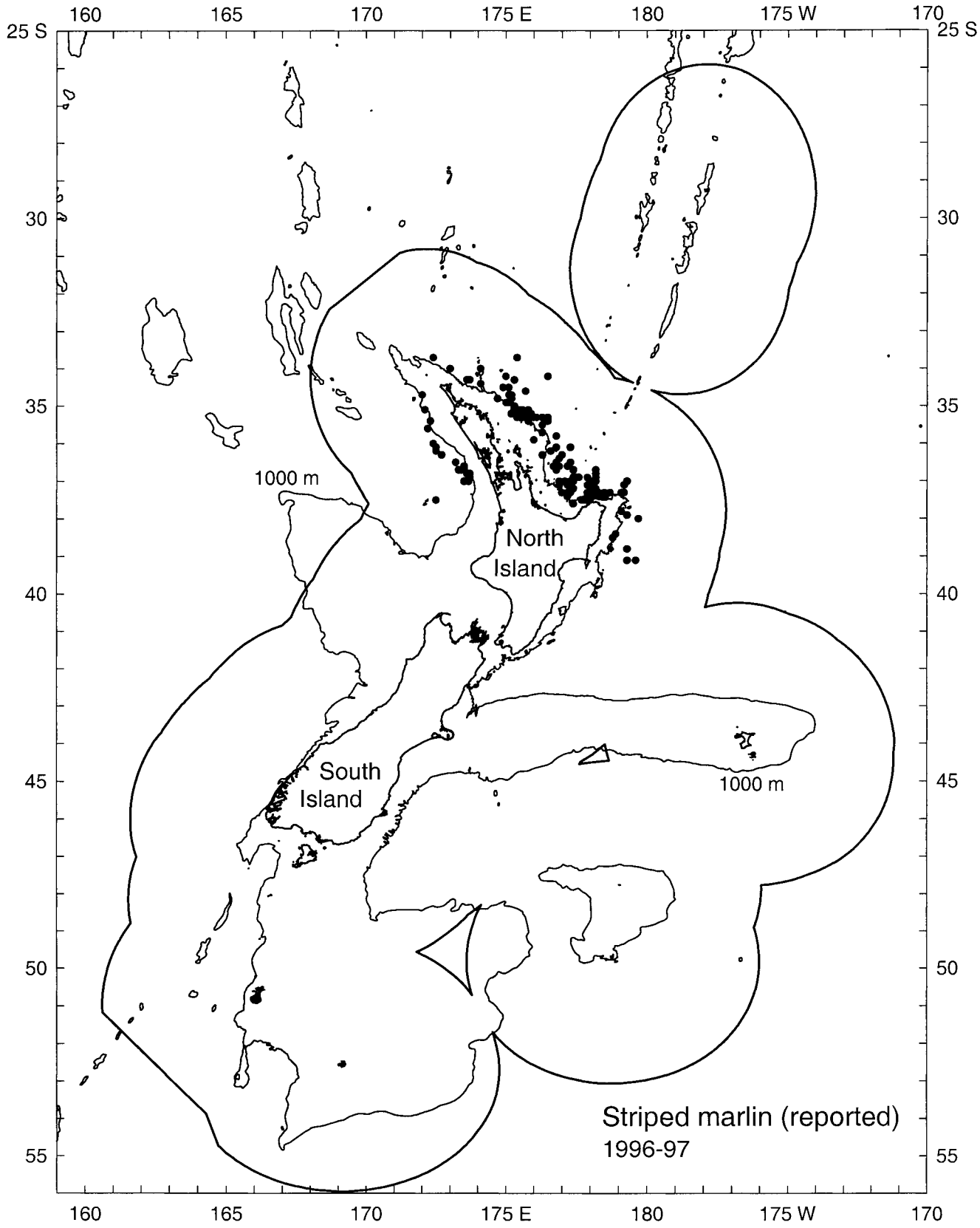


Figure 10: **Start positions for tuna longline sets catching striped marlin (TLCER), October 1996 to September 1997 (*N* = 301). Some points represent multiple captures.**

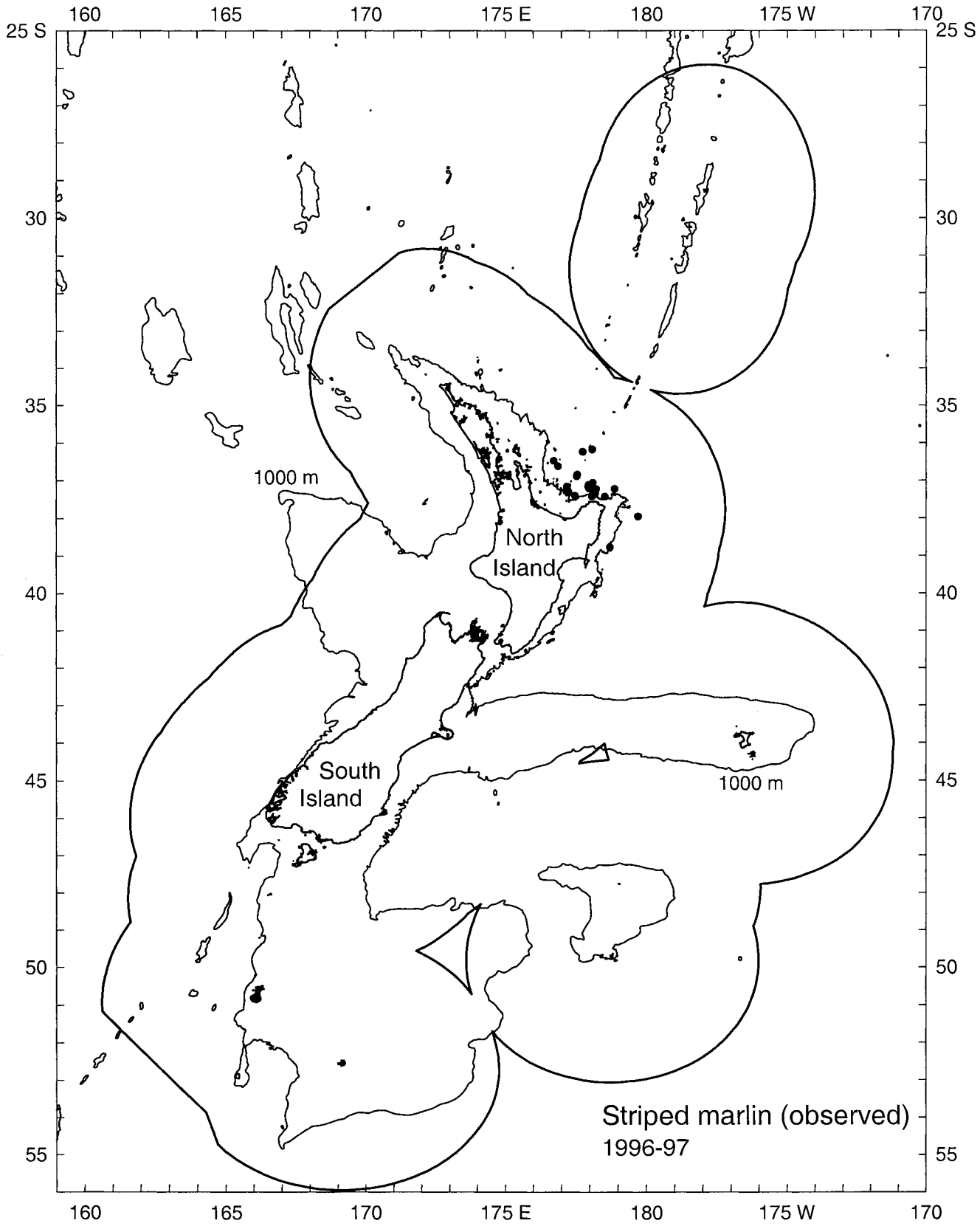
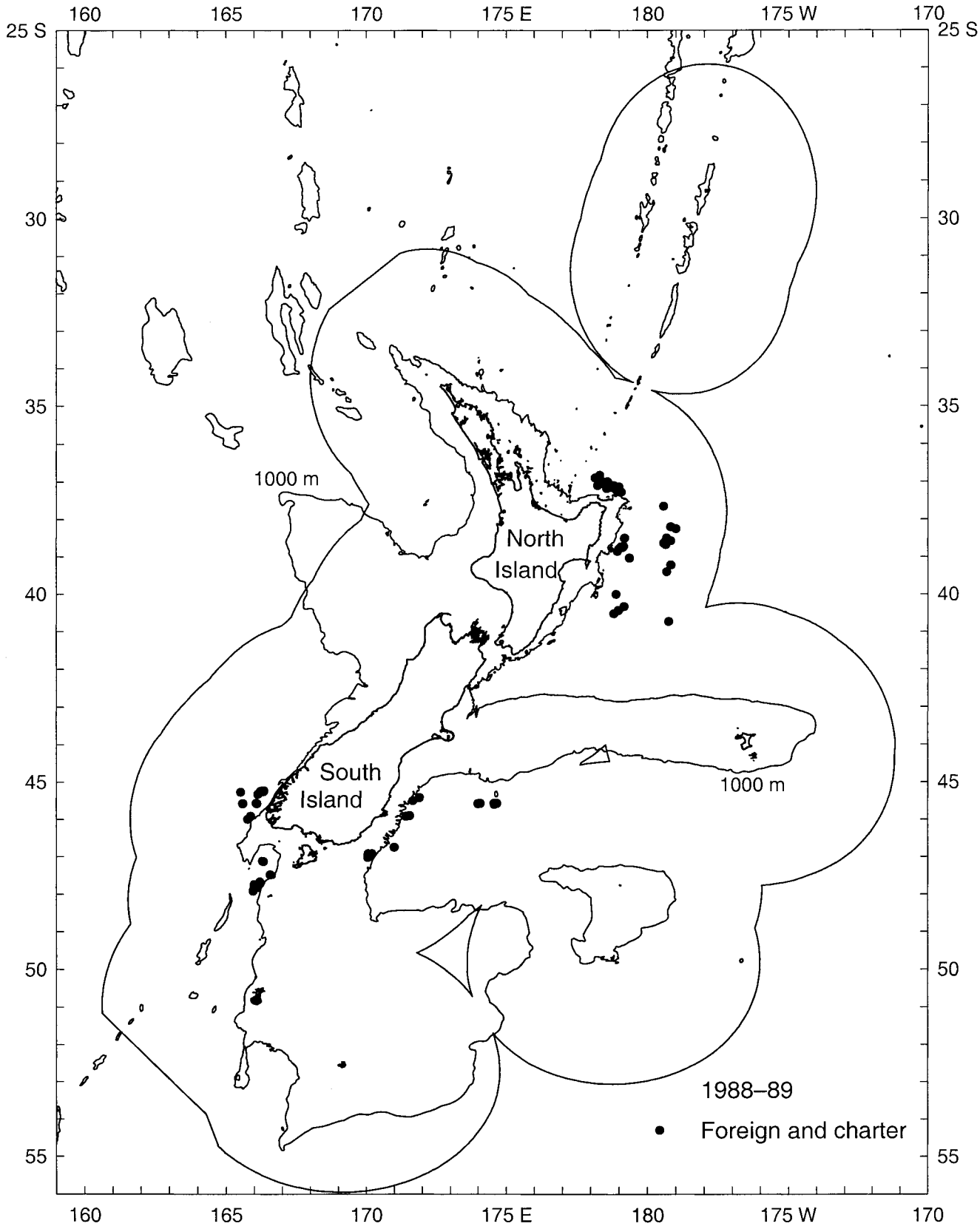
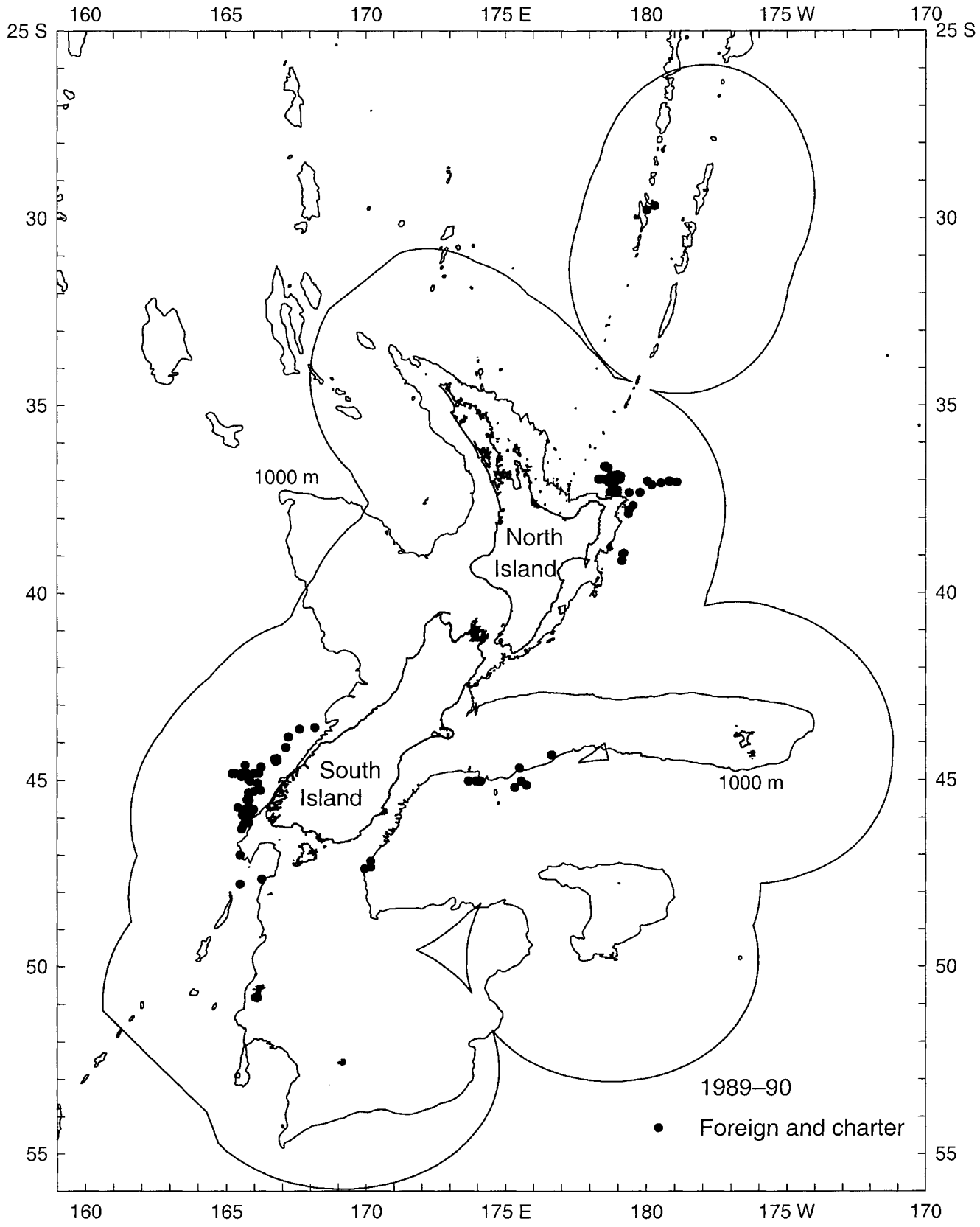


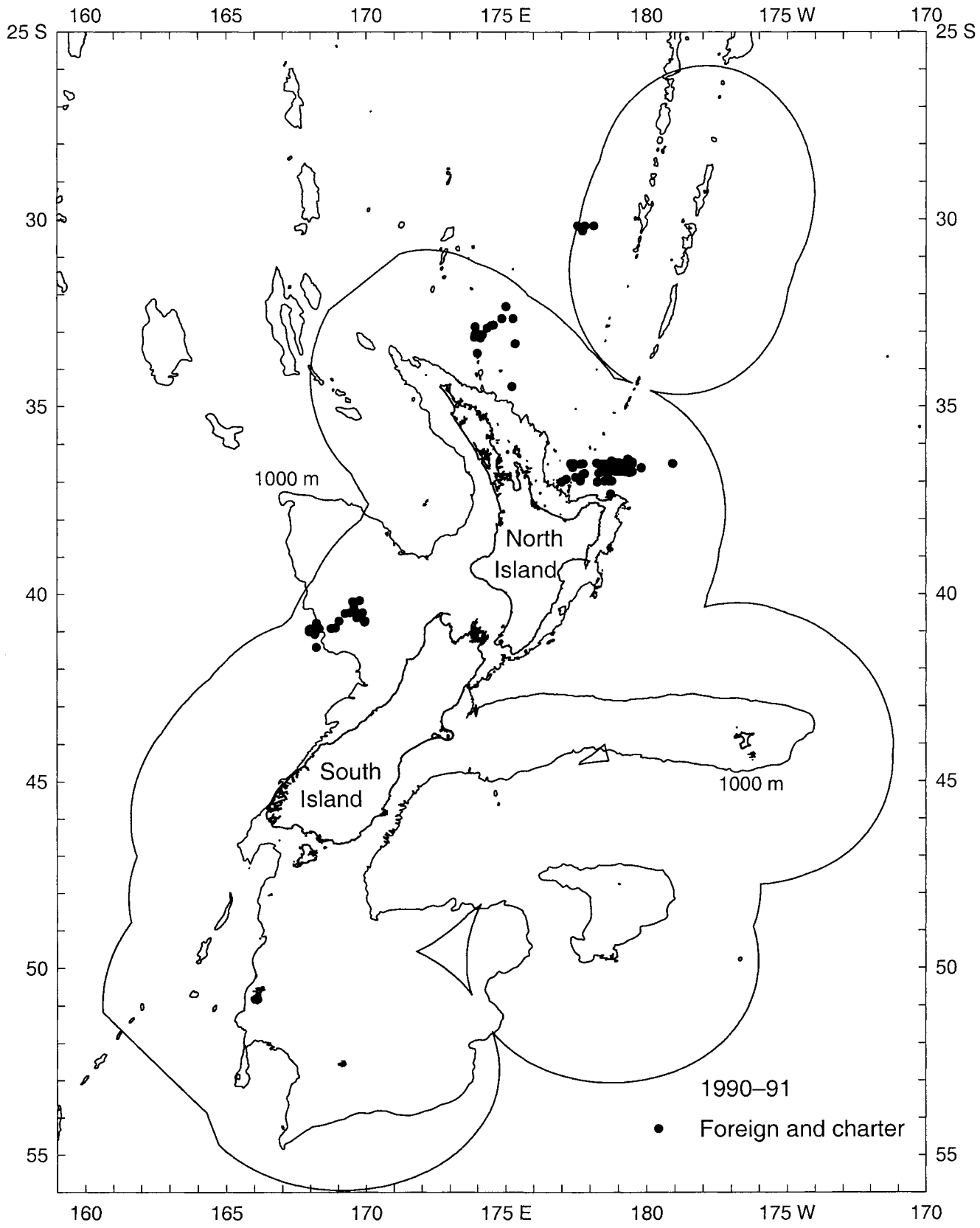
Figure 11: **Start positions for observed tuna longline sets catching striped marlin, October 1996 to September 1997 (*N* = 34).**



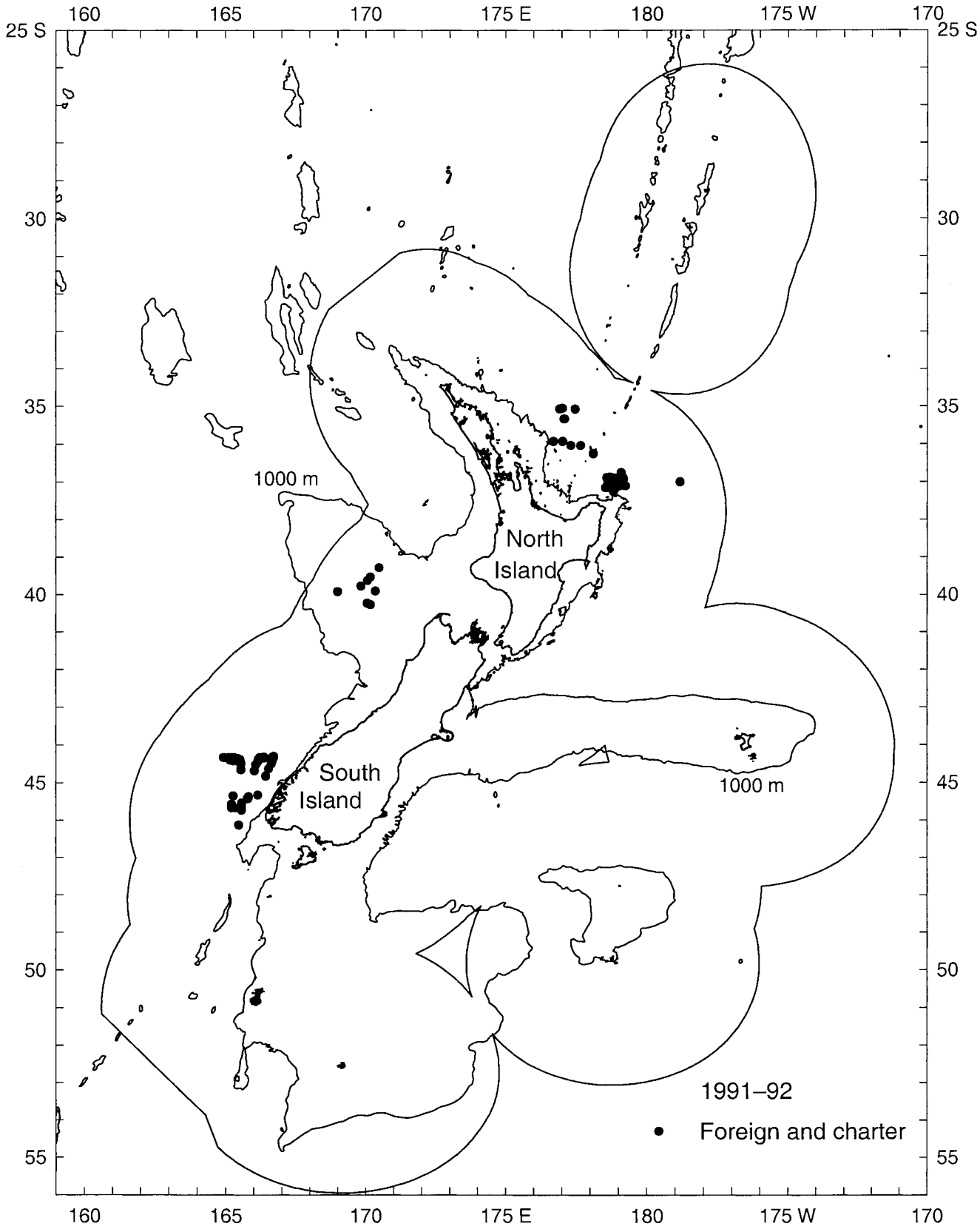
Appendix 1: **Start positions of observed tuna longline sets, 1988–89 (*N* = 87 sets).**



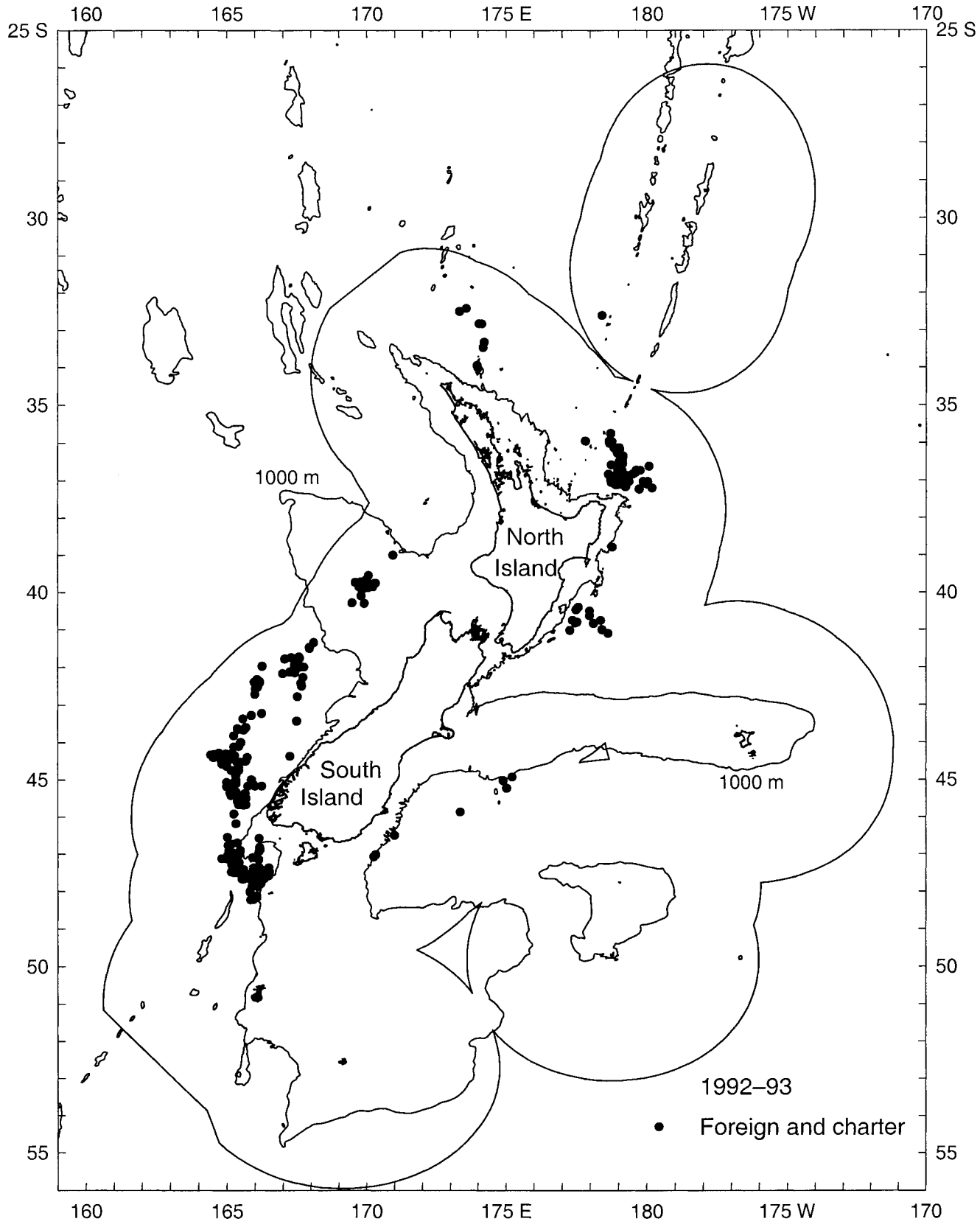
Appendix 1 (continued): **1989–90 (*N* = 154 sets).**



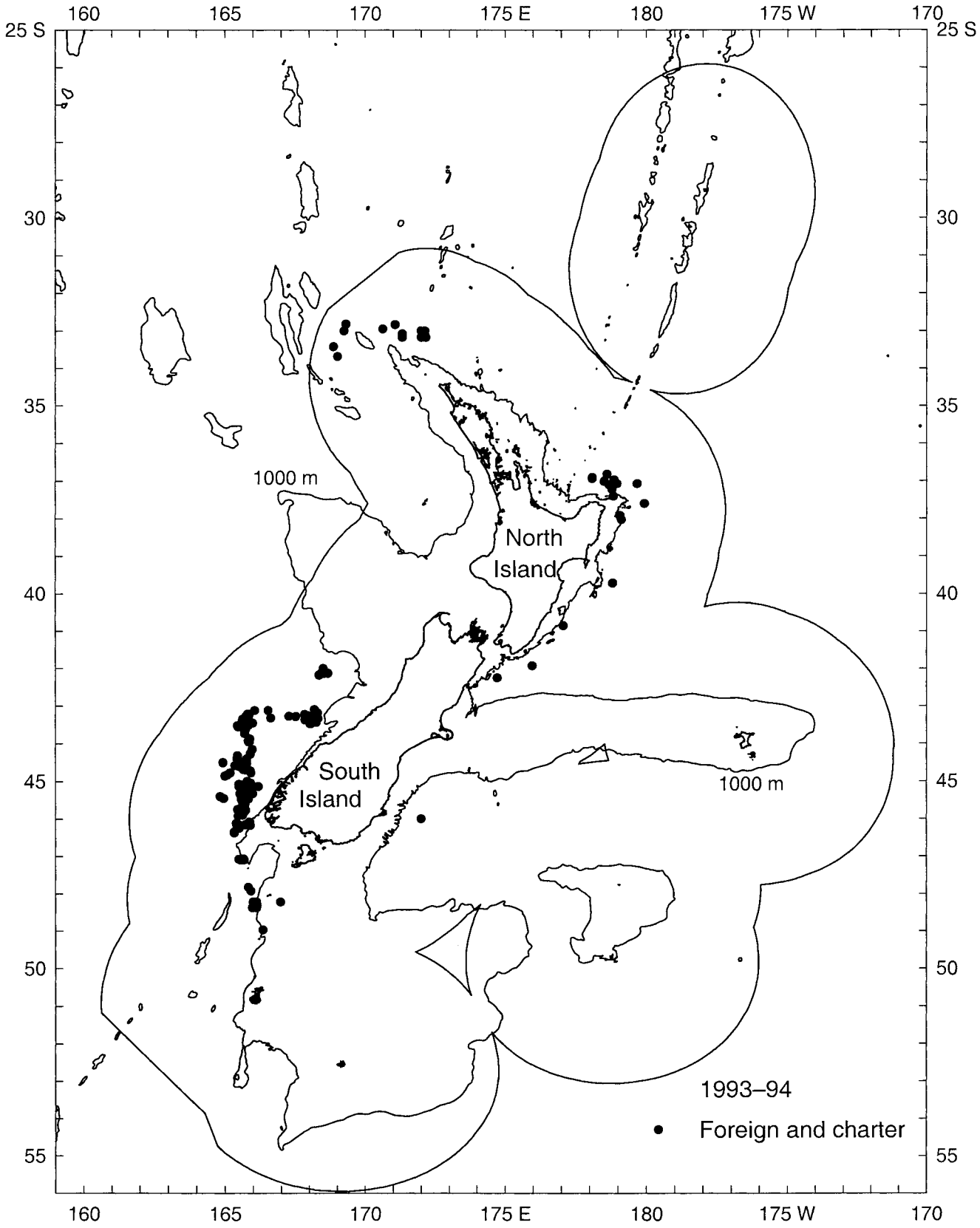
Appendix 1 (continued): **1990–91 (*N* = 150 sets).**



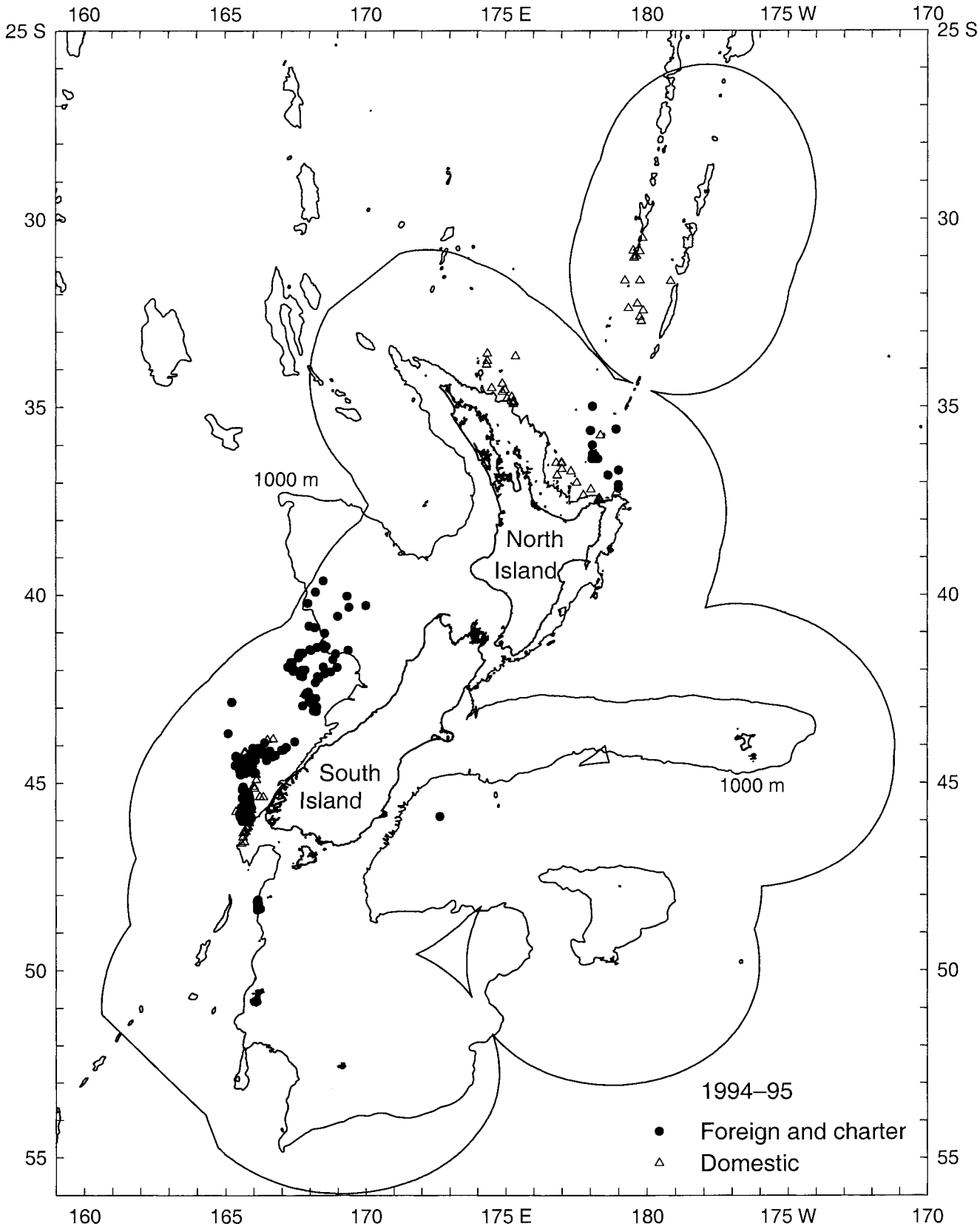
Appendix 1 (continued): **1991–92** (*N* = **176 sets**).



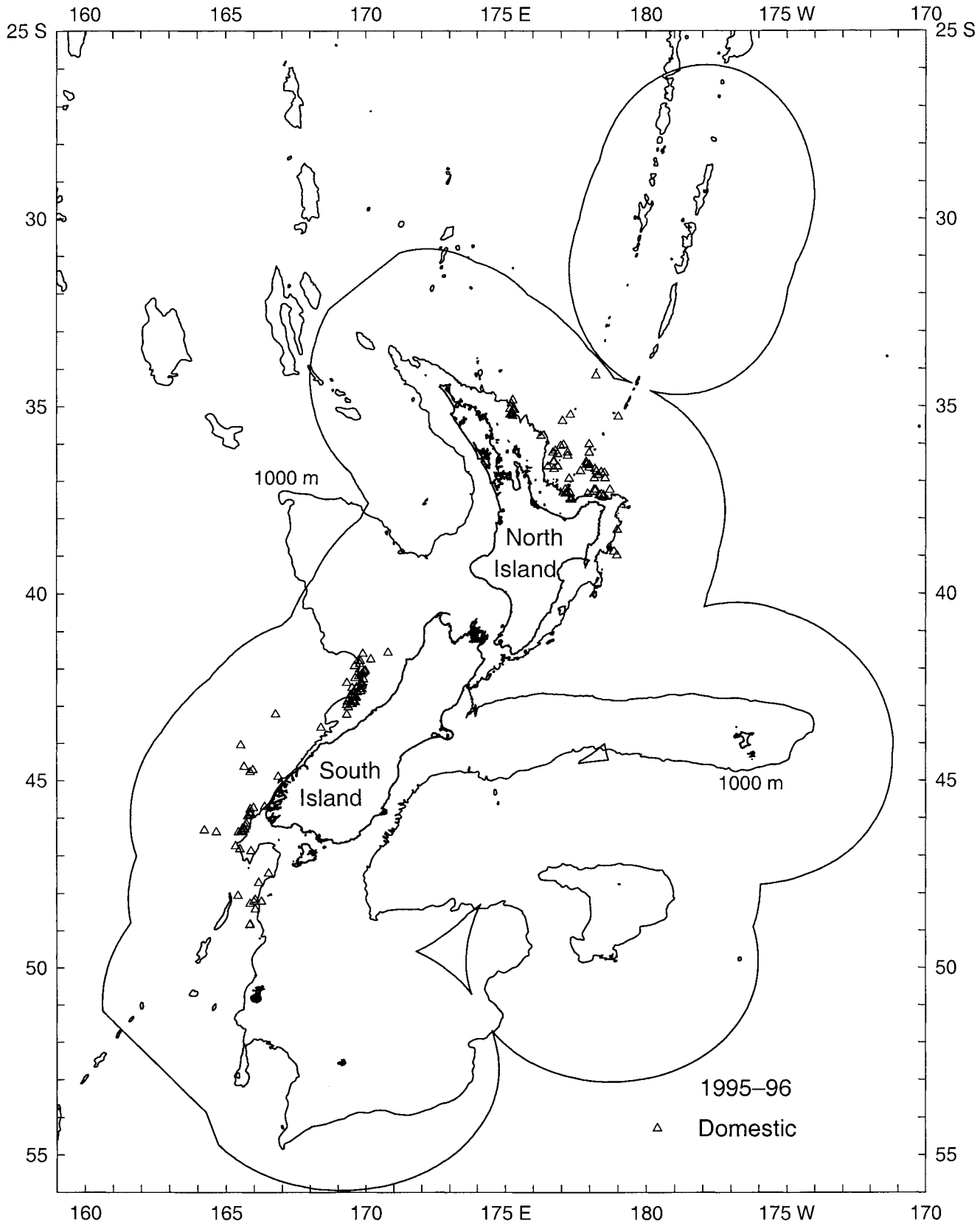
Appendix 1 (continued): **1992–93 (*N* = 373 sets).**



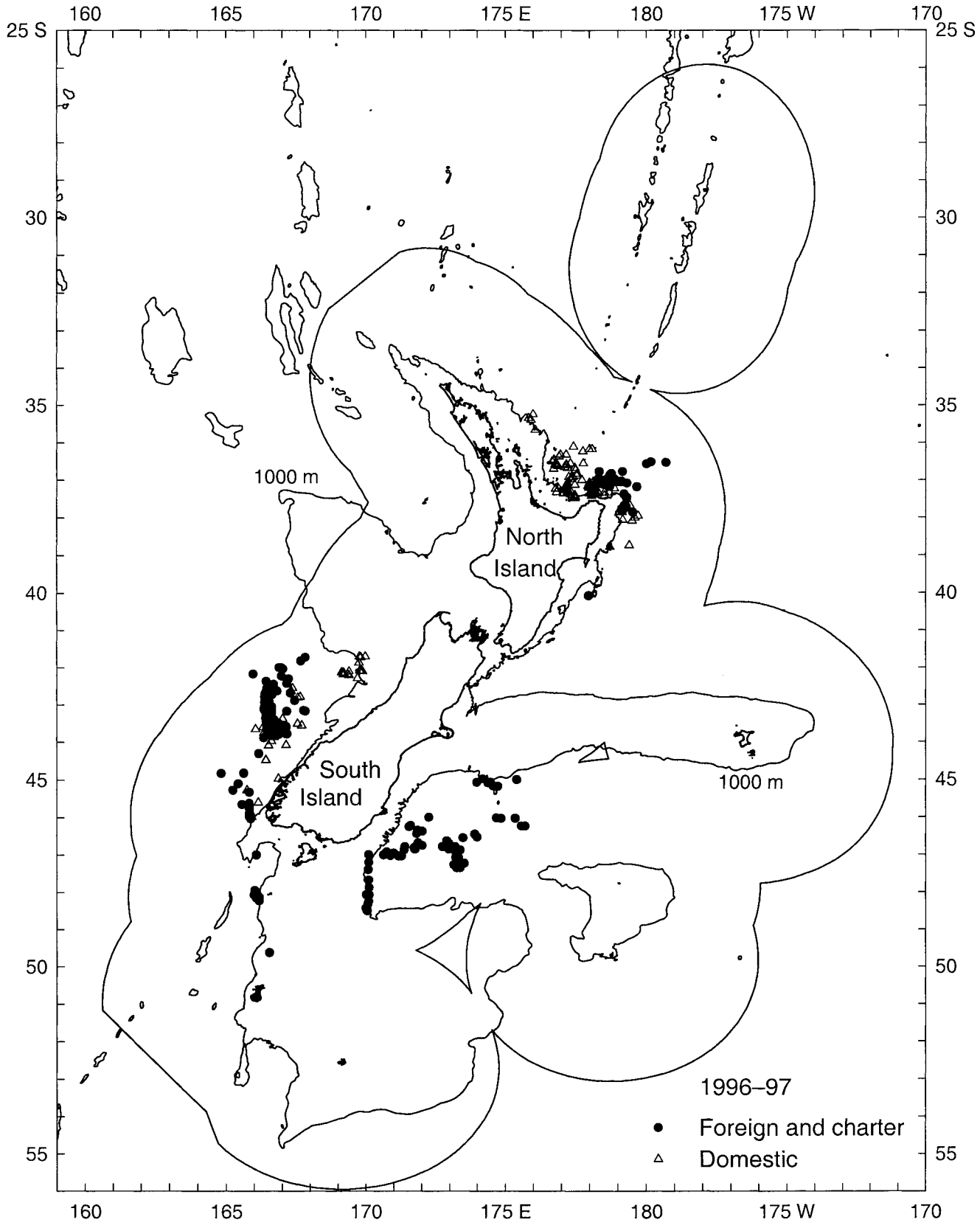
Appendix 1 (continued): **1993–94 (*N* = 243 sets).**



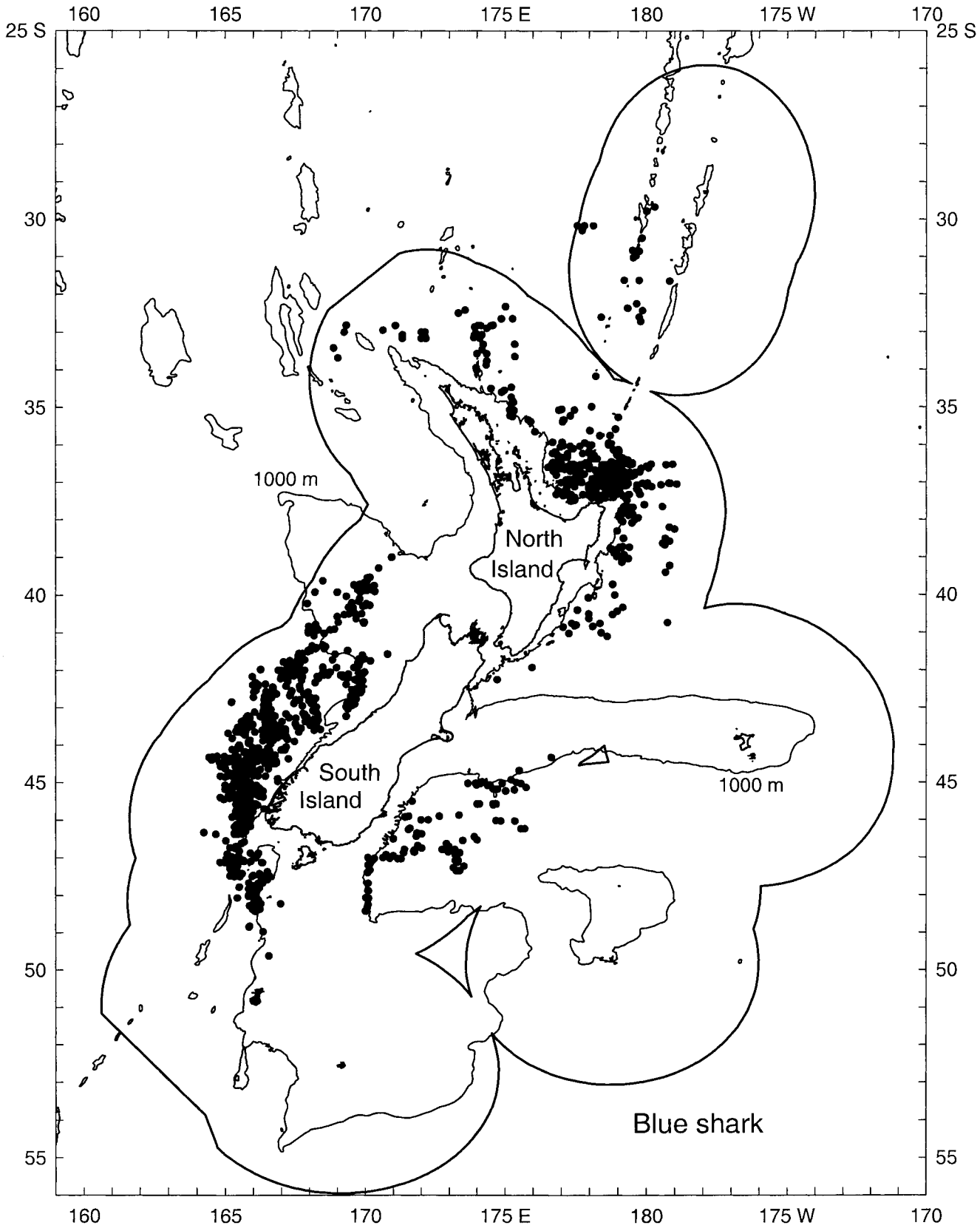
Appendix 1 (continued): **1994–95 (*N* = 339 sets).**



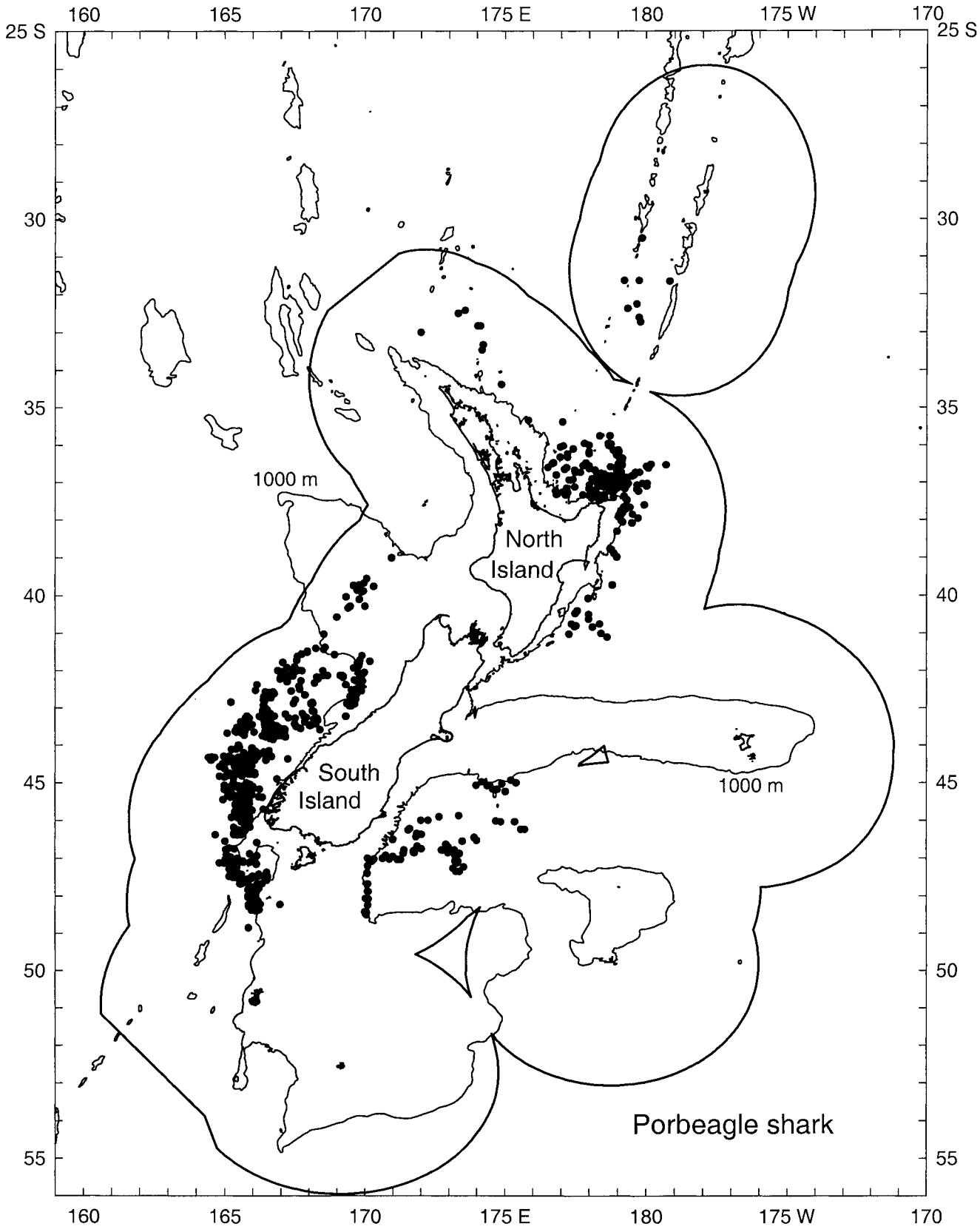
Appendix 1 (continued): **1995–96 (*N* = 147 sets).**



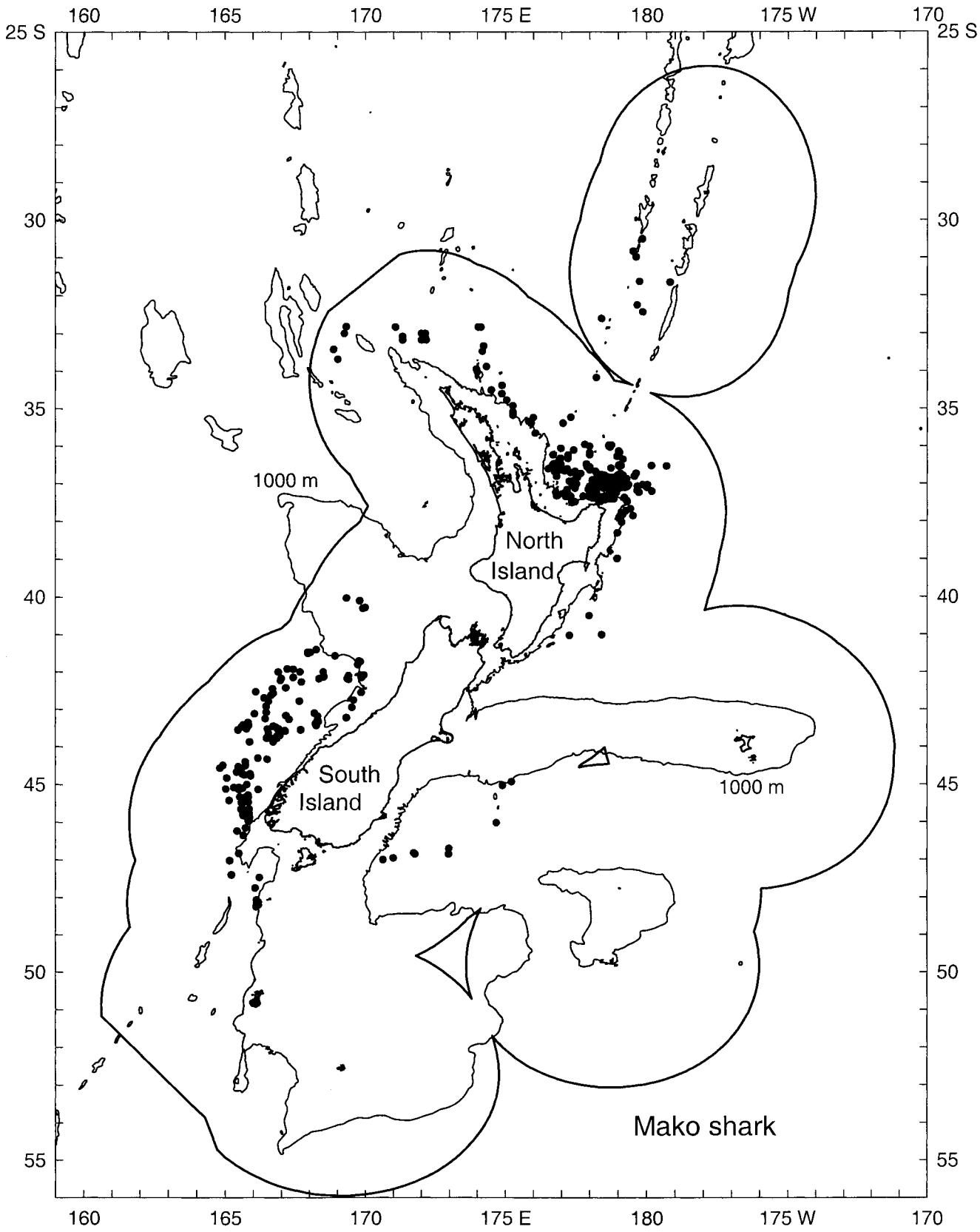
Appendix 1 (continued): **1996–97** (*N* = **424 sets**).



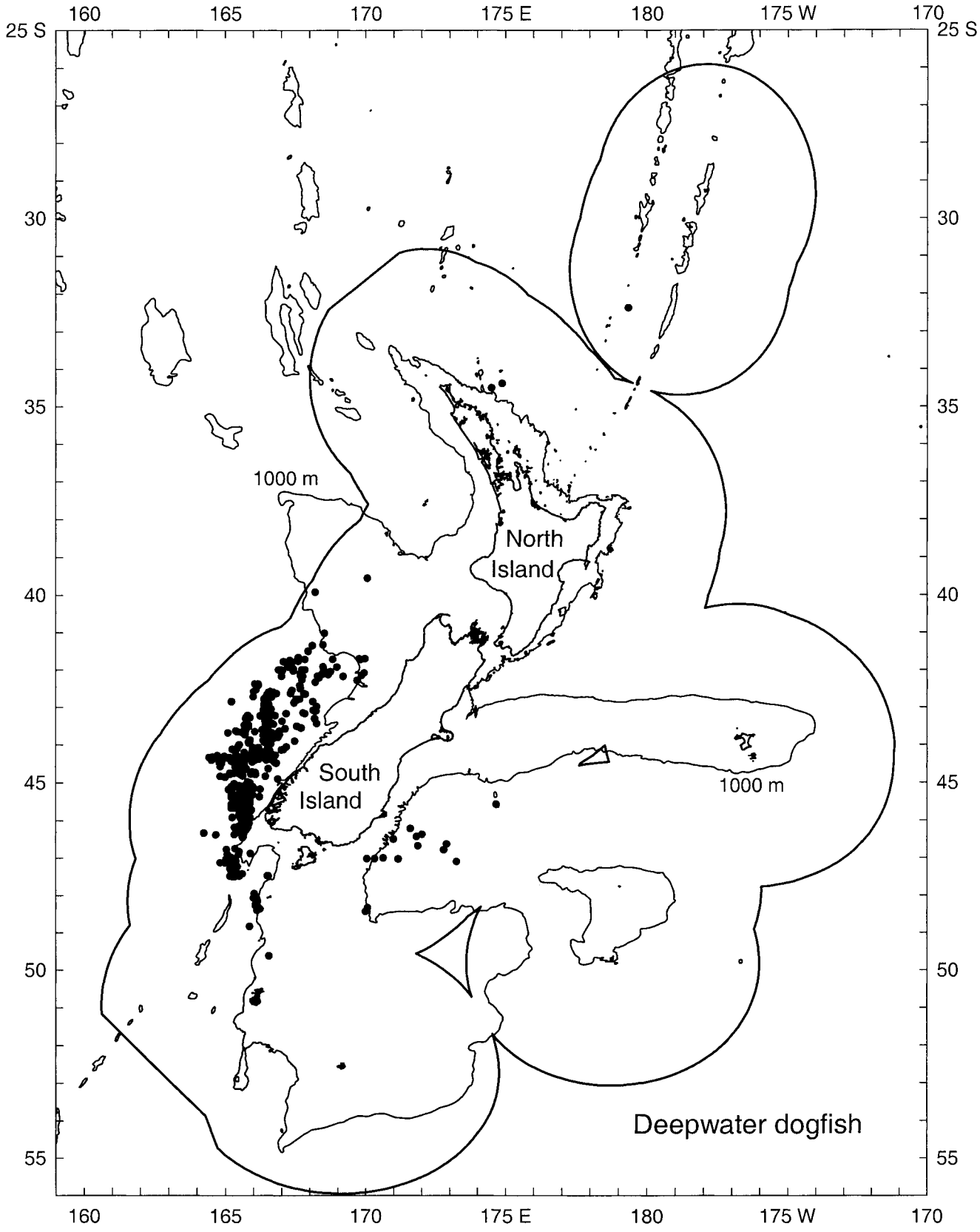
Appendix 2: **Start positions of observed tuna longline sets catching blue shark.**



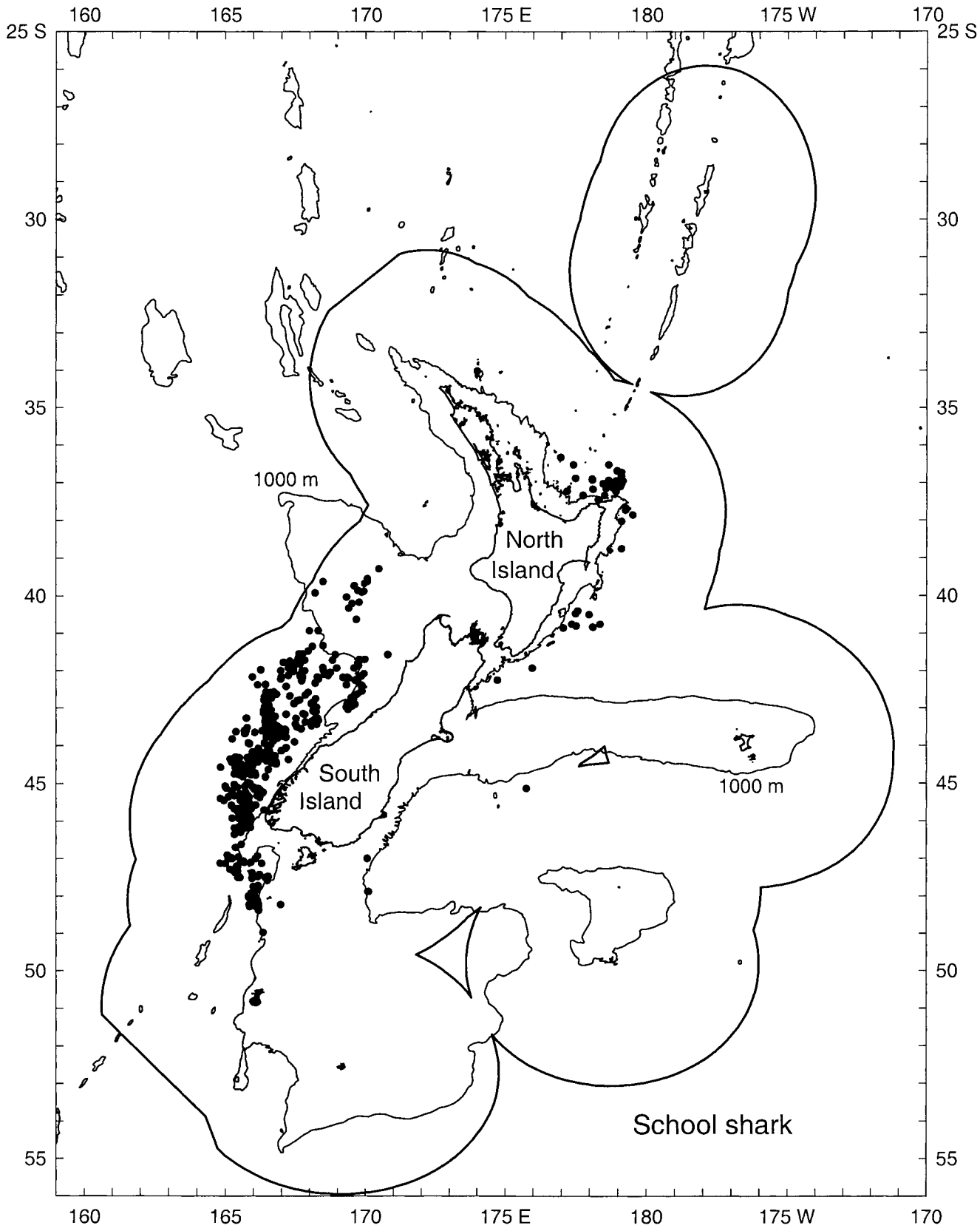
Appendix 2 (continued): **Porbeagle shark.**



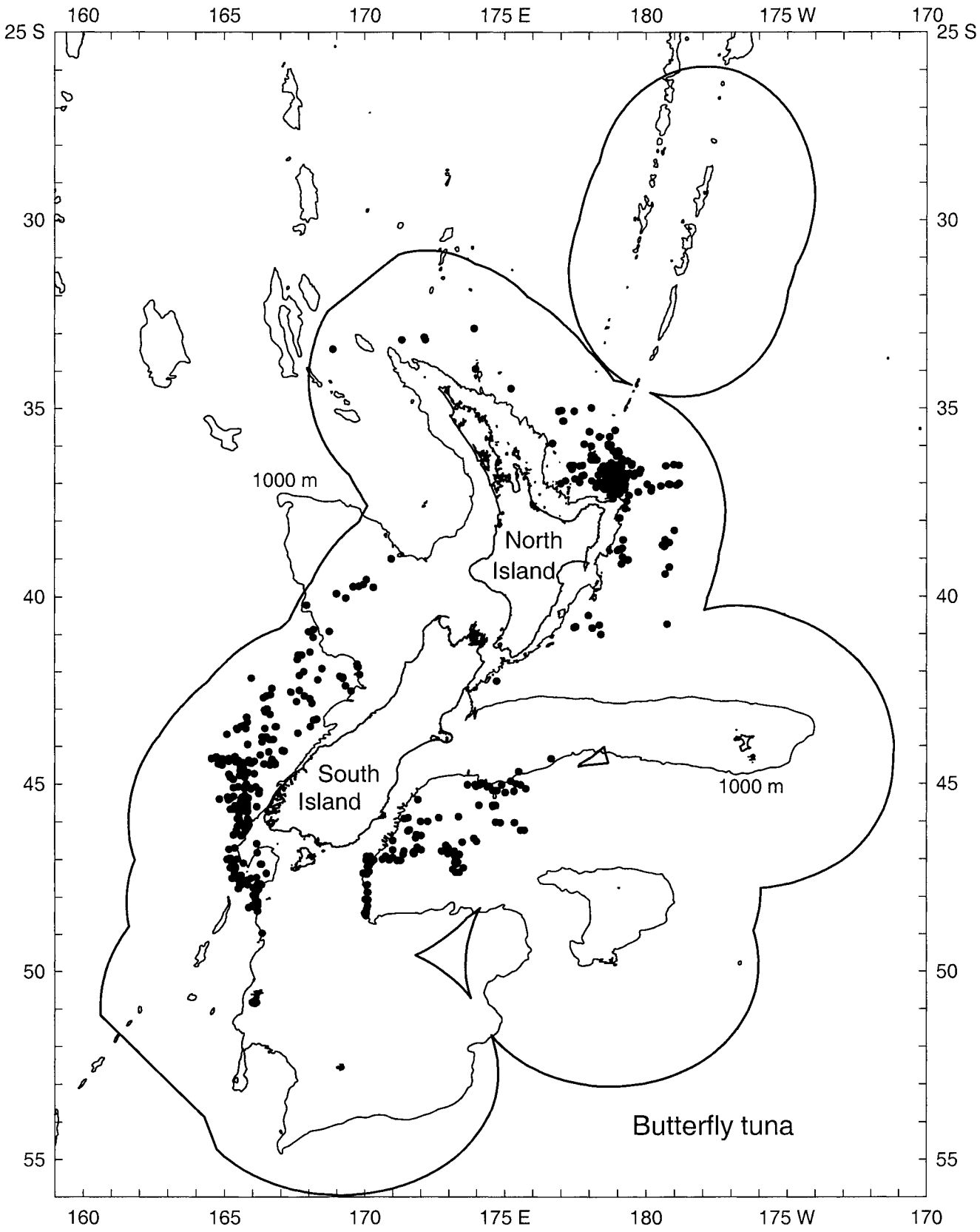
Appendix 2 (continued): **Mako shark.**



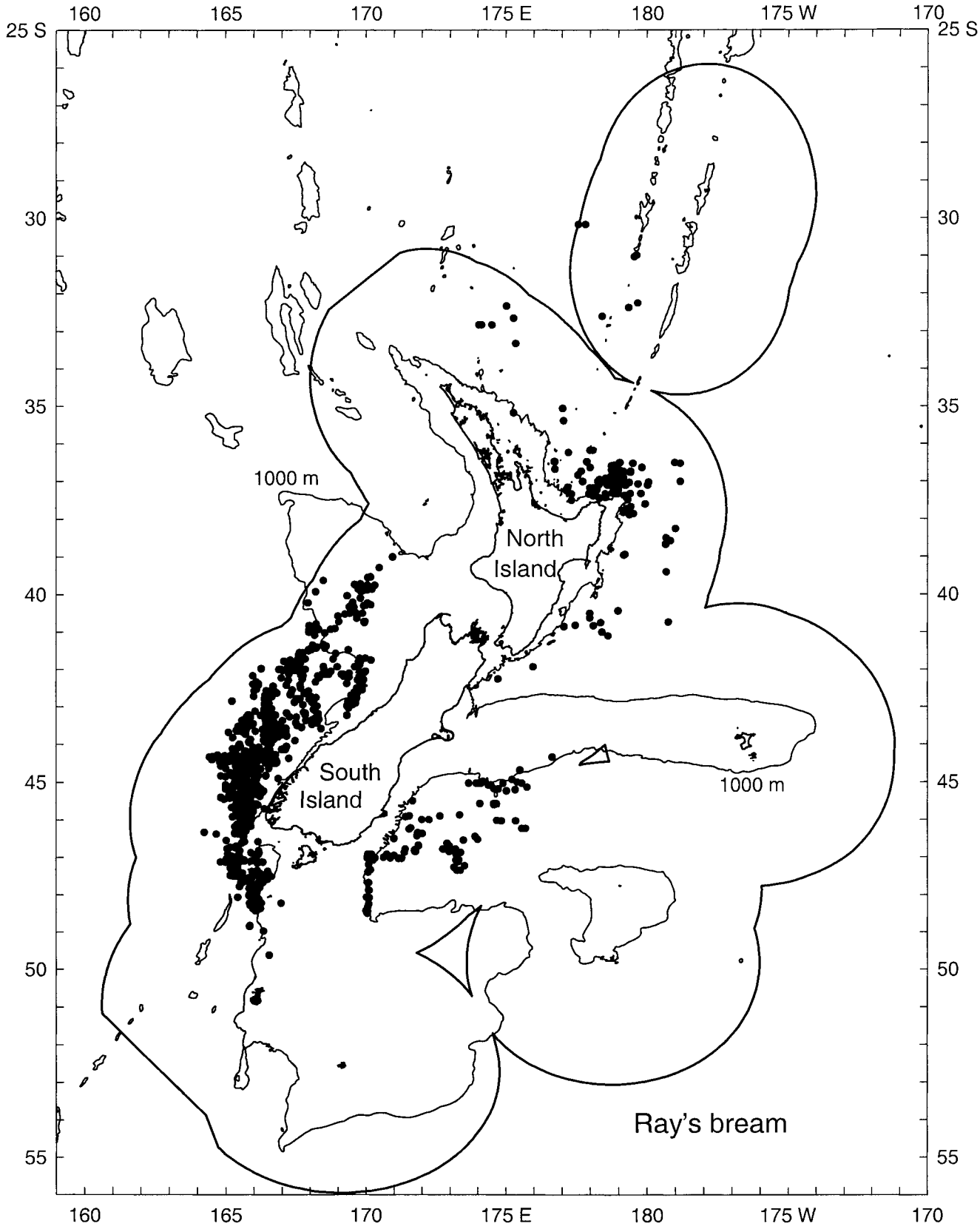
Appendix 2 (continued): **Deepwater dogfish (Squaliformes).**



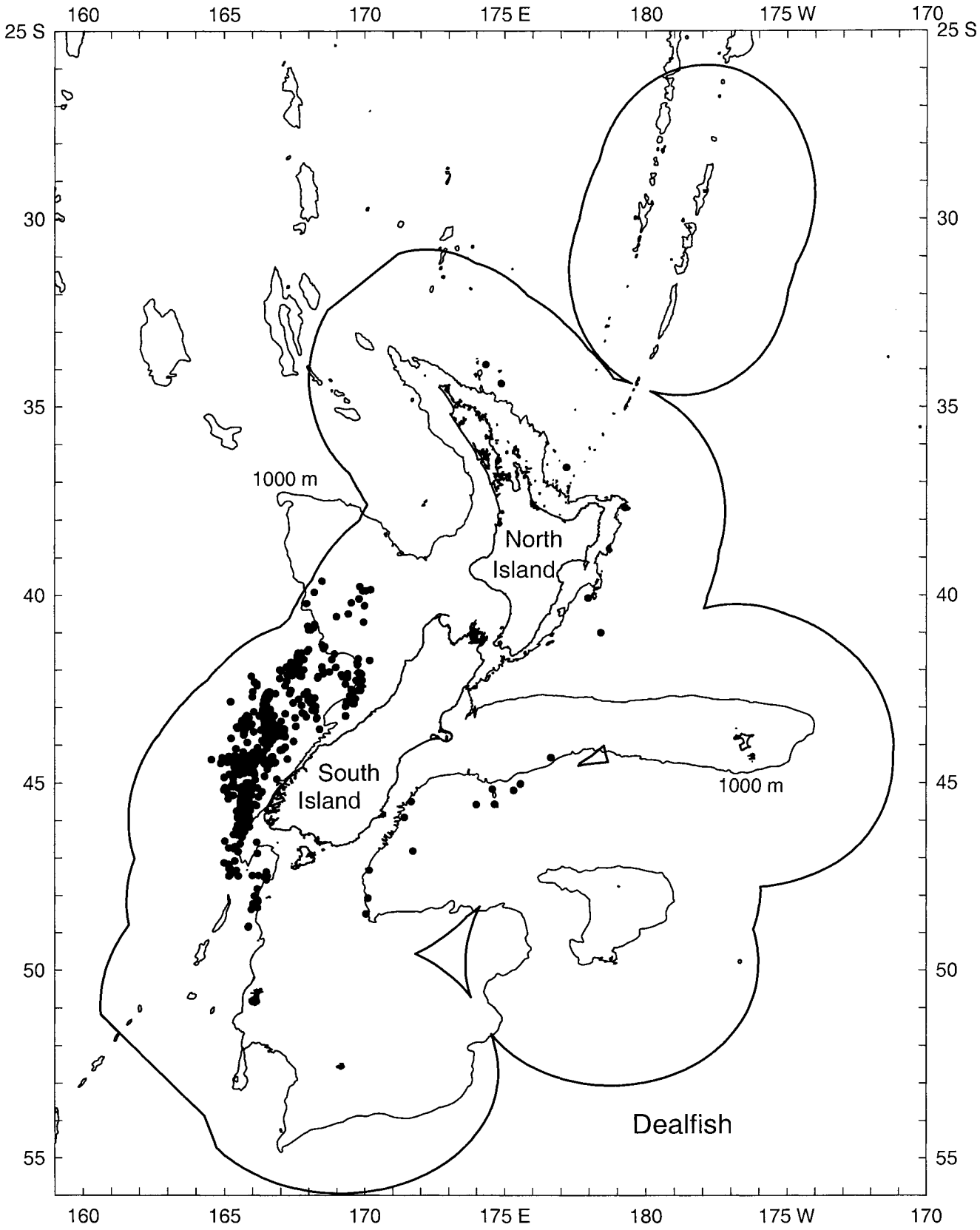
Appendix 2 (continued): **School shark.**



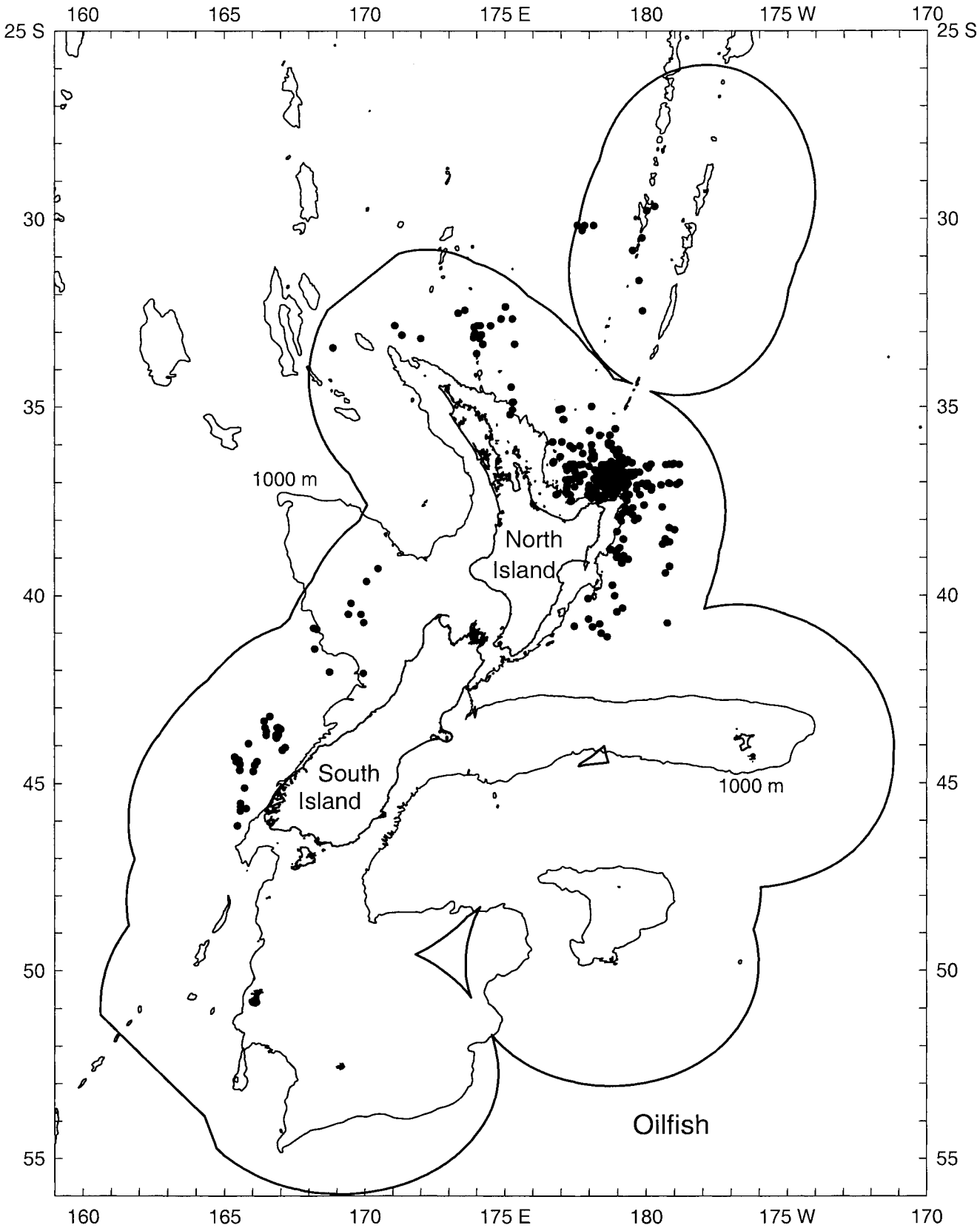
Appendix 2 (continued): **Butterfly tuna.**



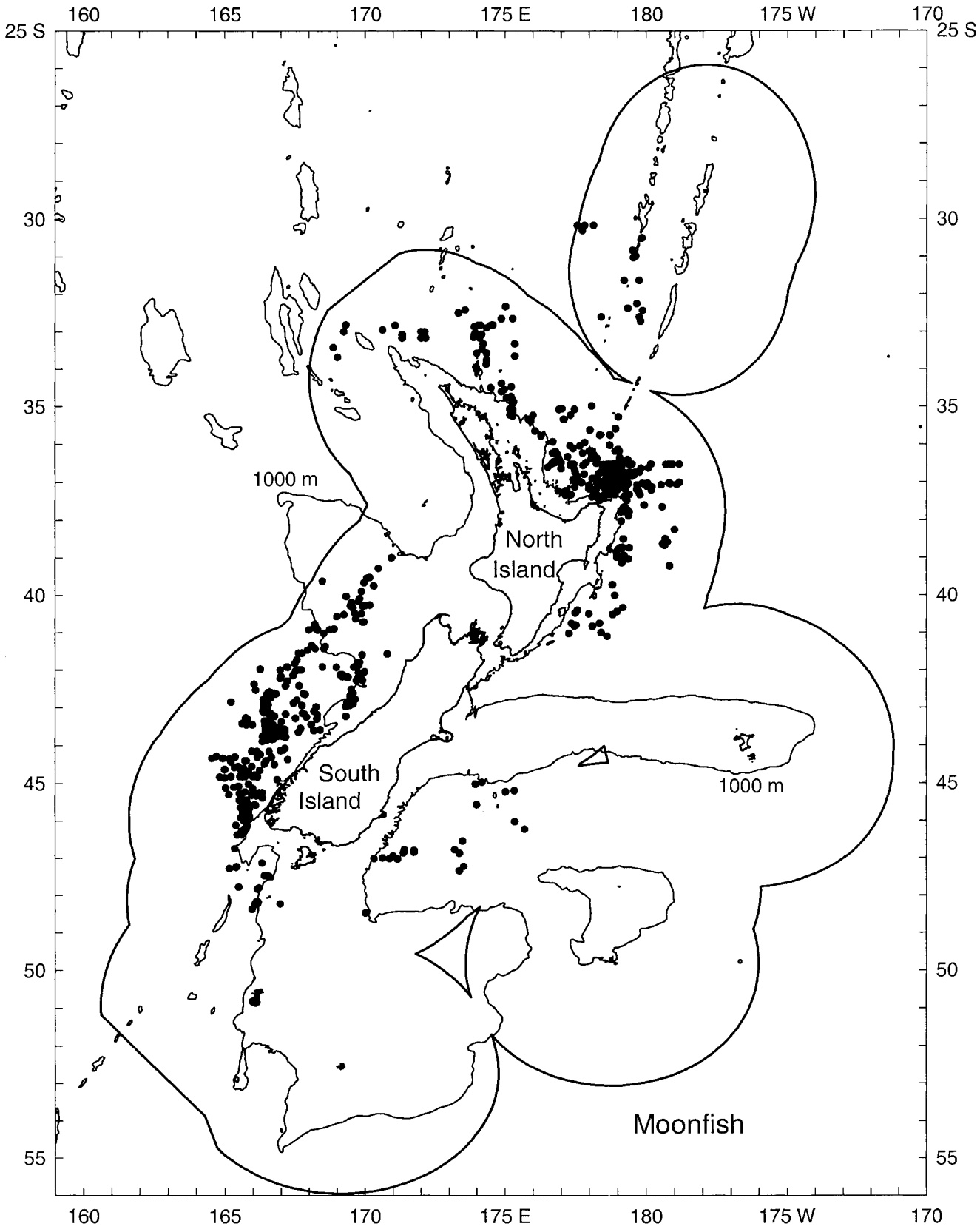
Appendix 2 (continued): **Ray's bream.**



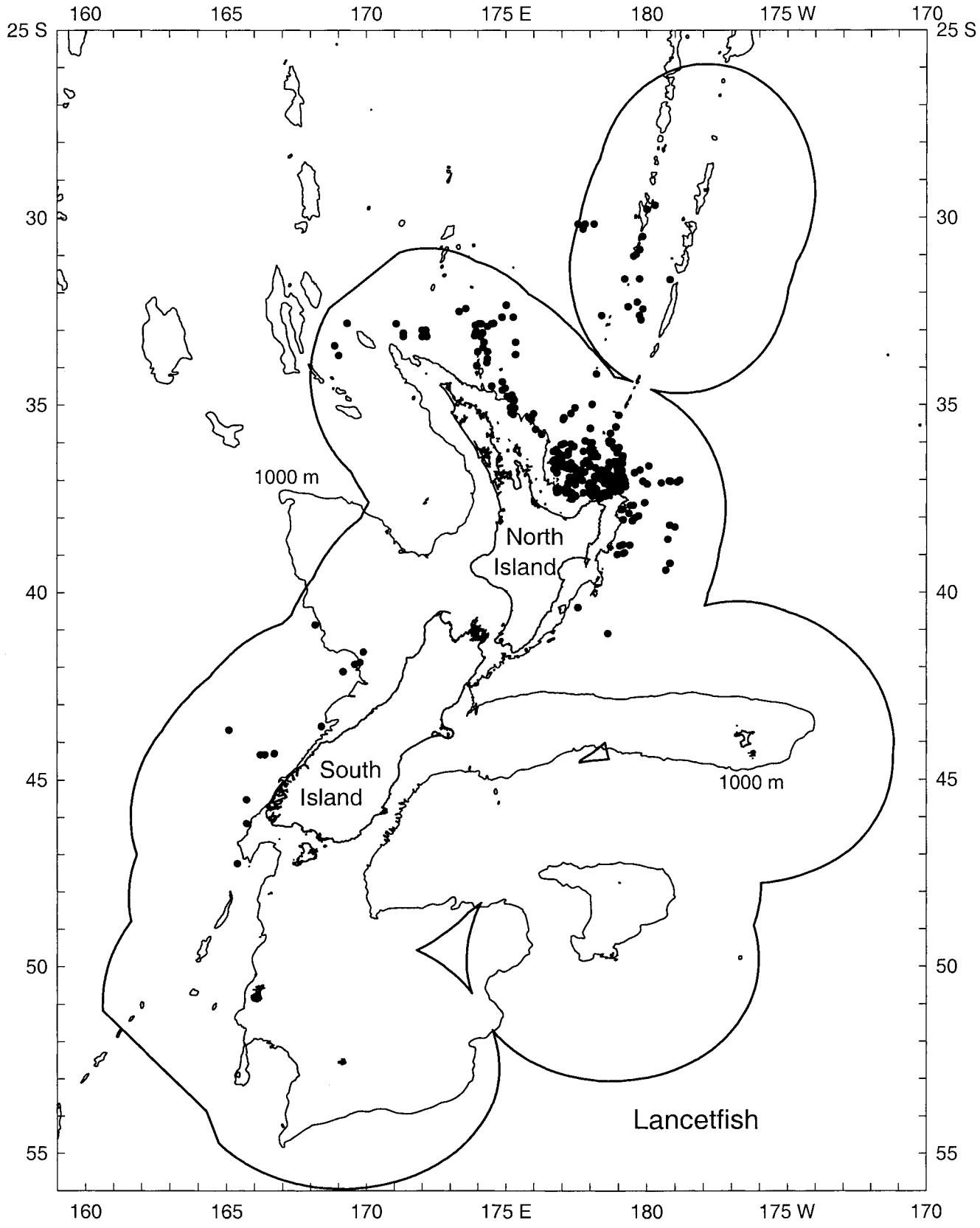
Appendix 2 (continued): **Dealfish.**



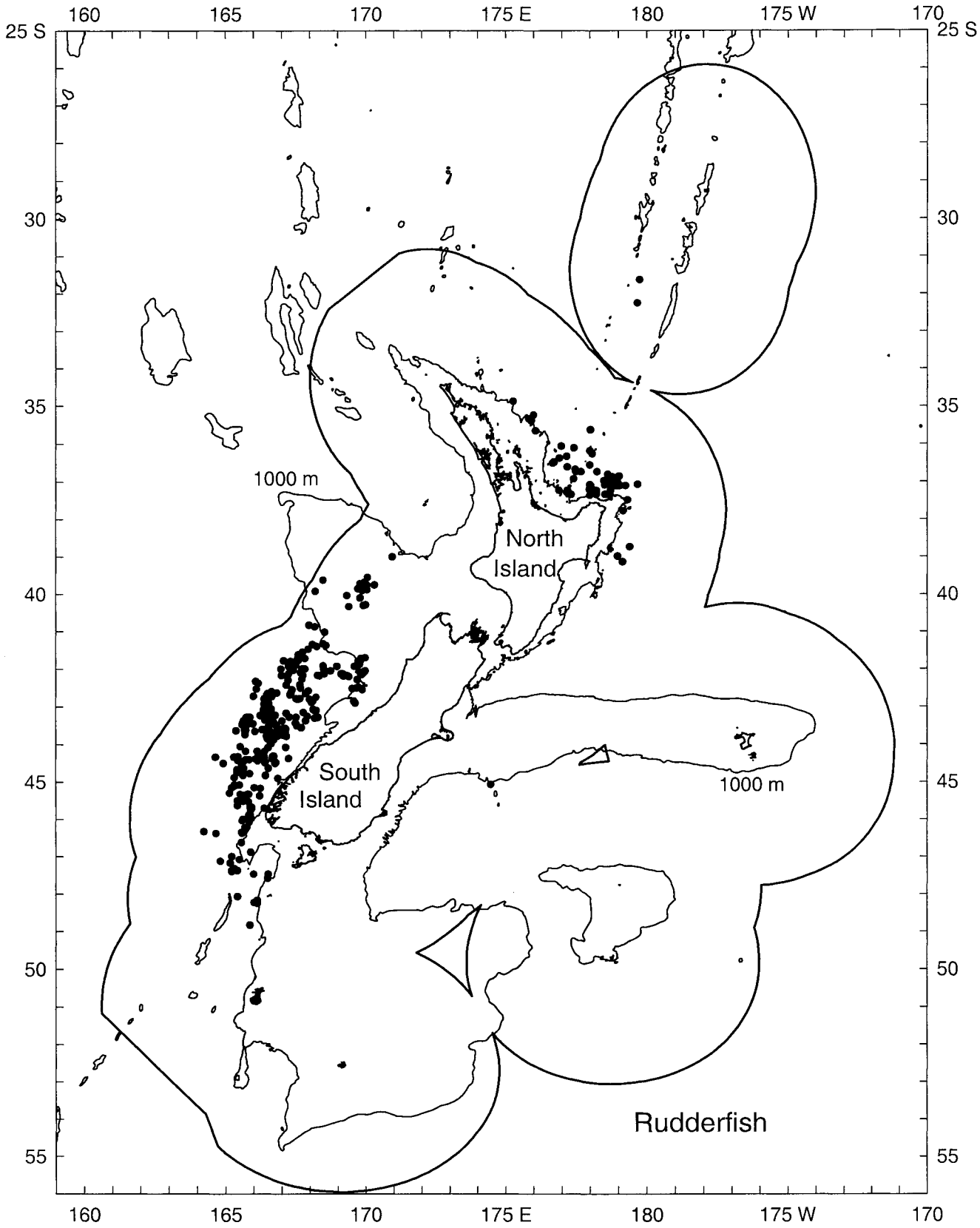
Appendix 2 (continued): **Oilfish.**



Appendix 2 (continued): **Moonfish.**



Appendix 2 (continued): **Lancetfish.**



Appendix 2 (continued): **Rudderfish.**

Appendix 3: **Bootstrap estimates of CPUE (numbers per 1000 hooks) for sharks. The three columns under each species are (from left to right) mean CPUE, and lower and upper 95% confidence limits**

Fleet	Region	Fish. year	No. sets	Blue shark			Porbeagle shark			Mako shark			Porbeagle & mako			Deepwater dogfish			School shark		
Foreign +charter	North	1988–89	48	8.88	6.88	11.13	–	–	–	–	–	–	1.96	1.51	2.51	0.00	0.00	0.00	0.02	0.00	0.04
		1989–90	77	5.97	4.90	7.19	–	–	–	–	–	–	3.16	2.64	3.72	0.00	0.00	0.00	0.00	0.00	0.00
		1990–91	122	5.97	4.08	8.54	–	–	–	–	–	–	1.37	1.20	1.56	0.00	0.00	0.00	0.01	0.00	0.02
		1991–92	83	9.56	6.22	13.77	–	–	–	–	–	–	2.68	2.31	3.06	0.00	0.00	0.00	0.04	0.02	0.06
		1992–93	127	37.63	30.57	45.23	3.97	3.48	4.53	0.51	0.40	0.63	4.46	4.00	4.97	0.00	0.00	0.00	0.10	0.06	0.15
		1993–94	32	70.97	41.85	105.70	3.28	1.71	4.90	0.68	0.48	0.91	3.98	2.48	5.65	0.00	0.00	0.00	1.04	0.05	3.47
		1994–95	13	114.35	91.46	138.45	7.15	5.28	9.30	0.39	0.16	0.67	7.52	5.57	9.83	0.00	0.00	0.00	0.00	0.00	0.00
		1996–97	44	52.94	41.51	66.82	2.47	1.91	3.13	1.15	0.95	1.37	3.63	3.03	4.31	0.00	0.00	0.00	0.05	0.01	0.09
	South	1988–89	39	6.70	4.57	8.98	–	–	–	–	–	–	0.25	0.16	0.34	0.12	0.03	0.25	0.13	0.06	0.21
		1989–90	77	11.06	7.68	14.93	–	–	–	–	–	–	0.49	0.35	0.66	0.04	0.01	0.08	0.51	0.32	0.71
		1990–91	28	3.66	2.53	4.91	–	–	–	–	–	–	0.32	0.21	0.44	0.00	0.00	0.00	0.07	0.01	0.13
		1991–92	93	1.15	0.73	1.73	–	–	–	–	–	–	0.68	0.52	0.86	0.45	0.27	0.68	0.23	0.14	0.33
		1992–93	246	3.65	3.13	4.22	1.06	0.87	1.26	0.05	0.03	0.09	1.10	0.92	1.32	0.62	0.47	0.79	0.17	0.13	0.20
		1993–94	211	4.12	3.58	4.64	0.78	0.64	0.96	0.08	0.06	0.10	0.86	0.72	1.03	0.20	0.15	0.25	0.29	0.21	0.38
		1994–95	239	2.83	2.35	3.34	1.08	0.91	1.30	0.17	0.12	0.24	1.25	1.07	1.47	0.83	0.67	1.00	0.52	0.41	0.66
		1996–97	226	14.65	11.59	18.27	1.80	1.44	2.22	0.10	0.07	0.13	1.90	1.56	2.29	0.47	0.36	0.59	0.40	0.31	0.48
Domestic	North	1994–95	50	6.60	3.42	10.39	0.99	0.27	2.27	1.02	0.64	1.46	2.01	1.15	3.34	0.04	0.00	0.09	0.18	0.03	0.38
		1995–96	66	13.33	9.22	18.54	4.10	2.67	5.95	2.14	1.52	2.82	6.22	4.58	8.13	0.00	0.00	0.00	0.00	0.00	0.00
		1996–97	101	4.16	3.31	5.14	1.07	0.76	1.45	1.36	1.01	1.69	2.43	1.89	3.03	0.00	0.00	0.00	0.04	0.01	0.09
	South	1994–95	37	3.88	2.59	5.30	0.42	0.22	0.65	0.01	0.00	0.03	0.43	0.24	0.71	0.34	0.17	0.56	0.17	0.07	0.32
		1995–96	81	41.75	34.11	51.00	2.63	2.10	3.31	0.14	0.06	0.23	2.78	2.24	3.46	0.43	0.19	0.72	1.58	0.48	3.49
		1996–97	53	18.98	15.52	22.47	0.42	0.28	0.56	0.10	0.06	0.15	0.52	0.37	0.67	0.69	0.45	0.95	0.63	0.39	0.93

Appendix 3 (continued): **Bootstrap estimates of CPUE (numbers per 1000 hooks) for tunas and broadbill swordfish. The three columns under each species are (from left to right) mean CPUE, and lower and upper 95% confidence limits**

Fleet	Region	Fish. year	No. sets	Albacore			Southern bluefin tuna			Broadbill swordfish			Butterfly tuna			Bigeye tuna			Yellowfin tuna		
Foreign +charter	North	1988–89	48	8.19	6.85	9.49	0.75	0.52	1.04	1.57	1.22	1.99	0.50	0.34	0.71	0.21	0.12	0.32	0.00	0.00	0.00
		1989–90	77	12.24	10.82	13.66	2.26	1.82	2.73	2.10	1.77	2.47	1.10	0.85	1.36	0.24	0.16	0.33	0.07	0.00	0.19
		1990–91	122	9.66	8.84	10.46	1.03	0.87	1.19	0.78	0.65	0.91	1.25	0.97	1.56	0.97	0.55	1.42	0.00	0.00	0.01
		1991–92	83	9.99	8.96	11.09	0.53	0.44	0.62	1.36	1.12	1.60	0.64	0.50	0.80	0.05	0.02	0.09	0.00	0.00	0.00
		1992–93	127	8.77	7.52	10.06	1.21	1.04	1.40	0.61	0.49	0.73	0.43	0.34	0.52	0.12	0.03	0.22	0.00	0.00	0.00
		1993–94	32	8.80	7.02	10.46	0.16	0.06	0.28	0.87	0.65	1.08	0.13	0.06	0.20	0.60	0.32	0.92	0.02	0.00	0.06
		1994–95	13	7.23	5.15	9.56	0.60	0.27	0.99	0.39	0.15	0.65	0.99	0.51	1.48	0.00	0.00	0.00	0.00	0.00	0.00
		1996–97	44	8.40	6.67	10.33	4.97	3.37	6.88	2.84	1.94	4.03	0.11	0.04	0.18	0.02	0.00	0.05	0.00	0.00	0.00
	South	1988–89	39	0.25	0.10	0.43	1.36	0.98	1.83	0.00	0.00	0.00	0.84	0.47	1.23	0.00	0.00	0.00	0.00	0.00	0.00
		1989–90	77	0.61	0.42	0.86	3.09	2.51	3.71	0.09	0.04	0.16	0.24	0.15	0.34	0.00	0.00	0.00	0.00	0.00	0.00
		1990–91	28	0.25	0.11	0.41	3.22	2.40	4.16	0.35	0.22	0.49	0.04	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
		1991–92	93	0.16	0.10	0.24	1.49	1.27	1.71	0.01	0.00	0.03	0.08	0.04	0.13	0.00	0.00	0.00	0.00	0.00	0.00
		1992–93	246	0.22	0.16	0.29	1.44	1.24	1.65	0.01	0.01	0.03	0.16	0.12	0.20	0.00	0.00	0.00	0.00	0.00	0.00
		1993–94	211	0.22	0.17	0.27	4.41	3.92	4.96	0.00	0.00	0.01	0.11	0.08	0.14	0.00	0.00	0.00	0.00	0.00	0.00
		1994–95	239	0.16	0.11	0.21	2.76	2.52	3.01	0.00	0.00	0.00	0.09	0.07	0.12	0.00	0.00	0.00	0.00	0.00	0.00
		1996–97	226	0.14	0.11	0.19	2.59	2.34	2.86	0.03	0.02	0.05	0.81	0.66	0.98	0.00	0.00	0.00	0.00	0.00	0.00
Domestic	North	1994–95	50	25.03	15.42	36.17	0.00	0.00	0.00	0.38	0.23	0.56	0.04	0.00	0.12	1.39	0.91	1.93	3.28	2.16	4.47
		1995–96	66	46.48	37.33	57.27	0.20	0.06	0.37	0.64	0.42	0.89	0.00	0.00	0.00	0.70	0.47	0.95	4.22	2.97	5.64
		1996–97	101	49.03	41.27	57.18	0.03	0.00	0.07	1.74	1.26	2.26	0.00	0.00	0.00	1.01	0.78	1.26	2.88	2.21	3.66
	South	1994–95	37	0.30	0.19	0.42	4.04	3.31	4.69	0.00	0.00	0.00	0.03	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
		1995–96	81	1.22	0.80	1.70	2.07	1.59	2.62	0.11	0.04	0.20	0.08	0.02	0.15	0.00	0.00	0.00	0.00	0.00	0.00
		1996–97	53	0.18	0.11	0.25	3.44	2.51	4.80	0.10	0.04	0.17	0.11	0.06	0.17	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 3 (continued): **Bootstrap estimates of CPUE (numbers per 1000 hooks) for other fish species. The three columns under each species are (from left to right) mean CPUE, and lower and upper 95% confidence limits**

Fleet	Region	Fish. year	No. sets	Ray's bream			Dealfish			Oilfish			Moonfish			Lancetfish			Rudderfish		
Foreign +charter	North	1988–89	48	0.18	0.09	0.32	0.00	0.00	0.00	0.99	0.64	1.38	0.64	0.36	0.99	0.14	0.08	0.21	0.01	0.00	0.02
		1989–90	77	0.41	0.24	0.62	0.00	0.00	0.00	1.51	1.23	1.83	0.79	0.63	0.97	0.19	0.11	0.29	0.03	0.00	0.05
		1990–91	122	0.12	0.06	0.19	0.00	0.00	0.00	2.19	1.72	2.73	1.14	0.88	1.44	0.29	0.18	0.42	0.00	0.00	0.00
		1991–92	83	0.09	0.05	0.13	0.00	0.00	0.00	3.65	2.99	4.34	1.11	0.95	1.29	0.19	0.12	0.28	0.01	0.00	0.02
		1992–93	127	0.34	0.08	0.79	0.00	0.00	0.01	1.95	1.65	2.27	1.04	0.88	1.22	0.72	0.55	0.91	0.03	0.01	0.05
		1993–94	32	0.11	0.02	0.24	0.00	0.00	0.00	1.63	0.75	2.57	4.14	2.30	6.49	0.71	0.32	1.19	0.03	0.00	0.08
		1994–95	13	0.00	0.00	0.00	0.00	0.00	0.00	2.05	1.35	2.82	3.02	1.43	5.06	0.89	0.38	1.69	0.21	0.03	0.42
		1996–97	44	1.10	0.31	2.10	0.02	0.00	0.04	3.49	2.77	4.20	0.57	0.36	0.82	0.05	0.01	0.09	0.01	0.00	0.03
	South	1988–89	39	2.02	1.47	2.61	0.12	0.04	0.23	0.00	0.00	0.00	0.11	0.05	0.18	0.00	0.00	0.00	0.00	0.00	0.00
		1989–90	77	2.18	1.71	2.72	0.11	0.05	0.16	0.00	0.00	0.00	0.25	0.16	0.33	0.00	0.00	0.00	0.03	0.01	0.05
		1990–91	28	1.29	0.85	1.78	0.08	0.02	0.15	0.08	0.02	0.14	0.58	0.36	0.82	0.00	0.00	0.00	0.00	0.00	0.00
		1991–92	93	2.22	1.85	2.63	0.80	0.53	1.09	0.16	0.08	0.24	0.04	0.01	0.08	0.01	0.00	0.02	0.17	0.10	0.24
		1992–93	246	2.31	2.05	2.58	0.24	0.17	0.31	0.00	0.00	0.00	0.08	0.06	0.11	0.00	0.00	0.00	0.16	0.12	0.21
		1993–94	211	13.75	11.40	16.46	0.59	0.43	0.77	0.00	0.00	0.01	0.05	0.03	0.07	0.00	0.00	0.01	0.09	0.06	0.12
		1994–95	239	4.91	4.29	5.52	1.88	1.55	2.25	0.01	0.00	0.03	0.08	0.06	0.11	0.00	0.00	0.01	0.14	0.10	0.19
		1996–97	226	5.92	4.88	7.08	3.59	2.50	4.75	0.06	0.03	0.09	0.26	0.20	0.31	0.00	0.00	0.00	0.22	0.16	0.28
Domestic	North	1994–95	50	0.23	0.05	0.50	0.02	0.00	0.06	0.30	0.13	0.49	2.52	1.67	3.56	5.78	4.29	7.31	0.08	0.00	0.18
		1995–96	66	0.24	0.13	0.36	0.00	0.00	0.00	0.97	0.53	1.52	0.80	0.53	1.11	3.93	3.01	5.04	0.43	0.18	0.72
		1996–97	101	0.17	0.08	0.26	0.01	0.00	0.03	0.91	0.63	1.26	1.26	0.86	1.72	8.46	6.74	10.33	0.63	0.43	0.83
	South	1994–95	37	8.43	7.06	9.87	1.62	0.77	2.82	0.00	0.00	0.00	0.17	0.07	0.27	0.00	0.00	0.00	0.18	0.06	0.34
		1995–96	81	10.47	7.55	13.99	1.21	0.80	1.73	0.01	0.00	0.03	0.92	0.61	1.27	0.05	0.01	0.11	1.07	0.71	1.53
		1996–97	53	6.31	4.99	7.75	4.04	2.33	6.03	0.00	0.00	0.00	0.31	0.21	0.43	0.01	0.00	0.02	1.11	0.87	1.36

Appendix 4: **Estimated numbers, with lower and upper 95% confidence limits, of sharks caught on tuna longlines. Numbers are mean bootstrap estimates for north and south regions combined**

Species	Fishing year	Number	Lower 95% limit	Upper 95% limit
Blue shark	1988–89	71 033	56 852	86 278
	1989–90	75 344	59 638	93 483
	1990–91	60 320	45 956	78 937
	1991–92	42 928	29 702	58 797
	1992–93	44 964	38 886	51 543
	1993–94	10 182	7 558	13 239
	1994–95	21 173	16 835	26 447
	1995–96	43 078	34 861	52 890
	1996–97	35 773	31 370	40 660
Porbeagle shark	1988–89	–	–	–
	1989–90	–	–	–
	1990–91	–	–	–
	1991–92	–	–	–
	1992–93	7 281	6 529	8 164
	1993–94	987	807	1 192
	1994–95	1 690	744	3 339
	1995–96	7 897	5 576	10 934
	1996–97	4 014	3 383	4 707
Mako shark	1988–89	–	–	–
	1989–90	–	–	–
	1990–91	–	–	–
	1991–92	–	–	–
	1992–93	626	493	799
	1993–94	129	102	160
	1994–95	1 374	872	1 949
	1995–96	3 446	2 532	4 520
	1996–97	2 301	1 848	2 794
Porbeagle and mako shark	1988–89	8 182	6 530	10 110
	1989–90	14 301	12 433	16 520
	1990–91	9 671	8 477	10 956
	1991–92	13 740	12 071	15 370
	1992–93	7 887	7 064	8 783
	1993–94	1 118	928	1 331
	1994–95	5 133	3 937	6 708
	1995–96	11 397	8 779	14 444
	1996–97	6 328	5 467	7 305
Deepwater dogfish	1988–89	782	160	1 613
	1989–90	210	47	405
	1990–91	0	0	0
	1991–92	2 063	1 237	3 063
	1992–93	2 341	1 769	3 022
	1993–94	174	128	219
	1994–95	1 510	1 229	1 808
	1995–96	226	110	356
	1996–97	746	601	903
School shark	1988–89	886	463	1 387
	1989–90	2 410	1 582	3 346
	1990–91	579	181	1 078
	1991–92	1 214	782	1 737
	1992–93	713	570	871
	1993–94	348	216	546
	1994–95	1 117	825	1 471
	1995–96	825	271	1 808
	1996–97	715	573	866

Appendix 4 (continued): **Estimated numbers, with lower and upper 95% confidence limits, of tunas and broadbill swordfish caught on tuna longlines. Numbers are mean bootstrap estimates for north and south regions combined**

Species	Fishing year	Number	Lower 95% limit	Upper 95% limit
Albacore	1988–89	29 123	24 514	34 014
	1989–90	48 917	43 291	54 665
	1990–91	52 303	47 935	56 983
	1991–92	40 293	36 049	44 757
	1992–93	8 071	6 945	9 147
	1993–94	993	830	1 152
	1994–95	34 564	21 481	49 254
	1995–96	74 025	59 601	90 800
	1996–97	73 544	61 255	85 548
Southern bluefin tuna	1988–89	11 053	8 264	14 020
	1989–90	23 516	20 181	26 936
	1990–91	30 879	24 336	37 590
	1991–92	9 070	7 920	10 251
	1992–93	6 485	5 681	7 306
	1993–94	3 875	3 425	4 335
	1994–95	7 174	6 522	7 803
	1995–96	1 386	1 053	1 771
	1996–97	4 725	4 203	5 262
Broadbill swordfish	1988–89	5 314	4 057	6 775
	1989–90	8 335	6 958	9 799
	1990–91	6 872	5 678	8 215
	1991–92	5 395	4 507	6 379
	1992–93	558	467	670
	1993–94	82	62	103
	1994–95	542	334	776
	1995–96	1 077	718	1 487
	1996–97	3 033	2 231	3 870
Butterfly tuna	1988–89	6 909	4 474	10 012
	1989–90	5 285	4 273	6 369
	1990–91	6 793	5 273	8 401
	1991–92	2 904	2 355	3 540
	1992–93	958	790	1 143
	1993–94	104	79	133
	1994–95	253	164	391
	1995–96	40	13	76
	1996–97	931	749	1 130
Bigeye tuna	1988–89	700	373	1 098
	1989–90	894	580	1 226
	1990–91	5 008	2 773	7 345
	1991–92	212	96	345
	1992–93	94	26	170
	1993–94	54	28	82
	1994–95	1 886	1 265	2 583
	1995–96	1 097	775	1 454
	1996–97	1 486	1 135	1 877
Yellowfin tuna	1988–89	0	0	0
	1989–90	286	0	718
	1990–91	15	0	46
	1991–92	0	0	0
	1992–93	0	0	0
	1993–94	2	0	5
	1994–95	4 470	2 967	6 117
	1995–96	6 581	4 473	8 819
	1996–97	4 256	3 235	5 310

Appendix 4 (continued): **Estimated numbers, with lower and upper 95% confidence limits, of other fish species caught on tuna longlines. Numbers are mean bootstrap estimates for north and south regions combined**

Species	Fishing year	Number	Lower 95% limit	Upper 95% limit
Ray's bream	1988–89	13 293	9 574	17 231
	1989–90	12 045	9 657	14 608
	1990–91	10 699	7 396	14 580
	1991–92	10 752	9 030	12 542
	1992–93	9 057	8 052	10 142
	1993–94	12 100	9 954	14 342
	1994–95	14 003	12 548	15 501
	1995–96	5 791	4 202	7 630
	1996–97	9 018	7 756	10 227
Dealfish	1988–89	757	264	1 347
	1989–90	505	276	806
	1990–91	646	185	1 213
	1991–92	3 674	2 403	4 944
	1992–93	898	638	1 195
	1993–94	518	378	685
	1994–95	3 925	3 100	5 014
	1995–96	624	419	858
	1996–97	5 310	3 982	6 700
Oilfish	1988–89	3 326	2 204	4 708
	1989–90	5 681	4 594	6 868
	1990–91	12 107	9 335	15 079
	1991–92	15 157	12 397	17 946
	1992–93	1 610	1 351	1 869
	1993–94	149	67	244
	1994–95	524	286	776
	1995–96	1 524	877	2 392
	1996–97	1 898	1 450	2 392
Moonfish	1988–89	2 831	1 791	4 076
	1989–90	4 162	3 419	4 911
	1990–91	10 494	8 312	12 920
	1991–92	4 535	3 849	5 176
	1992–93	1 178	1 011	1 342
	1993–94	416	227	655
	1994–95	3 797	2 611	5 124
	1995–96	1 768	1 269	2 305
	1996–97	2 340	1 732	2 957
Lancetfish	1988–89	482	269	736
	1989–90	722	417	1 078
	1990–91	1 535	970	2 220
	1991–92	805	530	1 123
	1992–93	599	457	775
	1993–94	66	31	109
	1994–95	7 840	5 918	9 894
	1995–96	6 257	4 770	8 015
	1996–97	12 525	10 079	15 076
Rudderfish	1988–89	26	0	74
	1989–90	233	101	381
	1990–91	0	0	0
	1991–92	808	490	1 140
	1992–93	621	453	815
	1993–94	80	57	107
	1994–95	470	297	689
	1995–96	1 253	792	1 829
	1996–97	1 548	1 234	1 878