Ministry for Primary Industries
Manatū Ahu Matua

# Fishery characterisation and standardised CPUE analyses for pale ghost shark, *Hydrolagus bemisi* (Didier, 2002) (Chimaeridae), 1989–90 to 2009–10

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D.J. MacGibbon
D. Fu

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## EXECUTIVE SUMMARY

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Commercial ghost shark landings in New Zealand consist almost entirely of two species (pale and dark). Prior to its inclusion in the QMS in 2000 there was little differentiation between the two species on catch landing returns. Past attempts to recreate catch histories for pale ghost shark (prior to its inclusion in the QMS) have been unsatisfactory and actual catches from this time are likely to be higher as much of the catch was probably discarded or made into fishmeal due to its relatively low value. Attempts in this study to develop a new model to back-calculate pre-QMS pale ghost shark catches were unsatisfactory due to suspected high levels of discarding of both ghost shark species during that time.

More reliable records are available since the 1999–00 fishing year when pale ghost shark were included in the QMS with a TACC of 803 t. The TACC was over-caught in GSP 1 and 5 every year until the 2004–05 fishing year when the TACCs were increased to 1150 t and 454 t for GSP 1 and 5 respectively, bringing the total to 1780 t. Since then landings have been within limits every year. The TACC in GSP 7 has never been caught.

Pale ghost shark are mainly caught as bycatch in bottom trawls targeting hoki, and, to a much lesser extent, hake and silver warehou on the Chatham Rise and East Coast South Island. They are also caught as bycatch in bottom trawls targeting hoki and ling in the Sub-Antarctic area. A small amount is also taken by bottom longline on the Chatham Rise and Sub-Antarctic. Although caught throughout the New Zealand Exclusive Economic Zone, catches outside the Sub-Antarctic and Chatham Rise are negligible. They are never targeted and there is little seasonality in the catch.

Pale ghost shark biology is poorly understood. No ageing methods have been validated. Weight and diameter of eye lenses, band counts in dorsal spines, and band counts of vertebrae have all been found to be unsuitable. Length at maturity for pale ghost shark on the Chatham Rise has been estimated as 59–60 and 69–70 cm for males and females respectively.

The species is widespread around mainland New Zealand but rare north of 40°S. Stock structure is unknown. Areas of narrow continental shelf separating the east coast North Island, Sub-Antarctic, and west coast of New Zealand may provide natural barriers to mixing and result in separate stocks in each of these three regions.

Monitoring of pale ghost shark stocks will require more data from research and commercial sources. Middle depth trawl surveys of the Chatham Rise and Sub-Antarctic are ongoing time series that record pale ghost shark biomass and length frequencies. Both surveys cover most of the species' distribution and probably provide a reasonable index of abundance. Length frequencies do not show distinct cohorts that can be tracked.

Observer coverage for the main fishery areas is reasonable but ideally should be expanded to produce more detailed data. This is particularly true for biological information such as reproductive condition, and the collection of suitable body parts for ageing (if a suitable method can be identified). If coverage is increased and spread throughout the year the resulting data may help determine stock structure.

CPUE analyses were carried out for the ECSI and Chatham Rise regions for vessels targeting hoki by bottom trawl between the 2000 and 2010 fishing years. Model assumptions were satisfactory and the model explained 25% of the variance. Aside from a steep increase between 2000 and 2001, indices were relatively flat throughout the time period. CPUE analyses were also carried out for the Sub-Antarctic region for the 2000 to 2010 fishing years, also for vessels targeting hoki by bottom trawl.

Model assumptions were satisfactory and the model explained 29% of the variance. The indices fluctuate without trend throughout the time period.

## 1. INTRODUCTION

Many of New Zealand's middle depth fisheries, other than gemfish, hoki, hake, ling, and southern blue whiting, are not routinely monitored or assessed despite their moderate size and value. Eighteen such species have been selected under the 10 year Research Programme for Deepwater Fisheries (Ministry of Fisheries 2010a) to be assessed under a 3 to 4-year rotating schedule. The six species selected for characterisation in 2011 are alfonsino (*Beryx splendens*), blue mackerel (*Scomber australasicus*), frostfish (*Lepidopus caudatus*), white warehou (*Seriolella caerulea*), sea perch (*Helicolenus percoides*) and pale ghost shark (*Hydrolagus bemisi*).

Pale ghost shark, along with dark ghost shark (*Hydrolagus novaezealandiae*), make up virtually all of the commercial ghost shark landings in New Zealand. Previous studies of both species are sparse. Horn (1997) summarised the biology, commercial landings, and trawl survey data of both ghost sharks in New Zealand waters from 1978–1997. Before their inclusion in the QMS the two species were rarely differentiated on catch landing returns. They exhibit niche differentiation, with water depth being the most influential factor. Pale ghost shark are generally found in deeper water than dark ghost shark, although there is overlap. Horn (1997) used data from trawl surveys by R.V. *Tangaroa* to determine the depths at which species dominance changed. Based on this, commercial landings were estimated for each species for each year based on depth and locality information in catch-effort data, assigning proportions of the total ghost shark catch to the two species based on the percentages of each found at different depths and locations. For the Chatham Rise, there was an even split of dark and pale ghost sharks at a depth of 415 m. In the Sub-Antarctic, the even split was at about 542 m.

Horn (1997) found that on average, pale ghost shark made up 25% of total reported ghost shark landings (range 19–36%) from the 1982–83 to 1994–95 fishing years. Most of the catch was taken from the Chatham Rise (including the Mernoo Bank), the eastern Stewart-Snares Shelf and the Auckland Islands Shelf. Catches from the west coast of the South Island increased from the late 1980s, possibly due to the development of the spawning hoki fishery there. Much of the catch was thought to have been discarded in the past. In 1994–95 it was proposed that the species be included in the QMS and at this point fishers may have reported catches more accurately in order to build a catch history.

Middle depth trawl surveys of the Chatham Rise and Sub-Antarctic regularly catch pale ghost shark. Biomass indices from time series in both areas can show considerable variation, particularly for the Chatham Rise. It is thought that such variation is likely to be due to changes in availability of ghost sharks to the trawl, rather than to fluctuations in population size (Horn 1997). Horn also found no indication that when the abundance of ghost sharks is low in one surveyed area it is high in another. Due to this variation he cautioned against the use of trawl surveys or catch-per-unit-effort analyses to monitor stocks.

This report summarises the analyses carried out under Ministry of Fisheries Project DEE201007GSP, Objectives 1–7: To characterise the New Zealand pale ghost shark fisheries by analysis of commercial catch and effort data up to 2009–10 including:

- Characterise the fisheries by analysis of commercial catch and effort data up to 2009–10.
- Carry out standardised CPUE analyses for the major fisheries (Fishstocks) where appropriate.
- Review the indices from CPUE analyses, trawl surveys and Observer logbooks to determine trends.
- Review stock structure using data accessed above and any other relevant biological or fishery information.
- Assess availability and utility of developing a series of age frequency distributions from otoliths (or other body parts in the case of pale ghost shark, which do not have otoliths).

- To make recommendations on future data requirements and methods for monitoring the stocks.

The report contains sections of text and tables that can be transferred to the Ministry for Primary Industries Plenary Report as appropriate. Tables and figures are provided in four appendices: A, Survey data; B, Observer data; C, Fishery characterisation; and D, Catch-per-unit-effort analyses.

## 2. FISHERY SUMMARY

### 2.1 Commercial fisheries

Pale ghost shark are elasmobranchs of the family Chimaeridae (short nose chimaeras). They are found all around mainland New Zealand but are rare north of 40°S. They are found at depths of between 100 and 1500 m but are most common at about 600 m (Anderson et al. 1998). The species entered the Quota Management System (QMS) on 1 October 1999 with a Total Allowable Commercial Catch (TACC) of 803 t. The TACC has undergone increases in 2004 in both GSP 1 (FMAs 1–4 and 10, Figure 1) and GSP 5 (FMAs 5 and 6) in response to constant overruns in the commercial catch. The TACC is now 1780 t and has not been exceeded in any QMA since the increases. The TACC has been static in GSP 7 (FMAs 7–9) since its introduction into the QMS and has never been caught.

Other than Horn's (1997) study, there have been no previous characterisations of pale ghost shark fisheries. Prior to its inclusion in the QMS the two main ghost shark species were rarely differentiated on catch and effort forms and were usually both recorded as "GSH". This code is now only used for dark ghost shark. Records of both ghost shark species combined by foreign charter and joint venture vessels are available from 1978 to 1983 (Table 1). Horn (1997) attempted to create a history of pre-QMS catches of pale ghost shark based on position and depth from trawl survey data to estimate the proportion of each ghost shark species caught in different areas. Pre-QMS estimates from 1983 to 1999 based on his method are presented in Table 2. However Horn's study did not take into account potential changes over time in the population size of each species that could occur as a result of differing commercial fishing selectivities between species, or other factors that may influence population changes. Prior to its entry into the QMS, much of the catch was also thought to have been discarded (Horn 1997). Post-QMS era catches (Table 3, Figure 2 are often much higher than Horn's pre-QMS era estimates. Reporting of pale ghost shark is thought to have improved since its inclusion in the QMS in the 1999–2000 fishing year, with reported catches peaking at 1895 t in 2003. In this report, fishing year is labelled as the most recent year (i.e., the 1999–2000 fishing year is referred to as 2000).

Horn (1997) proposed that both species of New Zealand ghost shark could be managed as three separate Fishstocks: east coast New Zealand (FMAs 1–4), Stewart-Snares shelf and Campbell Plateau (FMAs 5 and 6), and west coast New Zealand (FMAs 7–9). Horn based these three stocks on the areas of narrow continental shelf separating them, suggesting that they could provide barriers to stock mixing, particularly as pale ghost shark have a preference for deeper water. These areas became the QMAs used for pale ghost shark when it was introduced into the QMS. The division of fishery areas (Figure 2) used in this study based on the location of catches are: east coast North Island (ECNI, FMAs 1–2), east coast South Island and Chatham Rise (ECSI and CHAT, FMAs 3–4), Sub-Antarctic (SUBA, FMAs 5–6), and the west coast of both the North and South Islands (West Coast, FMAs 7–9). Nearly all of the catch is taken from the ECSI/CHAT and Sub-Antarctic regions, and only these two areas will be examined in detail, with brief summaries for ECNI and West Coast.

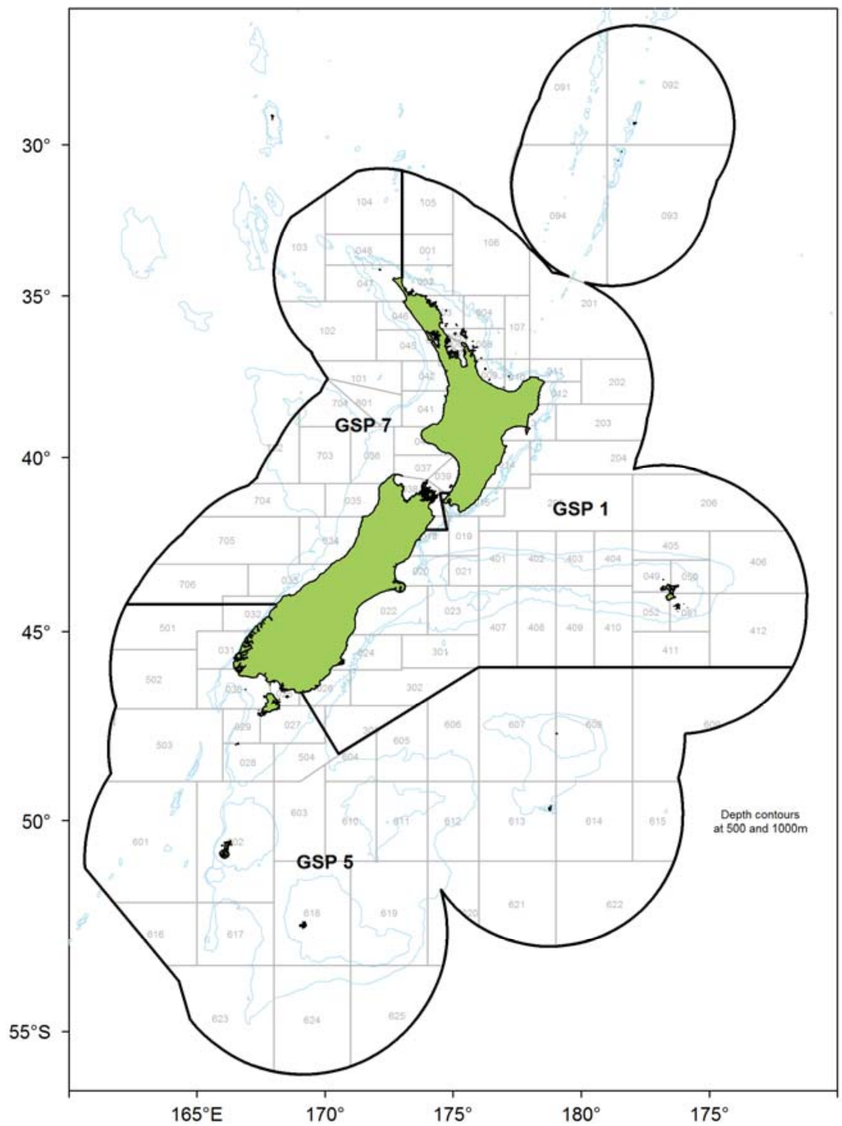


**Figure 1: Map showing the administrative Fishstock boundaries for GSP 1, GSP 5, and GSP 7.**

Pale ghost shark are a minor bycatch species and are rarely recorded in the top five species on trawl catch and effort forms. As a result this study uses daily processed catch data from vessels reporting on TCEPR forms to analyse commercial catch and effort data. This means that non-trawl methods such as bottom longline are not included in analyses. However, they contribute only a minor proportion of the total catch. Catches in GSP 1 and 5 account for 98% of total GSP landings and the use of daily processed catch data captures 95% and 91% of the total reported catches from QMR data for GSP 1 and GSP 5 respectively.

Pale ghost shark is caught all around mainland New Zealand in all QMAs but most of the catch is taken from GSP 1, primarily from QMAs 3 and 4. Catches in GSP 5 are also significant although less so than in GSP 1. Catches from GSP 7 account for little of the total landings; they have been less than 20 t in every year except for 2000 (35 t) and 2002 (71 t).

Almost all of the pale ghost shark catch is taken by bottom trawl. In GSP 1, most of this is taken by vessels targeting hoki, and to a lesser extent hake and silver warehou. In GSP 5, hoki is again the dominant target species producing a catch of pale ghost shark, followed by ling. There is little seasonality in the catch in these two QMAs other than a slight drop off in winter when hoki vessels move off the Chatham Rise to target hoki elsewhere on spawning grounds. In GSP 7, most of the catch is again taken by vessels targeting hoki (followed by hake) by bottom trawl, though the amount is small. This is the only area exhibiting any seasonality in the catch, owing to it being caught as bycatch in the target hoki and hake spawning fisheries during winter months.

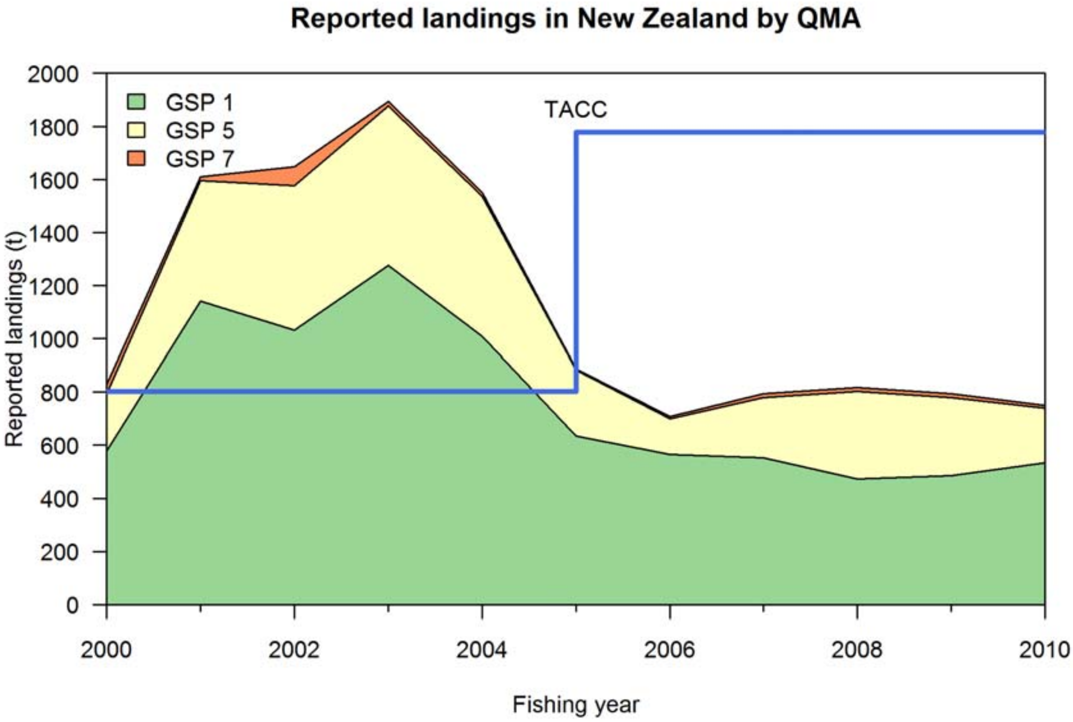


**Figure 2: Total reported pale ghost shark landings by QMA (shaded regions) and TACC from fishing years 2000 to 2010.**

**Table 1: Reported landings (t) of both ghost shark species combined by fishing year and EEZ area, taken by foreign licensed and joint venture vessels combined. An approximation of these areas with respect to current QMA boundaries is used to assign catches to QMAs. No data are available for the 1980–81 fishing year. The 1983-83 data are from a six month changeover period from 1 April 1983 to 30 September 1983. Source: Horn (1997).**

| Year | | | | | | | | | | | EEZ Area | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | C(M) | C(1) | D | E(B) | E(P) | E(C) | E(A) | F(E) | F(W) | G | H | Total |
| QMA | 1&2 | | 3 | 4 | | | | 6 | | 5 | 7 | 8 | |
| 1978–79 | 1 | 37 | 99 | 26 | 3 | 16 | 11 | 88 | 90 | 8 | 68 | 17 | 465 |
| 1979–80 | 1 | 55 | 54 | 426 | 10 | 4 | 28 | 138 | 183 | 7 | 1 | 5 | 912 |
| 1980–81 | | | | | | | | | | | | | – |
| 1981–82 | 0 | 84 | 28 | 117 | 0 | 2 | 6 | 29 | 71 | 9 | 4 | 0 | 350 |
| 1982–83 | 0 | 108 | 35 | 84 | 0 | 2 | 17 | 98 | 99 | 29 | 1 | 1 | 474 |
| 1983–83 | 0 | 84 | 41 | 73 | 0 | 0 | 17 | 5 | 16 | 17 | 0 | 0 | 253 |

**Table 2: Estimated landings (t) of pale ghost shark by fishery management area for fishing years 1982–83 to 1998–99 based on the reported landings of both species combined. The estimated landings up to 1994–95 are based on data in the 1997 Plenary Report. Landings from 1995–96 to 1998–99 were estimated assuming pale ghost shark made up 30% of the total ghost shark catch in QMAs 5 and 6, and 25% in all other QMAs. Source: Ministry of Fisheries (2010b).**

| | | | | | | | | | QMA | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
| 1982-83 | 1 | 1 | 74 | 35 | 21 | 13 | 2 | 1 | 0 | 0 | 148 |
| 1983-84 | 0 | 1 | 63 | 24 | 11 | 15 | 7 | 1 | 0 | 0 | 122 |
| 1984-85 | 1 | 1 | 60 | 49 | 16 | 19 | 12 | 0 | 0 | 0 | 158 |
| 1985-86 | 1 | 1 | 96 | 23 | 10 | 14 | 7 | 1 | 0 | 0 | 153 |
| 1986-87 | 1 | 2 | 110 | 27 | 11 | 12 | 13 | 1 | 0 | 0 | 177 |
| 1987-88 | 1 | 1 | 138 | 21 | 13 | 2 | 15 | 1 | 0 | 0 | 192 |
| 1988-89 | 2 | 7 | 124 | 9 | 19 | 2 | 34 | 1 | 0 | 0 | 198 |
| 1999-90 | 1 | 3 | 86 | 8 | 41 | 5 | 33 | 5 | 0 | 0 | 182 |
| 1990-91 | 1 | 7 | 148 | 63 | 61 | 82 | 39 | 1 | 0 | 0 | 402 |
| 1991-92 | 1 | 2 | 218 | 95 | 64 | 54 | 35 | 2 | 1 | 0 | 472 |
| 1992-93 | 2 | 1 | 227 | 99 | 77 | 55 | 53 | 7 | 0 | 0 | 521 |
| 1993-94 | 1 | 2 | 173 | 42 | 36 | 32 | 99 | 4 | 0 | 0 | 389 |
| 1994-95 | 1 | 1 | 246 | 62 | 27 | 26 | 234 | 1 | 0 | 0 | 598 |
| 1995-96 | 4 | 12 | 226 | 84 | 30 | 29 | 183 | 3 | 1 | 0 | 572 |
| 1996-97 | 6 | 22 | 272 | 134 | 40 | 58 | 309 | 3 | 3 | 0 | 847 |
| 1997-98 | 6 | 6 | 256 | 87 | 30 | 58 | 57 | 1 | 4 | 0 | 505 |
| 1998-99 | 6 | 20 | 315 | 107 | 27 | 47 | 136 | 2 | 7 | 0 | 667 |

**Table 3: Reported landings (t) of pale ghost shark by Fishstock and TACCs (t) from 1999–00 to 2008–09 fishing years (QMR data). Source: Ministry of Fisheries (2010b).**

| Fishstock | | GSP 1 | | GSP 5 | | GSP 7 | | |
|---|---|---|---|---|---|---|---|---|
| QMA (s) | | 1,2,3,4,10 | | 5,6 | | 7,8,9 | | Total |
| | Landings | TACC | Landings | TACC | Landings | TACC | Landings | TACC |
| 1999–00 | 577 | 509 | 216 | 118 | 35 | 176 | 828 | 803 |
| 2000–01 | 1 142 | 509 | 454 | 118 | 16 | 176 | 1 613 | 803 |
| 2001–02 | 1 033 | 509 | 545 | 118 | 71 | 176 | 1 649 | 803 |
| 2002–03 | 1 277 | 509 | 602 | 118 | 16 | 176 | 1 895 | 803 |
| 2003–04 | 1 009 | 509 | 529 | 118 | 15 | 176 | 1 553 | 803 |
| 2004–05 | 635 | 1 150 | 247 | 454 | 5 | 176 | 887 | 1 780 |
| 2005–06 | 565 | 1 150 | 134 | 454 | 9 | 176 | 708 | 1 780 |
| 2006–07 | 553 | 1 150 | 226 | 454 | 15 | 176 | 794 | 1 780 |
| 2007–08 | 473 | 1 150 | 329 | 454 | 16 | 176 | 818 | 1 780 |
| 2008–09 | 486 | 1 150 | 294 | 454 | 15 | 176 | 795 | 1 780 |

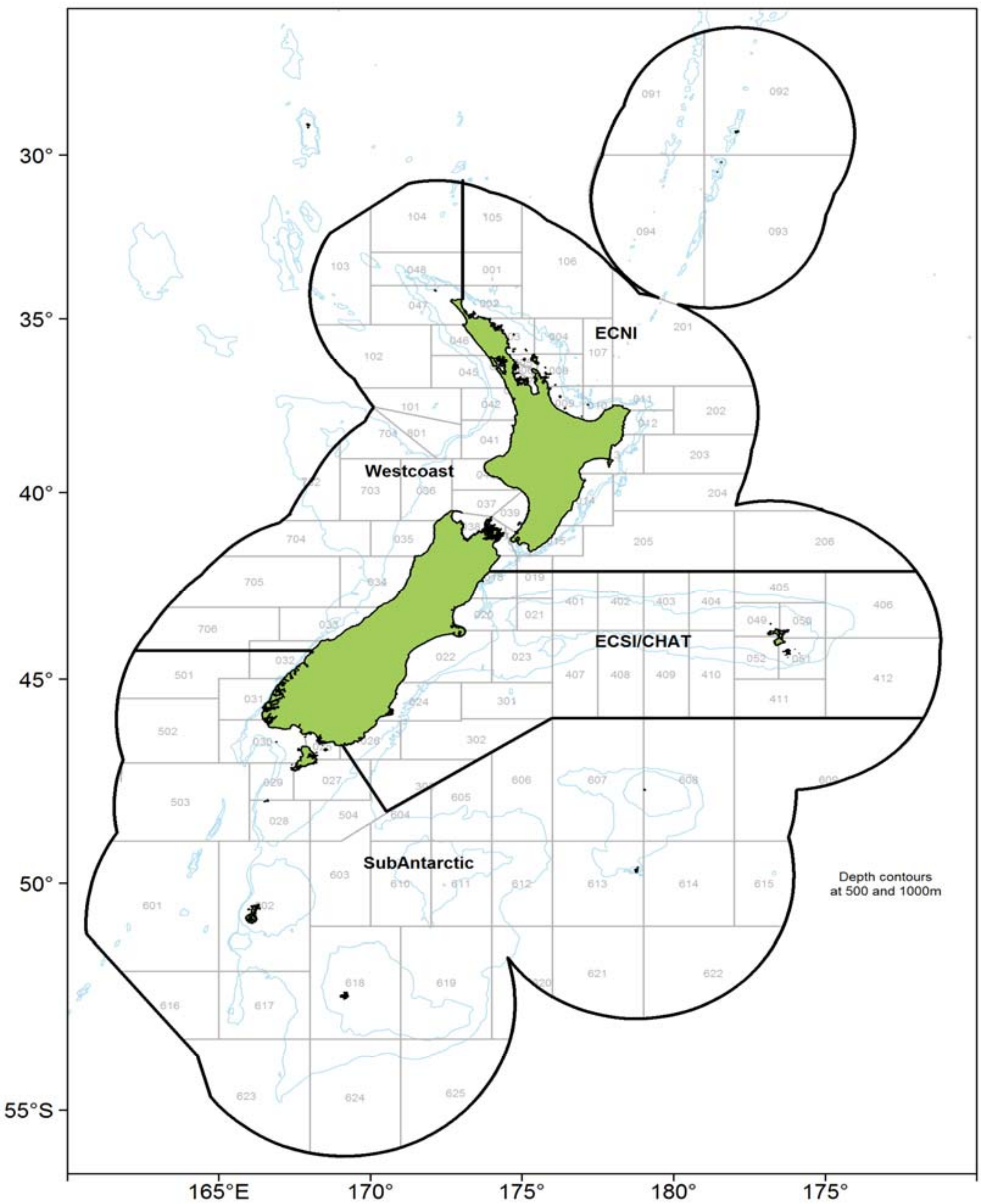


**Figure 3: Map showing the areas used in this analysis, including statistical areas, and the 500 m and 1000 m depth contours. ECNI, east coast North Island; ECSI/CHAT, east coast South Island and Chatham Rise).**

## 2.2 Recreational fisheries

Current catches of pale ghost shark by recreational fishers are believed to be negligible in all areas.

## 2.3 Maori customary fisheries

Quantitative information on the current level of customary non-commercial take is not available but likely to be negligible.

## 2.4 Illegal and misreported catch

Quantitative information on the level of illegal catch is not available. In 1998–99 a quantity of dark ghost shark were reported as pale ghost shark (Ministry of Fisheries 2010b). At this time dark ghost shark had been included in the QMS but pale ghost shark had not.

## 2.5 Other sources of mortality

There is no quantitative information of non-fishing sources of mortality of pale ghost shark.

## 2.6 Regulations affecting the fishery

Current and historical limits on catch or effort in pale ghost shark fisheries are described in Section 2.1. Trawl codend minimum mesh-size regulations that currently apply are 60 mm for Sub-Antarctic (FMA 6) fisheries and FMA 5 south of 48° S; and 100 mm elsewhere. From 1 October 1977, the trawl codend mesh-size change took effect at the boundary between the Snares and Auckland Islands fisheries (the old EEZ boundary between areas F and E), which was at 48° 30’S. The management area boundary was changed on 1 October 1983 to 49° S (now the boundary between FMAs 5 and 6) but the codend mesh size change takes effect at latitude 48° S to allow for targeting of squid around the Snares Islands (Hurst 1988).

Protection of bycatch species in multi-species fisheries is mainly through the QMS, with quotas currently set on 628 fish stocks. Catch of protected species such as seabirds and fur seals is monitored through the Ministry for Primary Industries Observer Programme and all trawl vessels have been required to deploy seabird mitigation devices to minimise interactions with trawl warps since April 2006 (Ministry of Fisheries 2009). Bottom longline vessels 7 m or more in length must use streamer lines to deter seabirds when setting lines and no vessel may discharge offal while setting lines. When hauling lines, offal may only be discharged from the opposite side of the vessel from which the line is being hauled.

# 3. BIOLOGY

## 3.1 Distribution

Pale ghost shark have been recorded in research bottom trawls in depths from 79 to 1538 m, but most often from about 400 to 1200 m (Anderson et al. 1998). They are distributed all around New Zealand waters but occur most often in deeper regions along the Chatham Rise and Campbell Plateau. They are relatively rare north of 40°S.

Little else is known about the movement and behaviour of pale ghost shark and it is not known if there are seasonal changes in their distribution. There are two years of comparable data from autumn and summer Sub-Antarctic surveys, and they show a marked drop in the biomass in summer compared with autumn in 1992, but little difference between seasons in 1993.

## 3.2 Spawning

McCutcheon (1980) defined sexually mature male ghost sharks as having thick and fleshy pelvic claspers, heavily spined prepelvic claspers, and a tenaculum free from the head and spined. Mature females are considered to be those with ovaries containing follicles greater than 10 mm in diameter.

He estimated the length at the onset of sexual maturity for pale ghost shark as 63–64 cm for males and 60–64 cm for females. Horn (1997) estimated the 50% length at maturity for pale ghost shark from the Chatham Rise in January as 59–60 cm and 69–70 cm for males and females respectively, using McCutcheon's criteria.

Fecundity is likely to be low in pale ghost shark as it is in most elasmobranchs. McCutcheon (1980) found that the ovaries of pale ghost shark generally contained about 15 large follicles and about 20–25 small ones. Egg cases were often longer than the uterus and protruded from the oviduct while tail sheaths and attachment threads were completed prior to laying.

Shuntov (1971) believed that *Hydrolagus* species aggregated on the Mernoo Bank in winter were pre-spawning and spawning. He did not state whether these were pale or dark ghost shark but the location of the Mernoo Bank means they were most likely to be dark ghost shark. He believed they spawned once a year and that all spawning activity was completed by December. McCutcheon (1980), however, observed a wide variety of developmental stages of both dark and pale ghost sharks from sites around the east coast of the South Island and postulated that spawning may in fact be year round. Horn (1997) thought that an extended spawning season or year round spawning might explain why length frequency modes are poorly defined. The related ghost shark *Hydrolagus colliei* from the northeast Pacific is believed to spawn year round with possible peaks in summer and autumn (Love 1991).

With just 46 individual fish from all regions examined for gonad development between 2000 and 2010 from the Observer Programme there is insufficient data to indicate location and timing of spawning.

## 3.3 Stocks and spatial distribution

There is no biological information on which to base stock structure for pale ghost shark. There is no obvious difference in size between fish on the Chatham Rise and fish from the Sub-Antarctic when examining series of scaled population length frequencies (Figures A5–A7, B6–9), nor is there any major difference in sex ratios between the two areas.

Horn (1997) proposed that both species of New Zealand ghost shark could be managed as three separate Fishstocks: east coast New Zealand (QMAs 1–4), Stewart-Snares shelf and Campbell Plateau (QMAs 5 and 6) and west coast New Zealand (QMAs 7–9). Horn based these three stocks on the areas of narrow continental shelf separating them, postulating that they could provide barriers to stock mixing, particularly as pale ghost shark have a preference for deeper water. Biological information from trawl surveys and the Observer Programme exhibits no obvious differences between pale ghost shark in different areas of the EEZ that would suggest separate biological stocks. There have been no tagging studies of pale ghost shark and given the depths at which they are most commonly found it is unlikely that this would be a viable option. The management areas proposed by Horn were adopted when pale ghost shark came into the QMS in the 1999–2000 fishing year and there is no indication that they need to be changed.

## 3.4 Ageing

Francis & Ó Maolagáin (2000) investigated the feasibility of ageing dark and pale ghost sharks by weight and diameter of eye lenses, concentric band counts in vertebrae, and by band counts in dorsal spines from fish caught on trawl surveys. They found ageing by band counts in the vertebral column unsuitable for either ghost shark species due to the lack of calcification in the vertebrae. Band counts in dorsal spines were unclear in both species and difficult to interpret. Eye lens diameter showed some promise for dark ghost shark although they concluded that further work needed to be done. Eye lens diameter was not however found to be useful for pale ghost shark, particularly as there is a lack of small fish in the survey catch and weak modal structure in length frequencies.

## 3.5 Growth curves

Von Bertalanffy parameters were derived for Sub-Antarctic and Chatham Rise pale ghost shark for each sex by Francis & Ó Maolagáin (2000) (Table 4). They found that growth rates were similar and moderately rapid for males and females with both sexes reaching 50 cm in 4–5 years. They caution the use of these parameters, however, as ageing of pale ghost sharks was difficult and unclear.

**Table 4: Von Bertalanffy growth parameters for pale ghost shark. Source: Francis & Ó Maolagáin (2000).**

| Region | Sex | $L_\infty$ | $K$ | $t_0$ |
|---|---|---|---|---|
| Sub-Antarctic | Female | 142.9 | 0.070 | –0.50 |
| | Male | 115.8 | 0.110 | –0.53 |
| Chatham Rise | Female | 161.5 | 0.058 | –0.94 |
| | Male | 99.7 | 0.134 | –0.05 |

## 3.6 Natural mortality (*M*)

Only the feasibility of ageing pale ghost shark has been investigated (see section 3.4) and further work needs to be done. Estimates of natural mortality cannot be calculated without knowledge of population age structures or estimates of longevity.

## 3.7 Length-weight relationship

Length-weight relationships are presented in Table 5. Parameters for the Chatham Rise are those reported by O'Driscoll et al. (2011) for all pale ghost shark from the summer Chatham Rise trawl survey time series from 1992–2010. Parameters for the Sub-Antarctic are those reported by Bagley et al. (Submited) for all pale ghost shark from the summer Sub-Antarctic trawl survey time series from 1991–1993 and 2001–2009.

**Table 5: Length-weight parameters for pale ghost shark.**

Weight (grams) = $\alpha L^{\beta}$ L= chimaera length* in cm.

| | Sexes combined | |
|---|---|---|
| | α | β |
| Chatham Rise | 0.008345 | 2.910726 |
| Sub-Antarctic | 0.011738 | 2.829785 |

*** Chimaera length is measured from the tip of the snout to end of the upper caudal fin.**

## 3.8 Feeding and trophic status

Dunn et al. (2010) studied the diets of pale and dark ghost sharks and another common chimaerid, *Harriotta raleighana*, commonly known as the spook fish. They examined stomach contents from specimens caught on three consecutive summer trawl surveys of the Chatham Rise (2005–2007) and found that the diet of pale ghost shark consisted mainly of crustaceans, echinoids, and polychaetes, but with an additional wide variety of mainly benthic prey item. Diet varied with temperature and fish size. Overall, brachyuran crabs were the most important prey category by weight (contributing 48%), with the species *Pycnoplax victoriensis* contributing 23.8% of total prey weight. This was followed by echinoids (10.1%), salps (9%), and polychaetes (8.5%).

Pale ghost shark share some of the same food resources as a number of teleost fishes including some QMS species (Dunn et al. 2010). Polychaetes often appear in the diet of Bollons' rattail (*Caelorinchus bollonsi*). Benthic crustaceans such as *Munida* spp. are common in the oblique-banded rat tail (*Caelorinchus aspercephalus*) and ling (*Genypterus blacodes*), and crabs are common in red cod (*Psuedophycis bachus*) and sea perch (*Helicolenus percoides*). However, on the Chatham Rise, echinoderms and molluscs appear to be largely exclusive to chimaeras as prey items. Competition between the three species examined by Dunn et al. was reduced by differing depth and spatial distributions, and by ontogenetic shifts in diet within each species. Consequently, the population dynamics of each species are unlikely to be greatly affected by competition with one another.

# 4. CURRENT AND ASSOCIATED RESEARCH PROGRAMMES

## Ministry for Primary Industries

Recent or ongoing research relevant to pale ghost shark includes: research trawl surveys by *Tangaroa* on the Chatham Rise and Sub-Antarctic, since 1991 (see Section 5) and fishery characterisations planned every three years under the Ministry for Primary Industries 10-year Research Plan for Deepwater Fisheries (Ministry of Fisheries 2010a).

# 5. FISHERY INDEPENDENT OBSERVATIONS

## 5.1 Research survey biomass indices and length frequencies

There have been no surveys designed specifically to estimate pale ghost shark abundance. The Chatham Rise and Sub-Antarctic *Tangaroa* random bottom trawl survey time series, started in 1991, are the only ongoing surveys that have consistently caught and measured pale ghost shark (note that for the Sub-Antarctic, the summer series was not carried out from 1994 to 1999 and the autumn time series ended in 1998). These surveys are primarily aimed at surveying hoki, hake and ling, as well as a variety of other middle depth species, and do not cover the full depth range of pale ghost shark, although the Chatham Rise survey was extended to 1300 m depth in 2010 as a pilot survey of deeper waters and now covers most of its depth range. Trends in biomass and length frequencies from these surveys are presented in Table 6a-c and Appendix A (Figures A1–A7).

Chatham Rise

Biomass estimates for the Chatham Rise time series range from 2769 t to 7902 t (Figure A1). Coefficients of variation are good, never exceeding 12% for the time series. Despite good c.v.s and no evidence of a systematic decline in biomass, estimates for the Chatham Rise series show considerable variation, particularly for the first ten years. The most extreme case is the nearly three-fold increase in biomass between 1995 and 1996. Given the generally low fecundity of elasmobranch species it is unlikely that these are real changes in biomass and are more likely to be due to changes in availability of pale ghost shark to the trawl, although reasons for this are unknown (Horn 1997).

Historically, the Chatham Rise time series only covered depths between 200 and 800 metres, significantly shallower than the known depth distribution of pale ghost shark. In 2010 a deepwater component was added, extending the survey down to 1300 m. To investigate whether this series now covers their full distribution the proportion of tows catching pale ghost shark in different depth, latitude, and longitude bins was plotted (Figure 4). The distribution is patchy for tows catching pale ghost shark deeper than 800 m. Only the last three surveys have sampled deeper than 800 m and

therefore the number of tows deeper than 800 m is low. It appears that there is still a significant chance of catching pale ghost shark in the deeper strata. However these distribution plots only indicate whether pale ghost shark occur at the given depth, latitude, or longitude, and not how abundant they are. As a percentage of the total, biomass from the deepwater strata is significantly lower than for the core strata at 0.6, 5.4, and 4.2% for the three surveys that have sampled deeper than 800 m (Table 6b). As such the core Chatham Rise survey may provide a reasonable index of relative pale ghost shark abundance.
The plot of pale ghost shark occurrence as a function of latitude indicates that pale ghost shark have a preference for deeper water with a higher proportion of tows containing pale ghost shark at the northern and southern (deeper) ends of the rise with a lower proportion in between. However the northern extreme of the rise appears to have a lower proportion of tows with pale ghost shark. This could be due to chance as few tows have been carried out there so far. The longitude plot does not appear to show any clear pattern. While only the last three surveys have sampled deeper than 800 m, the low proportion of biomass in deep water on the Chatham Rise is similar to that seen for deepwater on the Sub-Antarctic survey, which has sampled to 1000 m since the 2000 survey.

The biomass of recruited and pre-recruited pale ghost shark was investigated to see whether recruitment into the adult fishery could be predicted based on strong year classes of pre-recruits (based on biomass, not length frequencies, which show little modal progression) (Table 6c). Fish more than 60 cm in length were chosen as a proxy for recruited fish of both sexes based on the onset of sexual maturity given in Section 3.2 and the lack of fish less than 60 cm in the length frequencies. Biomass of pre-recruited fish does not track the biomass of recruited fish and does not suggest that adult biomass could be usefully predicted this way (Figure A4).

Numbers of pale ghost shark measured on the Chatham Rise range from 69 to 1842 on each survey. Females contribute slightly more to the biomass than males. Sex ratios are about even with a mean male:female ratio of 1.06 for the series (range 0.77–1.24). For both sexes, fish range from 10–94 cm chimaera length (CL, measured from the tip of the snout to the end of the upper caudal fin) (Figure A5). The plots from the first Chatham Rise survey (TAN9106) suggest that the few fish that were measured may have been measured as total length rather than chimaera length as nearly all are greater than 80 cm. Virtually all fish of both sexes are 40–80 cm, although females tend to reach slightly larger sizes than males. Mean length has steadily decreased over the time series from 67.9 to 63.3 cm CL. There is no clear evidence of modal progression in length frequency plots. No confident ageing method has yet been developed, so it is not possible to develop a catch-at-age history for pale ghost shark.

Sub-Antarctic
Compared with the Chatham Rise, biomass estimates are considerably higher for the summer Sub-Antarctic surveys in most years. Biomass estimates range from 4797 t to 16 955 t, and c.v.s range from 6 to 13 % (Figure A2). From 2001 the biomass estimates are relatively flat, and show much less variation than on the Chatham Rise. The biomass and percentage of total biomass of pale ghost shark catch from deepwater strata is given in Table 6b. Percentages are similarly low to the Chatham Rise time series (range 1.8–7.56%, mean 4.5%). In 2000, this time series started to sample depths up to 1000 m. To investigate whether the deeper strata might provide a good index of abundance, the proportion of tows catching pale ghost shark in different depth, latitude, and longitude bins was plotted (Figure 5). It appears that the depth range is still not completely covered, with more than 80% of tows deeper than 800 m catching pale ghost shark. The range of latitude may also be inadequate. While the northern limit of the survey ground shows few pale ghost shark caught and an increasing trend to the south, the proportion of tows catching pale ghost shark is high at the southern end of the survey range. It is not known if the proportion of tows containing pale ghost shark would remain high or decrease if the southern limit was extended. The range of longitude  may also inadequately cover the distribution. The eastern limit of the survey ground shows that around 50% of tows will contain pale ghost shark, while at the western limit nearly 100% of tows will catch pale ghost shark. However, as on the Chatham Rise the deepwater biomass is a minor part of the total. Water gets deeper to the

south and to the east and west of the survey ground. As such this survey probably covers most of the distribution of pale ghost shark and provides a reasonably good index of pale ghost shark abundance.

As was done for the Chatham Rise, biomass of recruited and pre-recruited pale ghost shark was investigated to see whether recruitment into the adult fishery could be predicted based on strong year classes of pre-recruits. The biomass of pre-recruits is relatively flat throughout the time series and does not suggest that adult biomass could be usefully predicted in this way (Figure A4).

Numbers of pale ghost shark measured in the Sub-Antarctic summer series range from 520 to 1915 per survey. Females contribute slightly more to the biomass than males. Sex ratios are about even with a mean male:female ratio of 0.97 for the series (range 0.77–1.29). For both sexes, fish range from 19 to 105 CL (Figure A6). The plots from the first Sub-Antarctic survey (TAN9105) also appear to have been measured as total length rather than chimaera length. Virtually all fish of both sexes are 50–80 cm, although females tend to reach slightly larger sizes than males. Mean length has steadily decreased over the time series from 66.3 to 63.5 cm CL. There is no clear evidence of modal progression in length frequency plots. It is not currently possible to develop a catch-at-age history for the Sub-Antarctic time series.

For the autumn Sub-Antarctic surveys, biomass estimates range from 10 531 to 16 035 t, and c.v.s from 9.5 to 10.3% (Figure A3). The biomass trajectory is relatively flat but consists of only four years of data. Biomass by sex was only available for the last two surveys but shows that males and females contribute about equally to the total biomass. Length frequencies are available from only two surveys (Figure A7).

**Table 6a: Biomass indices (t) and coefficients of variation (c.v.) of pale ghost shark from *Tangaroa* trawl surveys (Assumptions: areal availability, vertical availability and vulnerability = 1).**

| | Trip code | Date | Biomass (t) | % c.v. |
|---|---|---|---|---|
| Chatham Rise | | | | |
| | TAN9106 | Dec 91–Feb 92 | 6 049 | 6 |
| | TAN9212 | Dec 92–Feb 93 | 3 643 | 7 |
| | TAN9401 | Jan 94 | 5 928 | 9 |
| | TAN9501 | Jan–Feb 95 | 2 769 | 9 |
| | TAN9601 | Dec 95–Jan 96 | 7 902 | 10 |
| | TAN9701 | Jan–Jan 97 | 2 871 | 12 |
| | TAN9801 | Jan–Jan 98 | 3 958 | 10 |
| | TAN9901 | Jan–Jan 99 | 5 272 | 10 |
| | TAN0001 | Dec 99–Jan 00 | 4 892 | 8 |
| | TAN0101 | Dec 00–Jan 01 | 7 094 | 9 |
| | TAN0201 | Dec 01–Jan 02 | 4 896 | 10 |
| | TAN0301 | Dec 02–Jan 03 | 4 653 | 12 |
| | TAN0401 | Dec 03–Jan 04 | 3 627 | 9 |
| | TAN0501 | Dec 04–Jan 05 | 4 061 | 9 |
| | TAN0601 | Dec 05–Jan 06 | 3 237 | 10 |
| | TAN0701 | Dec 06–Jan 07 | 4 771 | 9 |
| | TAN0801 | Dec 07–Jan 08 | 3 220 | 6 |
| | TAN0901 | Dec 08–Jan 09 | 3 995 | 8 |
| | TAN1001 | Jan 10 | 3 216 | 12 |
| Sub-Antarctic (summer) | | | | |
| | TAN9105 | Nov–Dec 91 | 11 291 | 6 |
| | TAN9211 | Nov–Dec 92 | 4 797 | 7 |
| | TAN9310 | Nov–Dec 93 | 11 706 | 9 |
| | TAN0012 | Nov–Dec 00 | 16 955 | 13 |
| | TAN0118 | Nov–Dec 01 | 10 420 | 9 |
| | TAN0219 | Nov–Dec 02 | 89 77 | 10 |
| | TAN0317 | Nov–Dec 03 | 10 175 | 9 |
| | TAN0414 | Nov–Dec 04 | 8 220 | 11 |
| | TAN0515 | Nov–Dec 05 | 9 079 | 10 |
| | TAN0617 | Nov–Dec 06 | 12 151 | 10 |
| | TAN0714 | Nov–Dec 07 | 12 744 | 11 |
| | TAN0813 | Nov–Dec 08 | 9 341 | 13 |
| | TAN0911 | Nov–Dec 09 | 13 155 | 9 |
| Sub-Antarctic (autumn) | | | | |
| | TAN9204 | Apr–May 92 | 10 531 | 9 |
| | TAN9304 | May–Jun 93 | 14 635 | 9 |
| | TAN9605 | Mar–Apr 96 | 16 035 | 10 |
| | TAN9805 | Apr–May 98 | 15 118 | 10 |

**Table 6b: Deep strata biomass of pale ghost shark for the Chatham Rise and Sub-Antarctic Surveys.**

| Trip code | Total biomass | Deep strata biomass | Deep biomass as a percentage of total biomass |
|---|---|---|---|
| Chatham Rise | | | |
| TAN1001 | 3600 | 20 | 0.56 |
| TAN1101 | 2695 | 145 | 5.38 |
| TAN1201 | 4515 | 188 | 4.16 |
| Sub-Antarctic | | | |
| TAN0012 | 17823 | 886 | 4.97 |
| TAN0118 | 11219 | 813 | 7.25 |
| TAN0219 | 9297 | 326 | 3.51 |
| TAN0317 | 10360 | 189 | 1.82 |
| TAN0414 | 8549 | 333 | 3.90 |
| TAN0515 | 9416 | 347 | 3.69 |
| TAN0617 | 12619 | 477 | 3.78 |
| TAN0714 | 13107 | 368 | 2.81 |
| TAN0813 | 10097 | 763 | 7.56 |
| TAN0911 | 13553 | 406 | 3.00 |
| TAN1117 | 12579 | 902 | 7.17 |

**Table 6c: Biomass of recruited and pre-recruited pale ghost shark for the Chatham Rise and Sub-Antarctic summer time series. NB: TAN9106 from the Chatham Rise and TAN9105 from the Sub-Antarctic are excluded as too few fish were measured.**

| Trip code | Recruited biomass | Recruited % of total biomass | Pre-recruited biomass | Pre-recruited % of total biomass |
|---|---|---|---|---|
| Chatham Rise | | | | |
| TAN9212 | 3 385 | 93 | 258 | 7 |
| TAN9401 | 5 349 | 90 | 579 | 10 |
| TAN9501 | 2 616 | 94 | 153 | 6 |
| TAN9601 | 7 411 | 94 | 491 | 6 |
| TAN9701 | 2 741 | 95 | 130 | 5 |
| TAN9801 | 3 696 | 93 | 262 | 7 |
| TAN9901 | 5 010 | 95 | 262 | 5 |
| TAN0001 | 4 716 | 96 | 176 | 4 |
| TAN0101 | 6 304 | 89 | 790 | 11 |
| TAN0201 | 4 540 | 93 | 356 | 7 |
| TAN0301 | 4 300 | 92 | 353 | 8 |
| TAN0401 | 3 337 | 92 | 290 | 8 |
| TAN0501 | 3 623 | 89 | 438 | 11 |
| TAN0601 | 2 908 | 90 | 329 | 10 |
| TAN0701 | 4 249 | 89 | 522 | 11 |
| TAN0801 | 2 763 | 86 | 457 | 14 |
| TAN0901 | 3 287 | 82 | 708 | 18 |
| TAN1001 | 2 759 | 86 | 457 | 14 |

**Table 6c: Continued.**

| Trip code | Recruited biomass | Recruited % of total biomass | Pre-recruited biomass | Pre-recruited % of total biomass |
|---|---|---|---|---|
| Sub-Antarctic | | | | |
| TAN9211 | 4 381 | 93 | 416 | 7 |
| TAN9310 | 10 699 | 93 | 1007 | 7 |
| TAN0012 | 15 749 | 93 | 1206 | 7 |
| TAN0118 | 9 291 | 89 | 1129 | 11 |
| TAN0219 | 8 256 | 92 | 721 | 8 |
| TAN0317 | 9 569 | 94 | 606 | 6 |
| TAN0414 | 7 681 | 94 | 539 | 6 |
| TAN0515 | 8 323 | 92 | 756 | 8 |
| TAN0617 | 10 924 | 90 | 1227 | 10 |
| TAN0714 | 11 857 | 93 | 887 | 7 |
| TAN0813 | 8 184 | 88 | 1157 | 12 |
| TAN0911 | 11 956 | 91 | 1199 | 9 |

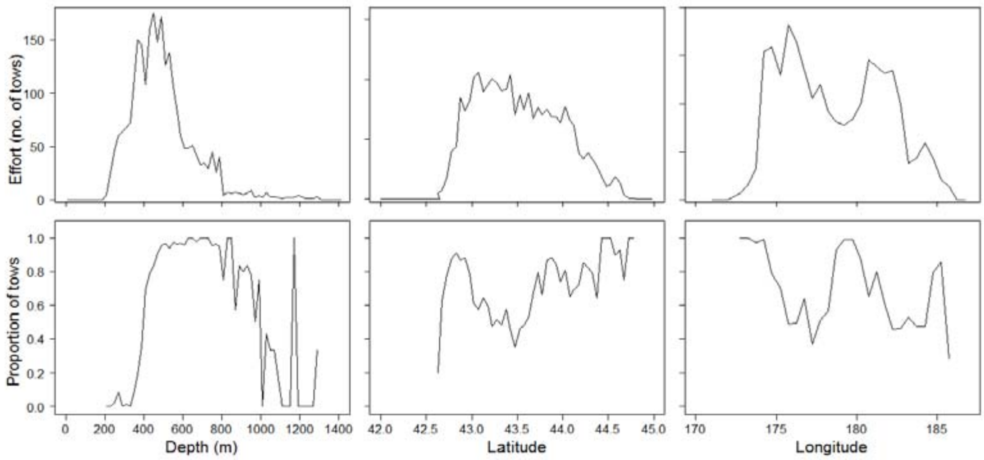


**Figure 4: Number of tows by depth, latitude, and longitude, and the corresponding proportion of tows that contain pale ghost shark for the Chatham Rise time series (deepwater strata included).**

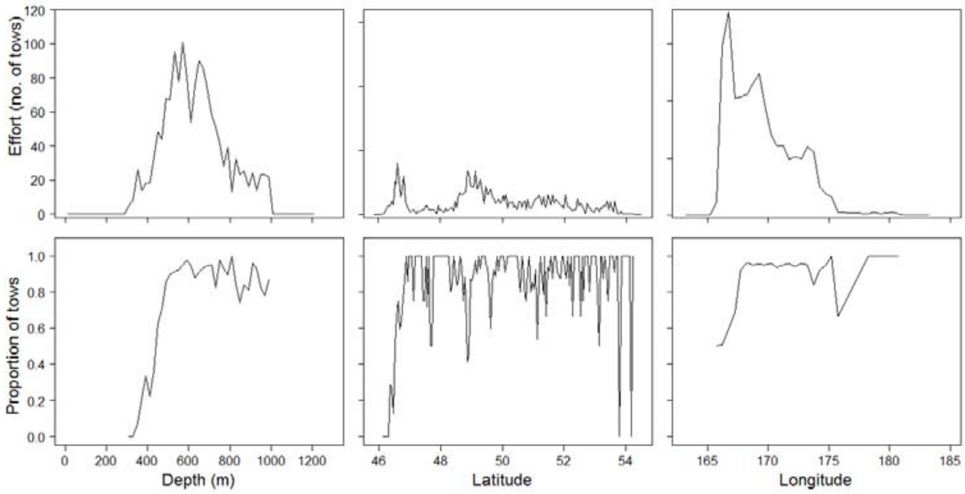


**Figure 5: Number of tows by depth, latitude, and longitude, and the corresponding proportion of tows that contain pale ghost shark for the Sub-Antarctic time series (deepwater strata included).**

# 6. FISHERY DEPENDENT OBSERVATIONS

## 6.1 Observer data

### Length and age sampling

The Ministry of Fisheries Observer Programme (now Ministry for Primary Industries) has collected pale ghost shark length and weight data from various fisheries since 1990. However prior to the inclusion of pale ghost shark in the QMS very little was coded as 'GSP'. Most pre-QMS observer data was coded as 'GSH' (just as commercial catches were) and it is not possible to reliably separate the data by species. Analysis of observer data for pale ghost shark in this study will focus on data collected from the 2000 fishing year onwards, when pale ghost shark entered the QMS. All tables and figures relating to observer data collected from pale ghost shark fisheries are contained in Appendix B (Tables B1–4, Figures B1–11).

Overall, 12.6% of the total commercial catch of pale ghost shark from 2000 to 2010 has been observed (Table B1) with the highest coverage in decreasing order coming from the West Coast (139.5%), ECNI (28.6%), ECSI and Chatham Rise (11.5%), and Sub-Antarctic (11.3%) areas. The coverage on the West Coast exceeds 100% because more catch was observed than was reported in the commercial catch-effort data in GSP 7. A higher proportion of pale ghost shark is caught by vessels reporting on CELR forms in GSP 7 compared with other QMAs. This study required the use of daily processed catch data which is only on TCEPR forms so a larger proportion of the data cannot be recovered for GSP 7. However given the low GSP 7 catches and their small contribution to the total pale ghost shark catch, this is not a concern. The numbers of observed tows (in decreasing order for each region) are ECSI and Chatham Rise (585), West Coast (191), Sub-Antarctic (190), and ECNI (13) (Table B2, a-e). Sampling shows little seasonality in the ECNI but catches are low from this region. For the ECSI and Chatham Rise and the Sub-Antarctic fisheries, coverage is good. There is a drop off during the winter months in the number of observed tows which is most likely related to the relocation of vessels targeting hoki (which catch most of the pale ghost shark) to the spawning grounds on the west coast of the South Island and in Cook Strait (where little pale ghost shark is caught). The WCSI fishery is mostly observed in the winter months during the hake and hoki spawning season.

The representativeness of the observer sampling of pale ghost shark was evaluated by plotting the proportion of landed catch for each year by area and month as circles, and overlaying this with the proportion of the observed catch for those same cells as crosses (Figure B1). If the proportions are the same, the circles and crosses are the same size; if over- or under-sampling has occurred, the crosses are either larger or smaller than the circles. Since 2000, overall sampling is well represented for all areas. By year and month, catches on the ECNI range from being not sampled to being over-sampled. However, catches here are minor (never more than 1 t in any given month for the period) (Figure B2). Observer coverage by month for the ECSI and Chatham Rise region is good, with very few months under-sampled (Figure B2). For the Sub-Antarctic, observer coverage by month is patchier than for the ECSI and Chatham Rise area but is generally good (Figure B4). The West Coast region is moderately well sampled in the months producing most of the catch, i.e., the hoki spawning season from June to September (Figure B5).

The current lack of a reliable ageing method means that there is no opportunity to monitor year class strength moving through any of the four main fisheries.

### Length frequencies

Scaled length frequencies were determined using the 'catch.at.age' software (Bull 2002) which scales the length frequency from each catch up to the tow catch, sums over catches in each stratum, scales up to the total stratum catch, and then sums across the strata to yield overall length frequencies. Numbers of pale ghost shark were estimated from catch weights using the length-weight relationship given in Table 5.

Length frequencies are plotted in Figures B6–B11. The size of fish caught by commercial vessels is similar between the ECSI and Chatham Rise region and the Sub-Antarctic with most of the catch comprising fish from 60–80 cm for both sexes. There is a smaller mode of fish at 30–60 cm. This is similar to the length frequency plots of male and female pale ghost shark from the Chatham Rise and Sub-Antarctic middle-depth surveys carried out by *Tangaroa*.

Length samples are inadequate to determine any real trends for the West Coast region. For some years where more data has been collected the lengths of pale ghost shark appear to be similar to the ECSI and Chatham Rise and Sub-Antarctic fish. There is insufficient data from the ECNI to construct length frequency plots.

### Female maturity

With just 46 females sampled for gonad maturity between 2000 and 2010 from all regions it is not possible to determine size at maturity.

## 6.2 Catch and effort data sources

Catch and effort data and daily processed data were requested from the Ministry for Primary Industries catch-effort database “warehou” as extract 8208. The data consist of all fishing and landing events associated with a set of fishing trips that reported a positive landing of pale ghost shark in GSP 1, 5, or 7, between 1 October 1989 and 30 September 2010. The fields from the database tables requested are listed in Table C1.

The daily processing catch associated with the fishing events were reported on the Trawl Catch Effort and Processing Return (TCEPR) forms. Daily processed catch was used because the landed catch was so poorly represented in the estimated catch as pale ghost shark is a minor bycatch species that does not often comprise one of the top five species in a haul. The greenweight associated with landing events were reported on the associated Catch Landing Return (CLR). TCEPR forms record tow-by-tow data and for each day record the catch for all species processed on that day. In some instances the fish processed on a given day will not necessarily have been caught on that same day. For example, target species are likely to be given processing priority resulting in bycatch species such as pale ghost shark not being processed until the following day, or bycatch species may not be caught in sufficient numbers to warrant processing them until there is enough to make up whatever units a vessel produces (e.g., box of fillets, head and gut block). There is no way to correct this, so for the purposes of this study daily processed records are treated as having being caught on the day of processing. Information on total harvest levels are provided via the QMR/MHR system, but only at the resolution of QMA.

The extracted data are groomed and restratified to derive the datasets required for the characterisation and CPUE analyses using a variation of Starr’s (2003) data processing method as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2006), and Manning (2007), and further modified for this study to make use of daily processed catch data in place of estimated catch data. The procedure has been developed for monitoring bycatch species in the AMP, and is comprehensively described by Manning et al. (2004) and Starr (2007). The major steps as used in this study are as follows.

Step 1: The fishing effort, processed catch, and landings data are groomed separately. Outlier values in key variables that fail a range check are corrected using median imputation. This involves replacing missing or outlier values with a median value calculated over some subset of the data. Where grooming fails to find a replacement, all fishing and landing events associated with the trip will be excluded.

Step 2: The fishing effort data are collapsed to one record per unique end date and vessel key. For each record, the fields are populated as follows:

| FIELD | METHOD |
|---|---|

| | |
|---|---|
| Form type | All TCP where daily processed data exists. |
| Trip ID | Most common. |
| Midday longitude and latitude | Most common. |
| Start stats area code | If all fishing events for a vessel occur in the same statistical area use that statistical area, otherwise use the most common area. |
| Target species | Dominant species *(If there is a species targeted for more than 50% of the trawls in a day, use this species, else leave as 'Mixed').* |
| Primary method | Dominant method (*If one method is used for more than 50% of tows in a day use that method, otherwise use 'BT+MW'*). |
| Fishing duration | Sum |
| Effort depth | Mean |
| Effort speed | Mean |
| Effort height | Mean |
| Effort width | Mean |
| Bottom depth | Mean |
| Effort num (defaults to one per tow for TCP data) | Sum |
| Fishing distance | Sum |
| GSP catch | The daily processed catch for GSP, matched by end date/vessel key in the fishing effort data with processed date/vessel key in the processed catch data. Where a trip lands from more than one QMA, the proportion landed for each is calculated and the GSP catch is multiplied accordingly to get the values for each QMA. |

Step 3: The greenweight landings for each fish stock for each trip are then allocated to the effort data. The greenweight landings are mapped using the fish stock code and trip ID.

Step 4: The greenweight landings are then allocated to the effort data using total processed catch for each date/vessel key as a proportion of the total processed catch for the trip.

# 7 DESCRIPTIVE ANALYSIS OF CATCH

## 7.1 Summary of catches

All tables and figures relating to characterisation of pale ghost shark fisheries are contained in Appendix C (Tables C1–10, Figures C1–29). Table C10 contains a list of species codes used. Unless otherwise stated "estimated catch" refers to greenweight catches estimated from daily processed catch.

The reported QMR/MHR landings, catch-effort landings (un-groomed), and TACCs for GSP 1–7 from 2000–2010 are shown in Figure C1. MHR and TACC were also presented earlier in Table 1. For all fish stocks, the ungroomed catch-effort landings are fairly close to the reported MHR landings. Reported MHR landings in GSP 1 and 5 overran the TACC from 2000 until 2005 when both QMAs received TACC increases. The TACC in GSP 7 has been significantly under-caught every year since pale ghost shark was included in the QMS in 2000.

The landings data provide a verified greenweight landed for a fish stock on a trip basis. However, landings data include all final landing events – where a vessel offloads catch to a Licensed Fish Receiver, as well as interim landing events, where catch is transferred or retained, and may therefore appear subsequently as a final landing event (SeaFIC 2007). Starr's (2007) procedure separates final and interim landings based on the landing destination code, and only landings with destination codes that indicate a final landing are retained (see Table 2 in Starr (2007)).

Table C2 summarises the number of landing events for the major destination codes in the dataset since 2000. For CLR forms, the majority of all landing events in all QMAs is “L” (landed to New Zealand). The next most common destination code in all QMAs is “R” (retained on board) but this is a very small fraction of total landings. Other destination codes are minor by comparison. The greenweight landings for each destination code are fairly constant through time. Landings on CELR forms are much smaller than on CLR forms. The most common destination code is again “L” for all QMAs. Other destination codes report much lower landings and from 2006 “L” is the only destination code in GSP 1 and 5. Aside from one tonne discarded (destination code “D”) in 2010, all landings in GSP 7 for the CELR form are reported as “L”.

It was unknown how the landings from “R” trips are recorded, as the catches could be landed by foreign vessels to ports outside New Zealand. Other interim landing events (retained as bait, in holding receptacles) were dropped (after Starr 2007, Parker & Fu 20011. The weight, number of records, and disposition of each potential landed state is given in Table C3. The retained landings, interim landings, and total landings dropped during data grooming are shown in Figure C2. For all QMAs in all years there is a close match between retained landings and the reported QMR landings. Only a small proportion of landings are dropped during the grooming process or removed due to being classified as interim landing events. Total daily processed catch in GSP 1, 5, and 7 represent 95%, 91%, and 46% of the QMR landings respectively (Table C4). Unmerged landings for GSP 1, 5, and 7 represent 98%, 98%, and 96% of QMR landings respectively.

The main processed state for pale ghost shark in all QMAs in all years is “dressed” which also includes “Headed and gutted”, and “Trunked” (Figure C3). Green, fishmeal, and all other processed states are much less common than dressed.

For some QMS species, conversion factors have changed over time. Consequently, for those species, different amounts of greenweight catch are associated with the same amount of processed catch for particular product forms. In such cases, the greenweights can be standardised using the most recent conversion factor for each processed state, based on the assumption that the changes in conversion factors reflect improving estimates of the actual conversion when processing, rather than real changes in processing methodology across the fleet. However, other than a minor adjustment of 5.56 to 5.6 for fishmeal, pale ghost shark conversion factors have been static and adjustments have not been necessary in this study.

The retained landings were allocated to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fish stock. Difficulties arise with effort strata associated with statistical areas that straddle stock management area boundaries (e.g., statistical area 018, 027, and 032 in the case of pale ghost shark), as the proportion of catches to be allocated to each QMA cannot be determined. The usual treatment for a trip fishing in a straddling statistical area is to assume that the catches of the straddling statistical area had been taken from a single fish stock if the trip had only reported to that stock, and to exclude all the fishing and landing events from that trip if it had reported to multiple fish stocks (“straddle” method). This may not be ideal if trips often straddle fishstock boundaries. Therefore, statistical areas were allocated to pale ghost shark QMAs based on the location of the centroid of each statistical area (“centroid” method). This resulted in a closer relationship between QMR/MHR landing, merged landings and processed catch for both areas. Details of the retained landings in unmerged and merged datasets and processed catches in the groomed and merged datasets, by QMA, are given in Table C4. The recovery rates, defined as the groomed and merged landings as a proportion of the groomed and unmerged landings (after Manning et al. 2004), are plotted in Figure C4.

Processed catch, QMR, retained, and merged landings are plotted in Figure C5. In GSP 1 the retained landings, merged landings, and processed catch are close to the QMR landings. In GSP 5 there is a good match between retained landings, merged landings, and processed catch with the reported QMR landings each year. In GSP 7 there are reasonable matches in most years but QMR landings and retained landings are considerably higher in 2000 and 2002. The reason for this is the use of daily processed catch data, which can only consider TCEPR data. A higher proportion of pale ghost shark is caught by vessels reporting on CELR forms in GSP 7 compared with other QMAs, hence QMR landings and merged landings do not match well with merged landings and processed catch. Given the minor amount of pale ghost shark caught in the region (usually less than 20 t) this is of little concern.

The reporting rate, defined to be the greenweight calculated from annual processed catch for this study as a proportion of the retained landings in the groomed and merged dataset, was also calculated (Figure C6). The TCEPR/CLR reporting rate is flat throughout most of the time period in GSP 1. The drop between 2000 and 2001 is probably a result of improved compliance in reporting pale ghost shark after its inclusion in the QMS. After 2001 it is fairly steady and close to one. The same pattern is seen in GSP 5. In GSP 7 there is more variability and the reporting rate is markedly higher or lower than one for roughly half of the years examined. The reason for this is unknown, but it could be due to misreporting of landing weights or perhaps incorrect reporting of processed states.

Only a minority of trips that landed pale ghost shark recorded no processed catch (Table C5). Zero processed catches are most common in GSP 1 with the highest proportion being 0.29 in 2005. Zero processed catch is least common in GSP 5 with the proportion being under 0.1 in all years; there were no trips reporting zero processed catch in 2003. The proportion of trips reporting no processed catch in GSP 7 has never exceeded 0.21. Figure C7 shows that, for all QMAs, processed catch and landed catch match closely for most trips. Where there is a discrepancy, the landed catch is usually greater than the reported processed catch.

## 7.2 Fishery Summary

Pale ghost shark is caught all around mainland New Zealand with the greatest catches coming from off the east coast of the South Island, Chatham Rise, Snares Shelf, Auckland Islands, and Pukaki Rise (Figure C8). There is no distinct season with catches being relatively consistent throughout all months of the year (Figure C9a).

While it is caught all around New Zealand, catches on the west coast of both the North and South Islands and the east coast of the North Island are negligible (Table C6, Figure C9b). The majority comes from the east coast South Island and Chatham Rise, followed by the Sub-Antarctic. Total processed catch for each region from the groomed and merged dataset are shown in Table C6. Since entering the QMS in 2000 the ECSI/CHAT region has consistently produced the highest catches with annual landings ranging from 298 to 1196 t. Catches in the Sub-Antarctic have also being significant, though much lower than the ECSI/CHAT region, with landings ranging from 107 to 583 t. Catches from the east coast North Island and the west coast have never exceeded 10 and 20 t respectively. As a percentage of the total catch for the post-QMS period, the east coast North Island and the west coast account for just 0.2 and 0.9% respectively.

Nearly all of the catch is taken by bottom trawl (Figure C9c). As this analysis was carried out on daily processed catch data from vessels reporting on TCEPR forms non-trawl fishing methods are not included. However, the amount of catch lost due to the exclusion of non-trawl methods such as bottom longline (which does catch pale ghost shark) is minor. Smaller trawlers reporting on CEL forms do not contribute much of the catch, quite likely because pale ghost shark are generally found deeper and further off shore than where most small vessels go. Table C4 gives the proportion of the processed catch from TCEPR vessels as a percentage of the reported QMR landings and shows that the majority of the catch is taken by trawlers reporting on TCEPR forms for GSP 1 and 5. These two QMAs account for 12 066 t or 98% of reported QMR landings. Nearly all of the pale ghost shark catch is taken as bycatch in the hoki target fishery, with small amounts taken in hake, ling, and silver warehou target fisheries (Figure C9d). Pale ghost shark is not a target fishery.

Most of the catch is taken by New Zealand flagged vessels, followed by Korean and Panamanian vessels (Table C7, Figure C10a). Engine power of vessels catching pale ghost shark range from 300 to 5700 kilowatts with most being 2700 kilowatts (Figure C10b). Gross tonnage of vessels ranges from 250 to

4750 tonnes with most being between 1750 and 2750 tonnes (Figure C10c). Overall length ranges from 25 to 115 metres with most being between 55 and 75 metres (Figure C10d).

### 7.2.1 East Coast South Island and Chatham Rise (ECSI/CHAT)

The ECSI/CHAT region contributes the greatest proportion of the pale ghost shark catch since its inclusion in the QMS, with 8187 t or 71% of the total processed catch (Table C6, Figure C9b). No clearly distinct season is apparent for the region, although it appears that catches may decrease slightly from July to September when the hoki fleet (which takes most of the pale ghost shark catch) moves away from the Chatham Rise to target spawning hoki fisheries (Table C8a, Figures C11a and C12c).

Statistical areas 020 and 023 are important on the east coast South Island and contribute 42% of the total catch. Within the Chatham Rise area the western end is more important, especially along the southern edge including the Veryan Bank (Table C8b, Figures C11b and C12a).

More than 99% of the catch is taken by bottom trawl (Table C8c, Figure C11c). The category “Other” comprises midwater trawl and days with an even split of midwater and bottom trawling and accounts for less than 1% of the total pale ghost shark catch for the region.

The hoki target fishery takes 93% of the pale ghost shark catch (Table C8d, Figure C11d). Silver warehou and hake target fisheries account for just 1% and 2% of the catch respectively; the remaining 4% is taken in a wide mixture of other target fisheries. Pale ghost shark itself is not targeted.

Unstandardised catch rates (kg per tow) of pale ghost shark for the main target species are presented in Figure C13. For the hoki target fishery the catch rate is fairly constant through most of the post-QMS period at around 100 kg per tow. The catch in the hake target fishery is more variable than in the hoki fishery and appears to be climbing steadily through the post-QMS period. Overall catch per tow in the hake fishery is much lower than in the hoki fishery though. Catches in the silver warehou fishery are also more variable than in the hoki fishery and also appear to increase through the post-QMS period although not greatly so. Catch per tow is again lower than in the hoki target fishery at around 60–90 kg per tow.

Daily fishing duration for bottom tows in the hoki target fishery is fairly constant through time with virtually all durations being between 15 and 20 hours per day (Figure C14). Hake fishing duration is more variable with shorter durations than seen in hoki. The silver warehou target fishery is the most variable and overall has lower daily fishing durations than either hoki or hake, often less than 15 hours per day.

Throughout the post-QMS period effort depth has remained constant for pale ghost shark caught in the hoki target fishery with nearly all tows being at around 500 m (Figure C15). Effort depth is also constant for the hake target fishery and is similar to the hoki fishery with most tows being just shallower than 500 m. Silver warehou targeting is more variable in effort depth than the hoki and hake fisheries, and is generally shallower with most tows being under 500 m, and often less than 400 m.

Bottom trawl gear effort width and vessel speed, tonnage, and length are shown in Figure C16. Effort width for all three of the main target fisheries catching pale ghost shark are similar with most being around 35–40 m. Effort speed is also similar for the three main target species with nearly all tows being between 3.5 and 4.5 knots. Gross tonnage of vessels is greatest for the hoki target fishery with most being over 2000 gross tonnes. Vessels targeting hake are mostly under 1000 gross tonnes and silver warehou under 2000 tonnes. Vessels targeting any of these species can range up to more than 3000 gross tonnes. Overall vessel length is smallest for the hake target fishery with most vessels being just under 60 metres. Vessels targeting hoki are mainly between 60 and 70 metres and silver warehou between 55 and 70 metres.

The location of pale ghost shark catches for vessels reporting on TCEPR forms has changed little since 2000 (Figure C17). The highest catches come from the east coast South Island area, around the Veryan Bank and along the southern edge of the western Chatham Rise. Catches from the northern edge of the western Chatham Rise appear to have decreased since the 2004 fishing year. The eastern end of the Chatham Rise contributes less of the total pale ghost shark catch.

Given its low contribution to the total pale ghost shark catch in the region (less than 1%), fishing effort variables for midwater trawls have not been summarised.

### 7.2.2 Southland and Sub-Antarctic (SUBA)

The Southland and Sub-Antarctic region contributes much less pale ghost shark processed catch than the ECSI/CHAT region at 3259 t for the post-QMS period (Table C6, Figure C9b). There does not appear to be a distinct season, with pale ghost shark being caught in all months of the year but, as on the Chatham Rise, there does appear to be a slight decrease in some years in July–August when vessels targeting hoki move to hoki spawning grounds (Table C9a, Figures C18a, C19d).

Most pale ghost shark in the region is caught in statistical areas 602 and 603 (Auckland Islands) (Table C9b, Figure C18b). These have been the dominant statistical areas for the post-QMS period with 55% of the total catch. Statistical areas 027 and 028 (Snares Shelf) are the next most important, with 24% of the total for the same period. Reasonable amounts are also taken from area 610 (edge of the Pukaki Rise, 7%). Catches from are 618 (Campbell Rise) were moderate until 2006 but have since declined.

More than 99% of the catch is taken by bottom trawl (Table C9c, Figure C18c). 82% of the pale ghost shark catch is taken in the hoki target fishery (Table C9d, Figure C18d). The proportion taken in the hoki target fishery was higher at the beginning of the post-QMS period (more than 90% each year) but has been dropping since 2004. At this time, the ling target fishery (the next most important target fishery catching pale ghost shark) appeared to increase its take of pale ghost shark. The most likely cause of the reduced proportion of the total pale ghost shark catch being caught in the hoki fishery is the reduction in hoki targeting in the area. Overall pale ghost shark catches decreased in the region from 2004. Figure C20 shows that the number of tows for hoki in the region decreased since 2004. The number of tows for ling increased from 2005. Pale ghost shark is also caught in a wide variety of other target fisheries that account for 7% of the catch.

Unstandardised catch rates (kg per tow) of pale ghost shark are presented in Figure C20. Catch rates are variable in the hoki target fishery but are usually around 60–100 kg per tow. Catch rates in the ling target fishery are also variable but are generally higher than in the hoki fishery with most tows containing more than 100 kg of pale ghost shark.

Daily fishing duration for bottom tows targeting hoki is mainly between 12 and 19 hours (Figure C21). This has been consistent during the post-QMS period. Similar values are seen for bottom tows targeting ling.

Effort depth for bottom tows for vessels targeting hoki is slightly deeper in the Southland /SUBA region with most tows being at about 600 m, compared to 500 m for the ECSI/CHAT region (Figure C22). Tows targeting ling appeared to be mainly in 400–500 m until the 2005 fishing year when most tows increase to around 500–600 m. This is the same time at which both the number of tows for ling and the proportion of pale ghost shark caught in the ling target fishery increased.

Effort width for bottom tows targeting hoki is mainly 30–40 m (Figure C23). Ling effort widths are slightly greater with most tows being around 30–45 m. A narrow range of effort speeds is seen for the hoki target fishery with most tows being about 4–4.5 knots. Effort speed for the ling target fishery is slightly slower with most being about 4–4.25 knots. Most vessels targeting hoki are over 2 000 gross tonnes in weight. Vessels targeting ling are usually smaller with most being around 500–2 000 gross tonnes. Overall lengths are similar for vessels targeting each species with most being 60–70 metres long.

The location of pale ghost shark catches from the Southland/SUBA region as reported on TCEPR forms is shown in Figure C24. There has been no change in the location of effort through the study period but there is a noticeable decline in the amount being taken from the south Campbell Rise from the 2005 fishing year, most likely as a result of reduced hoki target fishing. Catches have been highest along the Snares Shelf and Auckland Islands throughout the post-QMS period.

Given its low contribution to the total pale ghost shark catch in the region (less than 1%), fishing effort variables for midwater trawls have not been summarised.

### 7.2.3 Other areas where pale ghost shark are caught in minor quantities

This study identified two other areas where pale ghost shark are caught but in negligible quantities: the east coast North Island, and the West Coast (of both the North and South Islands). For the post-QMS period, catches in these areas comprise just 28 t (0.2 %) and 108 t (0.9%) respectively (Table C6, Figure C9). Consequently, this analysis will not go into detail about these areas and each will be briefly summarised below.

Pale ghost shark from the east coast North Island is mainly caught on the lower east coast in statistical areas 013 (14 t, 50%), 014 (5 t, 18%), and 015 (3 t, 11%). It is caught mainly in target fisheries for hoki (10 t, 35%), orange roughy (8 t, 29%), and scampi (4 t, 14%). It is caught all year round but about half is taken in November and December. 26 t (93%) is taken by bottom trawl).

Most pale ghost shark from the west coast region is caught in the winter spawning fisheries for hoki and hake off the west coast of the South Island: 49 t (45%) is from the hoki target fishery and 45 t (42%) from the hake target fishery. Bottom trawl took 104 t (96%) of the catch, 58 t (54%) was taken from statistical area 034 and 39 t (36%) from statistical area 035, and 101 t (94%) was caught during the winter months from May to September.

## 7.3 Pre-QMS era catches (1990–1999 fishing years)

As discussed in Section 1, catch volumes of pale ghost shark before the 2000 fishing year are unknown, as dark and pale ghost shark were usually both coded as ‘GSH’, a code that is now used exclusively for dark ghost shark. There was also thought to be a great deal of discarding before 2000.

One of the objectives of this study was to attempt to create a model to produce a catch history for pale ghost shark using observer data from the hoki target fishery in which the majority of pale ghost shark is caught. Three models were developed and are discussed here. Each uses post-QMS era data to back calculate pre-QMS era catches. Pre-QMS observer data could not be used as it appears that, as on commercial catch returns, little of the observed catch of ghost shark was differentiated (Table 7). Before its inclusion in the QMS most of the observed ghost shark catch from the hoki target fishery is coded as ‘GSH’ with little coded as ‘GSP’. Following pale ghost shark’s inclusion in the QMS we see the opposite, with more ghost shark coded as ‘GSP’ than ‘GSH’. The relationship between pale ghost shark catch and hoki catch for various regions is shown in Figure C25; there is little relationship between the two. The same figure also shows that there is no clear relationship between the proportion of tows containing pale ghost shark (that were targeting hoki) at various depths for the same regions.

**Table 7: Sum of observed catches of ghost shark for each code from the hoki target fishery for fishing years 1990–2010.**

| Year | Observed 'GSP' catch | Observed 'GSH' catch |
|---|---|---|
| 1990 | 3 | 42 |
| 1991 | 45 | 57 |
| 1992 | 33 | 80 |
| 1993 | 5 | 39 |
| 1994 | 16 | 57 |
| 1995 | 4 | 31 |
| 1996 | 0 | 39 |
| 1997 | 0 | 16 |
| 1998 | 0 | 118 |
| 1999 | 79 | 59 |
| 2000 | 125 | 28 |
| 2001 | 142 | 29 |
| 2002 | 160 | 17 |
| 2003 | 149 | 19 |
| 2004 | 100 | 13 |
| 2005 | 86 | 15 |
| 2006 | 79 | 9 |
| 2007 | 61 | 8 |
| 2008 | 121 | 9 |
| 2009 | 80 | 12 |
| 2010 | 99 | 12 |

### 7.3.1 Model 1: Predicting pale ghost shark catch from observed hoki catch

The first model attempted to recreate pale ghost shark catches using a general linear model approach. Pale ghost shark catch was predicted using hoki catch, latitude, longitude, bottom depth, net depth, and month as predictor variables.

The model was not satisfactory. When applied to both the Observer Programme data and the commercial catch effort data for hoki tows after the 2000 fishing year, no relationship was found between the observed and predicted pale ghost shark catch (Figure C26).

### 7.3.2 Model 2: Predicting pale ghost shark catch as a proportion of observed hoki catch

The second model attempted to recreate the pale ghost shark catch by estimating it as a *proportion* of the hoki catch, using latitude, longitude, bottom depth, net depth, and month as predictor variables.

The model was not satisfactory. When applied to both the Observer Programme data and the commercial catch effort data for hoki tows after the 2000 fishing year, no relationship was found between the observed and predicted pale ghost shark catch (Figure C27).

### 7.3.3 Model 3: Predicting pale ghost shark catch as a proportion of observed total ghost shark catch (pale and dark)

The third model attempted to recreate the pale ghost shark catch by estimating it as a *proportion* of the total ghost shark catch (pale and dark ghost shark), using latitude, longitude, bottom depth, net depth, and month as predictor variables.

A relationship was found when the model was applied to both observer data and the commercial catch-effort data after the 2000 fishing year and is presented in Figure C28. The observed versus predicted catch for individual tows, monthly totals by year, by year, and monthly totals for the entire time period are presented in Figure C29 and all show a positive relationship.

Unfortunately though, this model cannot be used to back calculate pale ghost shark catches from the pre-QMS era. This is because a significant proportion of both dark and pale ghost shark catches are believed to have been discarded during this time (Horn 1997). If applied to pre-QMS catches reported generically as ghost shark we would only get an amount of pale ghost shark that is a proportion of reported values which are lower than what would actually have been caught.

## 7.4 Summary

A summary of the main fishery areas is given in Table 8.

Catches of pale ghost shark for fishing years 1990–1999 are unreliable due to both dark and pale ghost shark sharing the same species code, and to discarding. No satisfactory model could be developed to back-calculate catches prior to its inclusion in the QMS. For this reason this study has focussed on catches from the 2000 fishing year onwards when reported catches are believed to be accurate.

Pale ghost shark is never targeted and is rarely recorded in the top five species on TCEPR forms. As most vessels catching pale ghost shark report on TCEPR forms it was necessary to use daily processed catch data for this analysis. There was a close match between daily processed catch and the reported QMR landings for the post-QMS period for the two most important QMAs (GSP 1 and 5) which together account for more than 98% of total landings.

Catches have been fairly steady since 2000 for the ECSI/CHAT region which accounts for most of the catch. The next most important region is Southland/Sub-Antarctic where catches have decreased somewhat since the mid-2000s, most likely due to the reduction in the hoki target fishing. Although caught in a wide variety of target fisheries, most of the pale ghost shark catch is taken in the hoki target fishery in both regions. The other two regions identified in this analysis (West Coast and East Coast North Island) contribute only a minor proportion of the catch.

More than 99% of the catch in this analysis was taken by bottom trawl. Pale ghost shark are also caught by bottom longline but only in minor quantities and the necessary use of daily processed catch data prevented the inclusion of non-trawl data and from trawlers not reporting on TCEPR forms.

Fishing effort variables and vessel characteristics are similar between the two main regions where pale ghost shark are caught, probably because the same vessels are active in both areas at various times of the year

On the basis of this characterisation, standardised CPUE analyses will be carried out for vessels targeting hoki for the ECSI and Chatham Rise, and the Sub-Antarctic regions. This is discussed in the following section.

**Table 8: Summary of features of the main pale ghost shark fisheries since the 2000 fishing year. Area definitions are given in Figure 2, species codes in Table C10.**

| Area | ECSI/CHAT | Southland/SUBA |
|---|---|---|
| FMA | 3 & 4 | 5 & 6 |
| **General characteristics** | | |
| Key fishery areas | ECSI, Veryan Bank | Auckland Islands, Snares Shelf |
| Key statistical areas | 020, 023 | 602, 603 |
| Secondary statistical areas | 407, 408 | 027, 028 |
| Season | Year round, slight decline June–September | Year round, slight decline July–September |
| Gear type | BT | BT |
| **Target species** | | |
| Key target species | HOK | HOK |
| Secondary target species | HAK, SWA | LIN |
| Target GSP as a % of total catch | 0% | 0% |
| Target GSP catch trends | NA | NA |
| Target GSP catch rate trends | NA | NA |

## 8. CPUE ANALYSES

**Table 9: Summary of CPUE analyses for ECSI fishery (see Appendix D1 for details, Table C10 for species codes).**

| Area | Statistical areas used | Major target species | Months |
|---|---|---|---|
| ECSI/CHAT | 020, 021, 022, 023, 026,401, 402, 403, 407, 408, 409,410 | HOK | Oct–May |
| SUBA | 027, 028, 504, 602,603,610,618 | HOK | Oct–May |

All tables and figures relating to CPUE analyses of the pale ghost shark are contained in Appendix D (Tables D1–6, Figures D1–14). Species codes are in Table C10.

The recent standardised CPUE analyses for silver warehou (Parker & Fu 2011) arrow squid, (Hurst et al. 2010) and ribaldo (MacGibbon & Hurst 2011) considered only TCEPR (tow by tow) data because CELR data were minor. Using tow by tow data allows for the trend in catch rates to be modelled using smaller spatial and temporal scales, and also enables additional factors influencing CPUE to be included (such as tow distance or bottom depth). As pale ghost shark are rarely recorded in the top five species on TCEPR forms, this study used daily processed catch. This means that some variables normally available for CPUE tow-by-tow analyses can only be used by summing over the day or taking a daily mean, as described in Section 6.2. This is the same approach as was used for the lookdown dory CPUE analyses by MacGibbon et al. (Submitted).

The ECSI and Chatham Rise region was considered for standardised CPUE analyses as there were reasonable amounts of pale ghost shark caught (usually several hundred tonnes per annum, and sometimes more than 1000 t) for the post-QMS period (2000–2010 fishing years). The Sub-Antarctic region was also selected for having consistent catches each year although they are lower in comparison to the ECSI and Chatham Rise but are usually around 200 t per year. Catches from the ECNI and West Coast are too low to consider standardised CPUE analyses for pale ghost shark.

One model was run for each of the two regions. Other divisions of the data set resulted in datasets with very small amounts of pale ghost shark catch. The models both use bottom trawl pale ghost shark from hoki target tows in the statistical areas and months shown in Table 9.

Estimates of relative year effects in each CPUE model were obtained from a stepwise multiple regression method in which the data were modelled using a lognormal generalised linear model following Dunn (2002). A forward stepwise multiple–regression fitting algorithm (Chambers & Hastie 1991) implemented in the R statistical programming language (R Development Core Team 2011) was used to fit all models. The algorithm generates a final regression model iteratively and used the *fishing year* term as the initial or base model in all cases. The reduction in residual deviance relative to the null deviance, $R^2$, is calculated for each single term added to the base model. The term that results in the greatest reduction in residual deviance is added to the base model if this would result in an improvement in the residual deviance of more than 1%. The algorithm then repeats this process, updating the model, until no new terms can be added. A stopping rule of 1% change in residual deviance was used as this results in a relatively parsimonious model with moderate explanatory power (Parker & Fu 2011). Alternative stopping rules or error structures were not investigated. Note that while $R^2$ values are reported they do not necessarily assist in helping choose between the various models.

Variables offered to both the ECSI and Chatham Rise and the Sub-Antarctic models were fishing year, vessel key, statistical area, and month. Also offered to the model as third order polynomials were effort width, effort height, effort depth, distance towed, latitude, longitude, and fishing duration. The variable *fishing year* was forced to be in the model as the relative year effects calculated from the regression coefficients represent the change in CPUE over time. Year indices were standardised to the mean and were presented in canonical form (Francis 1999).

Vessel effects were incorporated into the CPUE standardisations to allow for possible differences in fishing power between vessels. A set of core vessels was defined based on vessels that had at least four consecutive years in the fisheries examined and collectively reported about 90% of the catch.

The dependent variable was the log–transformed daily processed catch. Model fits were investigated using standard regression diagnostic plots. For each model, a plot of residuals against fitted values and a plot of residuals against quantiles of the standard normal distribution were produced to check for departures from the regression assumptions of homoscedasticity and normality of errors in log-space (i.e., log-normal errors).

## 8.1 ECSI and Chatham Rise Standardised CPUE Model

The number of records, proportion of zeros, catch, effort and unstandardised CPUE for the ECSI and Chatham Rise region model are listed in Table D1. Standardised model results are shown in Table D2–D3 and Figures D1–D7.

A total of 39 unique vessels (range 10–26 vessels each year) using bottom tows caught an estimated 3573 t of pale ghost shark since 2000, from 9358 processing days (Table D1). The percentage of zero days was low, ranging between 5 and 26%. Thirteen core vessels (range 6–13 per year) caught an estimated 3179 t of pale ghost shark, representing 89% of the total catch. Estimated pale ghost shark catches for core vessels ranged from 49–600 t annually, totalling 7957 processing days with an average of 723 days per year (Table D1). A number of the core vessels have been present throughout the time period examined and, apart from a few vessels catching smaller amounts of pale ghost shark, the catches between vessels are fairly even (Figure D1).

The variable ‘fishing year’ is forced into the model as explained in Section 8 above and accounted for 16.3% of the residual deviance (Table D2). Two other variables were retained: ‘vessel’, bringing the residual deviance explained to 21.8% and distance towed, bringing the total for the model to 24.51%.

CPUE series from the lognormal models are presented in Table D3 and Figure D2. The indices show a sharp increase from 2000 to 2002, possibly as vessels began to comply with the requirement to report pale ghost shark with its then new status as a QMS species. Indices then decline slightly to 2005, but are generally flat for most of the time period (Figure D2). The unstandardised geometric and arithmetic CPUE indices follow each other very closely, and are also close to the standardised index. A comparison of the CPUE indices with abundance indices from the Chatham Rise trawl surveys (standardised to the mean) is made in Figure D3. The indices do not track each other well.

The effects of the selected variables on the expected catch rates of pale ghost shark for the model are shown in Figure D4. Catch rates are relatively flat, but slightly increasing overall, with distance towed. There is a wide range of expected catch rates between vessels. Processing days when twin trawls were used were not included in the data set, so the higher catch rates of some vessels over others is not explained by this. Figures D5 shows that vessel had a slightly positive influence in 2000 but this decreased steadily to 2007 after which influence becomes slightly positive again for the rest of the period examined. Distance towed has a slightly positive influence through 2000 to 2007 after which it drops downs to being slightly negative (Figure D6).

The diagnostics plots for the model are satisfactory (Figure D7).

## 8.2 Sub-Antarctic Standardised CPUE Model 1

The number of records, proportion of zeros, catch, effort and unstandardised CPUE for the Sub-Antarctic model are listed in Table D4. Standardised model results are shown in Tables D5–D6 and Figures D8–D15.

A total of 34 unique vessels (range 4–22 vessels each year) using bottom tows caught an estimated 1302 t of pale ghost shark since 2000, from 3448 processing days (Table D4). The percentage of zero days was generally low ranging between 7 and 31%. Twelve core vessels (range 4–12 per year) caught an estimated 1160 t of pale ghost shark, representing 90% of the total catch. Estimated pale ghost shark catches for core vessels ranged from 12–263 t annually, totalling 2997 processing days with an average of 272 days per year. A number of the core vessels have been present throughout the time period examined and apart from a few vessels catching larger amounts of pale ghost shark, the catches between vessels are fairly even (Figure D8).

The variable ‘fishing year’ is forced into the model as explained in Section 8 above and accounted for 17.58% of the residual deviance (Table D5). Three other variables were retained: ‘vessel’, bringing the residual deviance explained to 22.72%, fishing duration, bringing the total to 26.06%, and month, bringing the total residual deviance explained for the model to 29.08%

CPUE series from the lognormal models are presented in Table D6 and Figure D9. As in the ECSI and Chatham Rise region, the indices show a sharp increase at the start of the period from 2000 to 2001, possibly as vessels began to comply with the requirement to report pale ghost shark with its then new status as a QMS species. The indices then fluctuate through the time period examined. The unstandardised geometric and arithmetic CPUE indices follow each other relatively closely, and are also close to the standardised index. A comparison of the CPUE indices with abundance indices from the Sub-Antarctic trawl surveys (standardised to the mean) is made in Figure D10. The indices do not track each other well.

The effects of the selected variables on the expected catch rates of pale ghost shark for the model are shown in Figure D11. Catch rates appear to increase slightly from November to March then decrease in April and May. Catch rates increase with increasing fishing duration. Two vessels in particular appear to catch more pale ghost shark than the other ten vessels in the core data set. Processing days when twin trawls were used were not included in the data set so the higher catch rates of these two vessels over others is not explained by this. Figure D12 shows that vessel had a very positive influence in 2004 but this decreased for the rest of the period examined. Fishing duration has a large negative influence in 2005?? and a large positive influence in 2007 but generally has little influence (Figure D13). Fishing month has a slightly positive influence for the first few years followed by a slightly negative influence for the rest of the time period examined (Figure D14).

The diagnostics plots for the model are satisfactory (Figure D15).

### 8.3 CPUE summary

Standardised CPUE of pale ghost shark was attempted for the ECSI and Chatham Rise region and the Sub-Antarctic region. The pale ghost shark catches from fisheries in both regions are mainly bycatch of targeting hoki, with ling also being relatively important in the Sub-Antarctic.

Fishing year was forced into each region's CPUE model, and explained more of the null model deviance than any other retained variable. Vessel and distance towed were the next two variables to enter both models. Month did not enter the model for the ECSI and Chatham Rise region, but did for the Sub-Antarctic.

The ECSI and Chatham Rise region has a mainly flat CPUE index for most of the time period whereas the Sub-Antarctic model fluctuated more. A large proportion of the underlying variability was not explained. While this is not unusual for CPUE analyses (e.g., Vignaux 1994, Punt et al. 2000), it may be a reflection of a lack of explanatory information available to the models to explain catch rates. Also, all CPUE analyses were carried on hoki target vessels, which operate in a very narrow depth range compared with the known depth range of pale ghost shark.

## 9. SUMMARY AND RECOMMENDATIONS

### 9.1 Commercial and research data

Known commercial harvesting of pale ghost shark has been occurring since the late 1970s. Catches are at low levels compared with many other middle depth species such as hoki, hake, ling, and silver warehou, the four target species producing most of the pale ghost shark bycatch. Target fishing for pale ghost shark does not occur. No research surveys have been optimised to survey pale ghost shark though they are commonly caught on Chatham Rise and Sub-Antarctic middle depth trawl surveys carried out by R.V. *Tangaroa*. These surveys cover most of the species' distribution and probably provide a reasonable index of abundance. Distinct cohorts are difficult to identify in length frequency plots from both trawl surveys and observer data. No satisfactory ageing methods have been developed for pale ghost shark. Almost no data has been collected on gonad stages. There is no biological data available to indicate stock boundaries. The bathymetry of New Zealand's EEZ probably creates natural boundaries that roughly equate to the current management areas, which are probably sufficient.

The establishment of an ageing protocol, and the collection of more length frequency and other biological data could help to better define stock divisions.

### 9.2 Status of the stocks

The status of the stocks is not known. Biomass indices from Chatham Rise and Sub-Antarctic middle-depth surveys carried out since 1991 both fluctuate, but do not show any evidence of a systematic decline. The CPUE model for the ECSI and Chatham Rise region shows a generally flat trend. The Sub-Antarctic CPUE model fluctuates widely and bears little relation to the trawl survey index. The CPUE indices also show no evidence of a systematic decline in either area. There is no ageing protocol for pale ghost shark and length frequencies are difficult to interpret, so it is not possible to monitor year class strength.

Consequently, it is not known if current TACCs and recent catches are sustainable or whether they are at levels which will allow the stocks to move towards a size that will support the maximum sustainable yield. There are insufficient data with which to develop stock assessment models.

## 9.3 Observer Programme sampling

Pale ghost shark coverage by observers is reasonable in the areas where they are frequently caught. However the data mainly consists of length frequencies. More biological data, such as gonad stages, are needed to help define spawning areas. The collection of suitable body parts for ageing (if these can be identified) could also help with this.

## 9.4 Future data needs and research requirements

Recognising that CPUE and trawl surveys will probably not provide a reliable and validated relative abundance indicator for pale ghost shark in isolation, and with the goal of developing a quantitative stock assessment in the future, the data collection needs for pale ghost shark are as follows:

1. Expansion of trawl surveys to cover depth and geographical ranges of pale ghost shark to provide more reliable biomass estimates. This has already occurred to some extent since 2010 on the Chatham Rise trawl survey when the survey area was extended down to 1300 m. An alternative is to assume a constant proportion of biomass in the unsampled depth range.(Note: the main area of uncertainty for GSP biomass on the Chatham Rise is probably the south-east Rise where there is a large area not covered by the survey that is of depths suitable for GSP.)
2. The establishment and validation of an ageing protocol, followed by optimised length and age sampling to develop catch-at-age history for key fishing areas. This would enhance knowledge of recruitment and age structure of the fishery. More gonad sampling is required from all areas with sampling spread throughout the year to indicate if there are seasonal changes. More information on pale ghost shark biology may help to better determine stock structure.
3. A closer match between estimated catch and landed catch. This may improve as more trawl vessels switch to using TCER forms that record tow-by-tow information for the top eight species. Also, with the increased observer coverage proposed under the Ministry for Primary Industries 10 year Research Plan for Deepwater Fisheries, more accurate catch recording of minor species such as pale ghost shark will be possible.

## 10. ACKNOWLEDGMENTS

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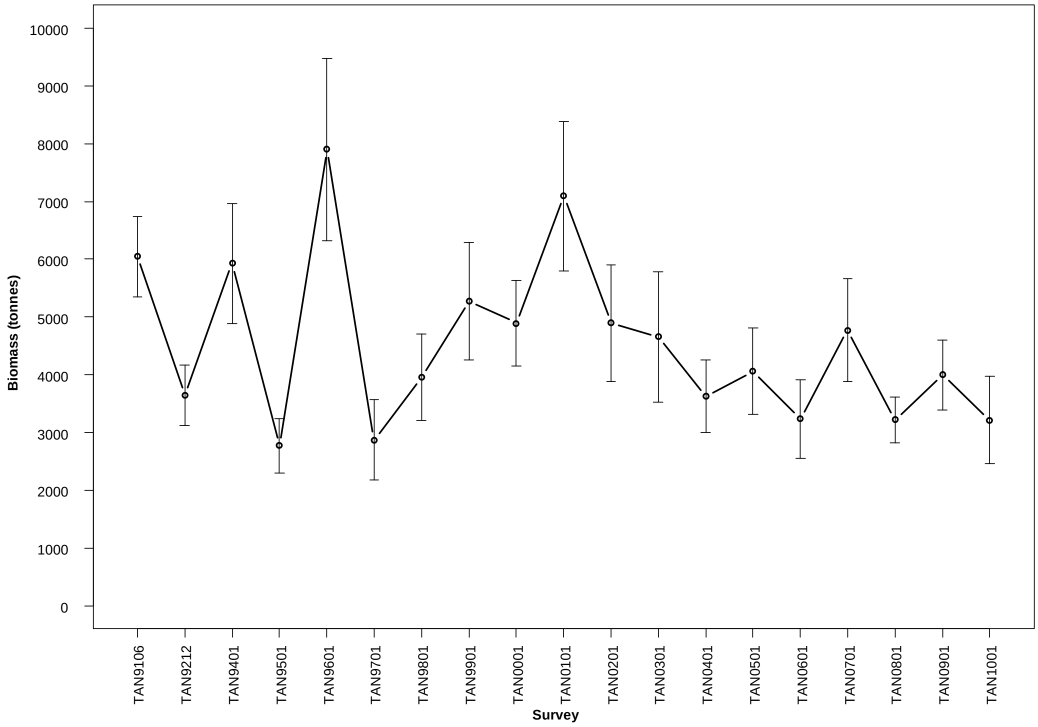
## APPENDIX A: TRAWL SURVEY SUMMARIES



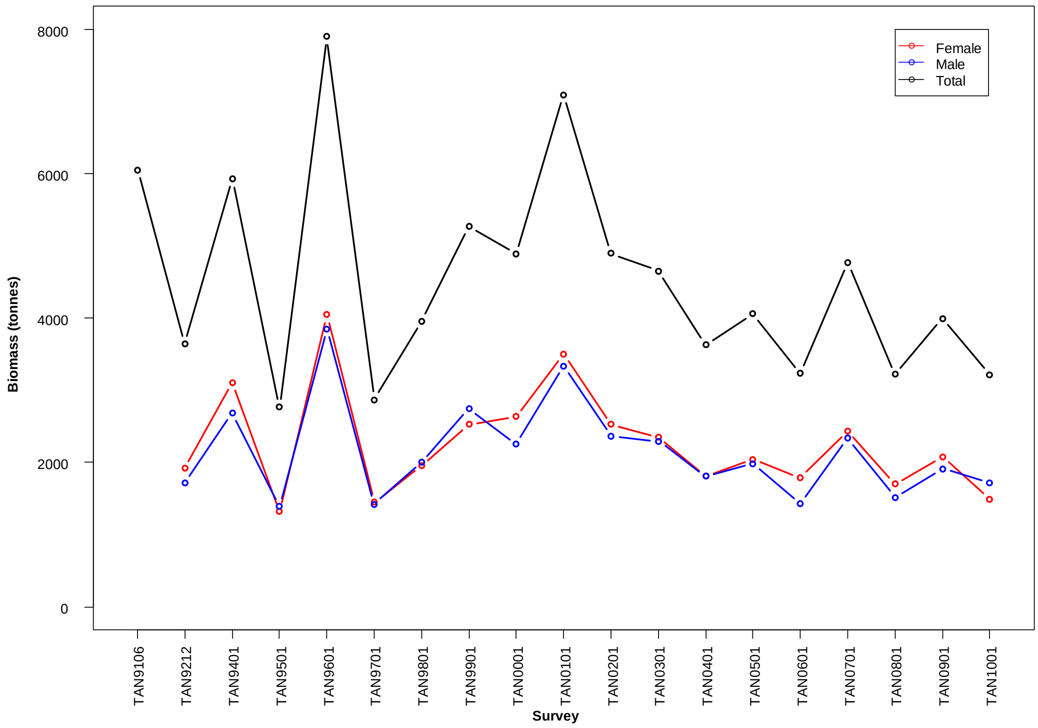
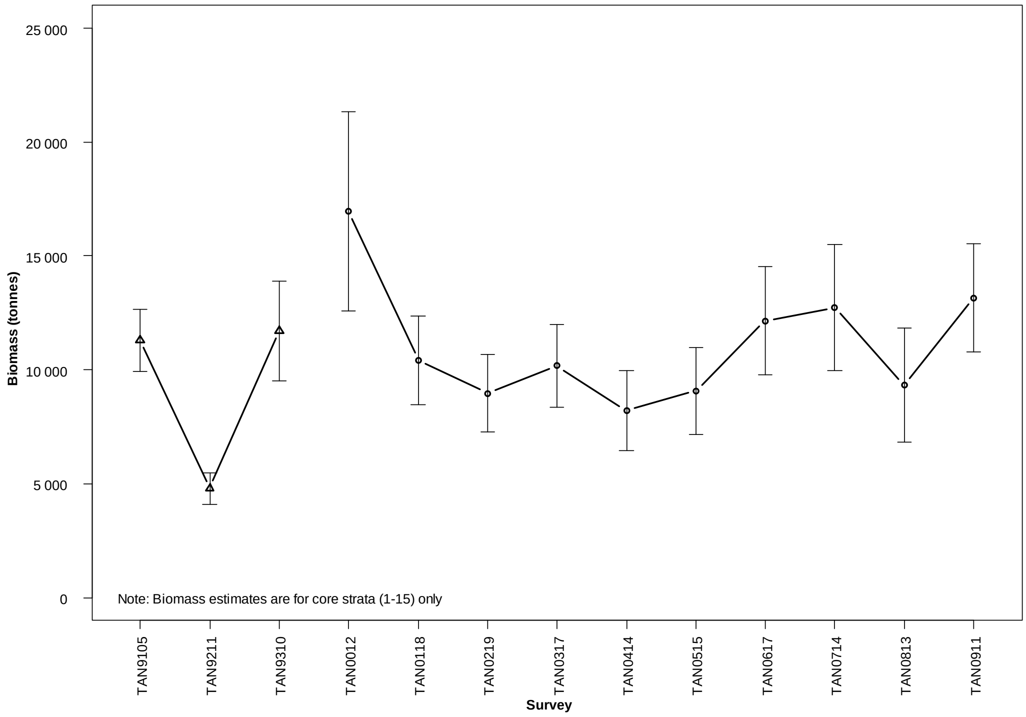




**Figure A1: Doorspread biomass estimates of pale ghost shark, for all fish (above, error bars are plus or minus two standard deviations) and by sex (below), from the Chatham Rise, from *Tangaroa* surveys from 1991 to 2010. NB: Biomass estimates by sex for TAN9106 were not available. Estimates are for the core 200–800 m strata.**



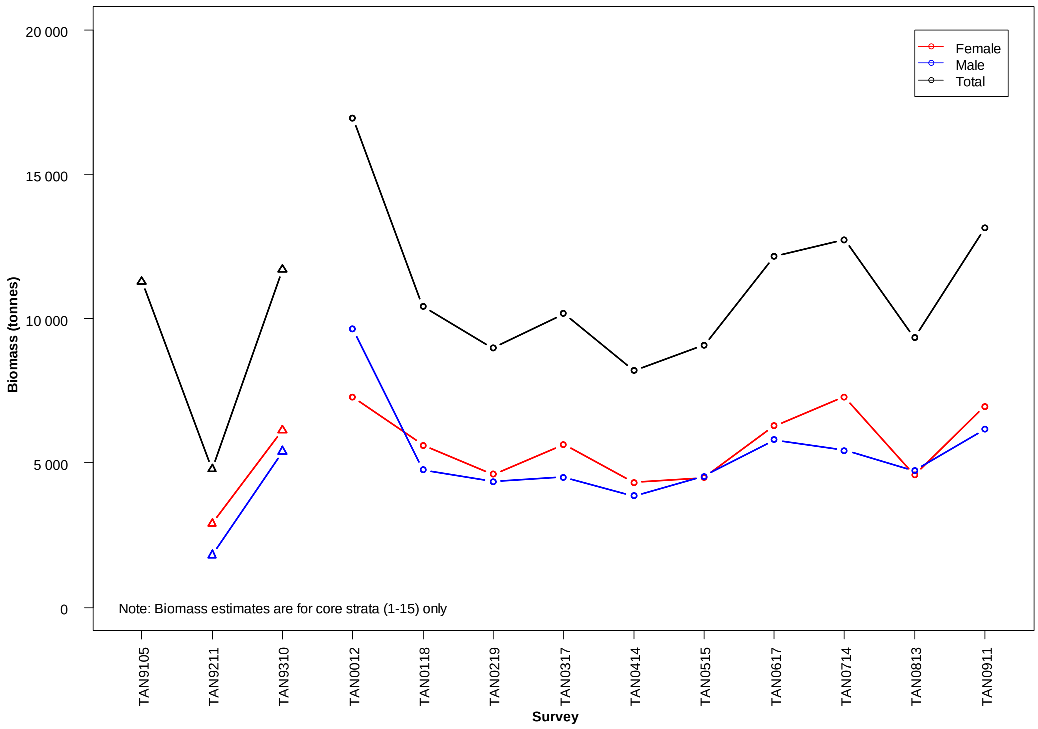




**Figure A2: Doorspread biomass estimates of pale ghost shark, for all fish (above, error bars are plus or minus two standard deviations) and by sex (below), for 1991–1993 and 2000–2009 from surveys of Sub-Antarctic by *Tangaroa*. Note: biomass by sex was not available for TAN9105.**

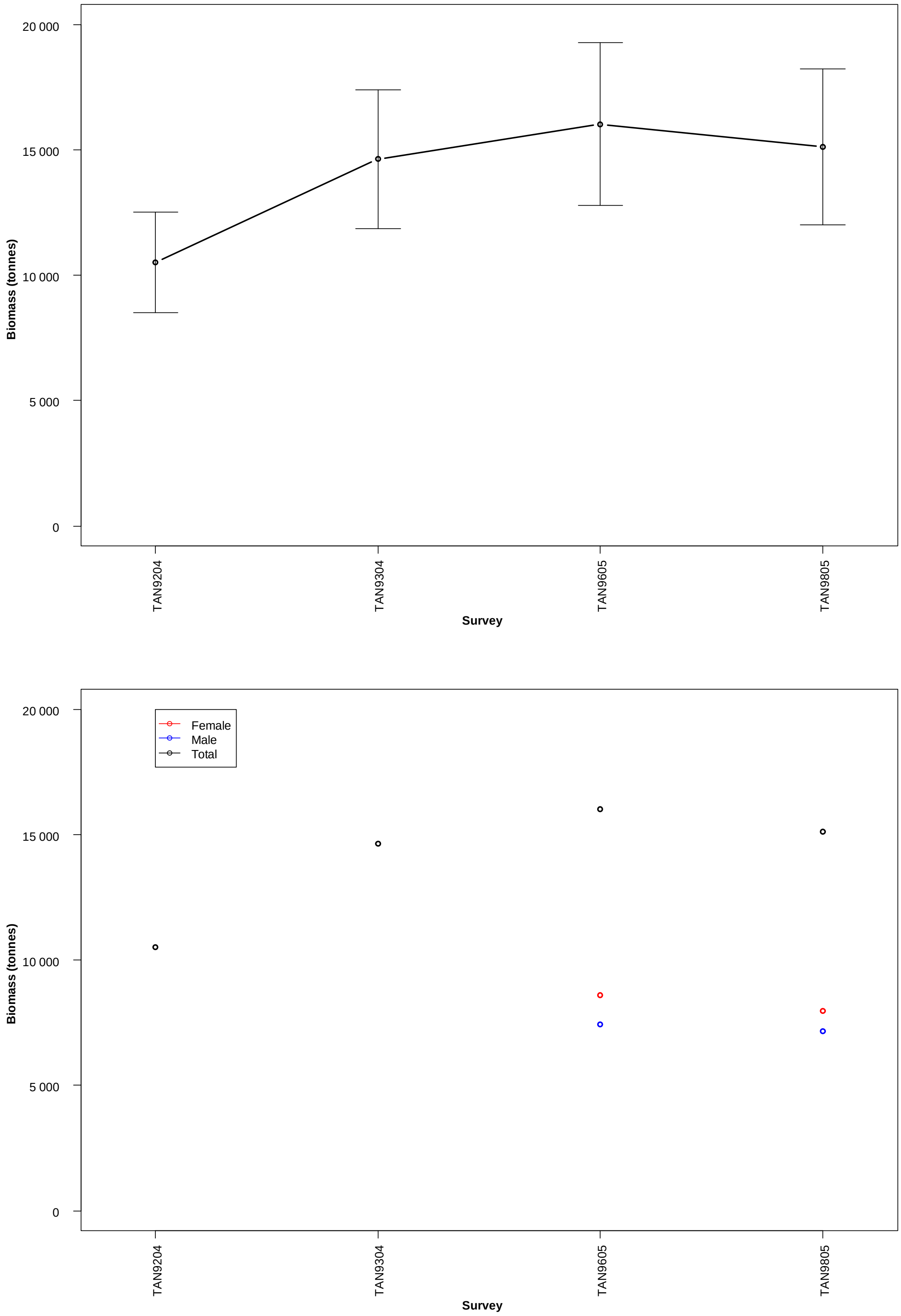



**Figure A3: Doorspread biomass estimates (1992–93, 1996 and 1998) for all fish (above) and by sex (below), from autumn surveys of Sub-Antarctic by *Tangaroa*. Error bars are plus or minus two standard deviations. Data by sex was not available for TAN9204 and TAN9304.**

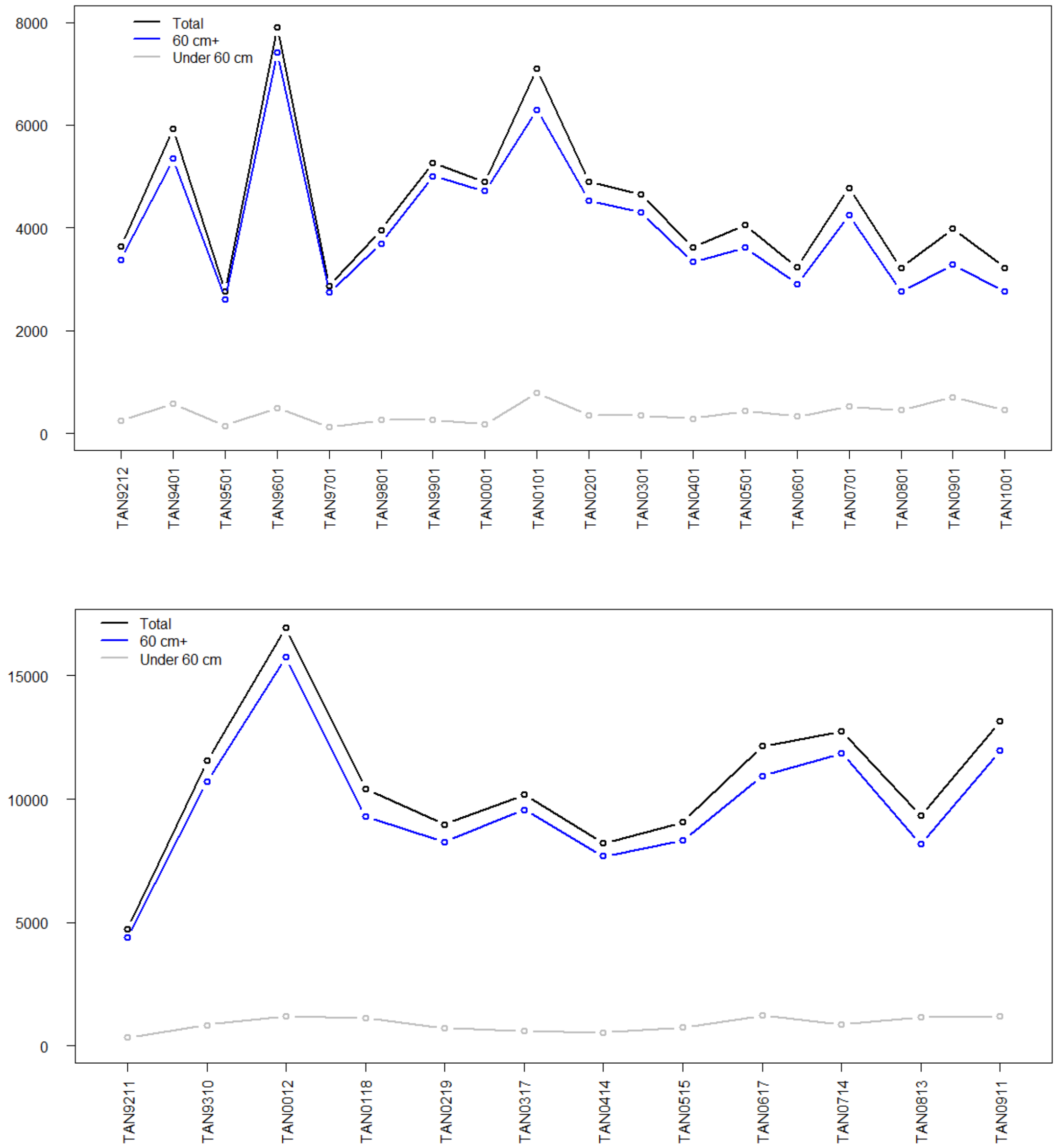



**Figure A4: Total biomass, biomass of 60 cm or longer, and under 60 cm pale ghost shark for the Chatham Rise time series (top plot) and Sub-Antarctic series (bottom plot).**

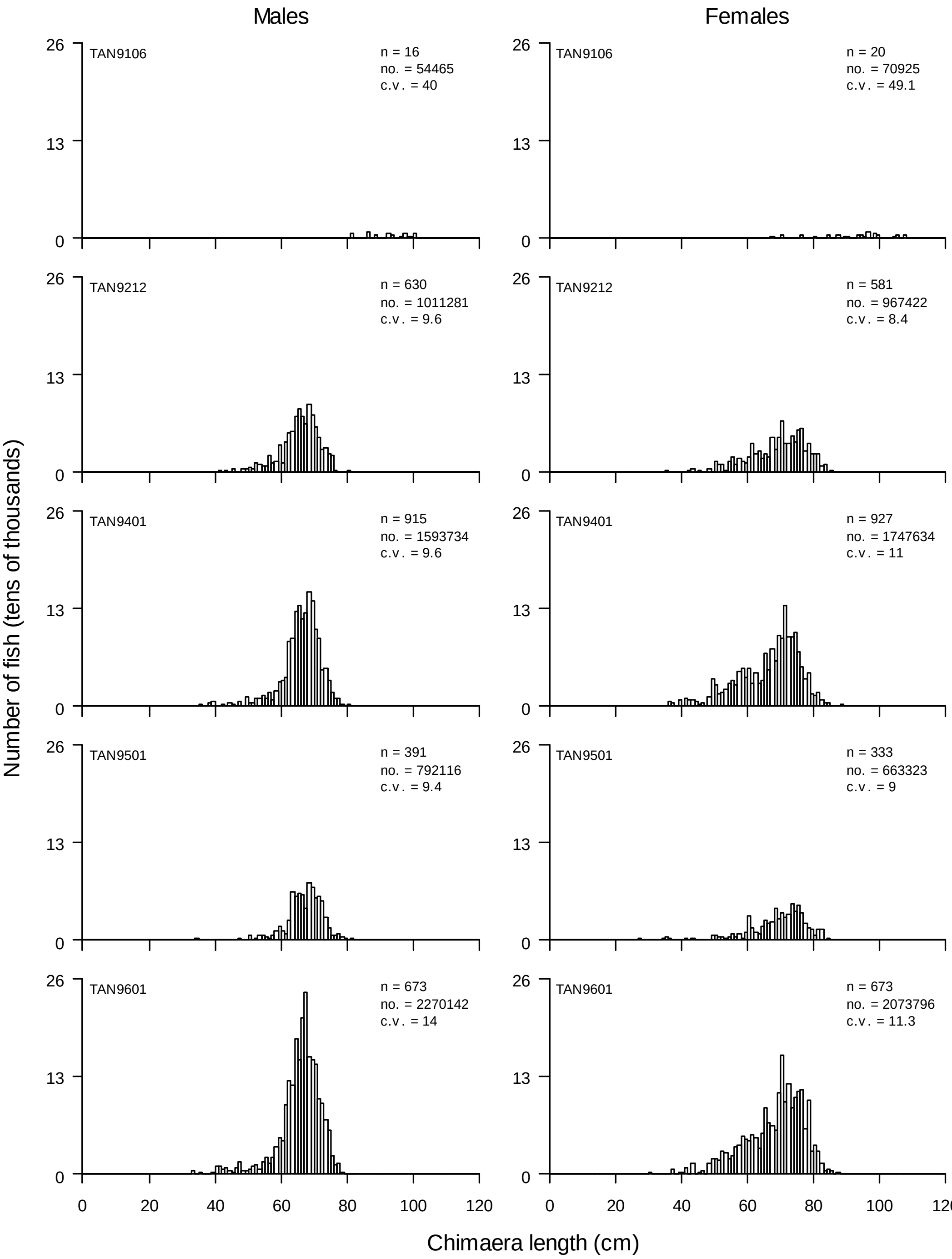



**Figure A5: Scaled population length frequencies by sex of pale ghost shark from the Chatham Rise from *Tangaroa* surveys from 1991 to 1996. NB: total length was measured on fish in TAN9106. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

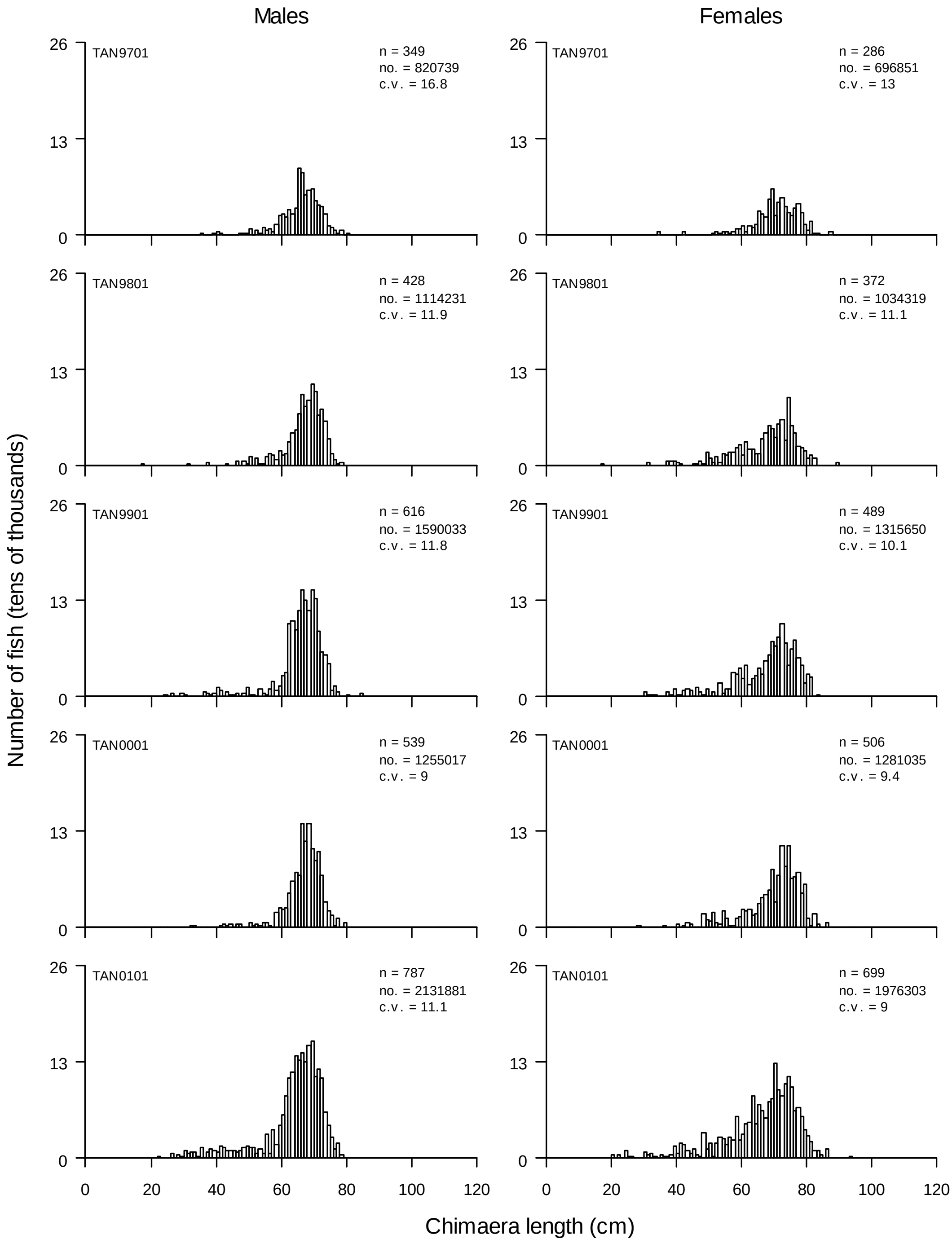



**Figure A5 continued: Scaled population length frequencies by sex of pale ghost shark from the Chatham Rise from *Tangaroa* surveys from 1997 to 2001. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

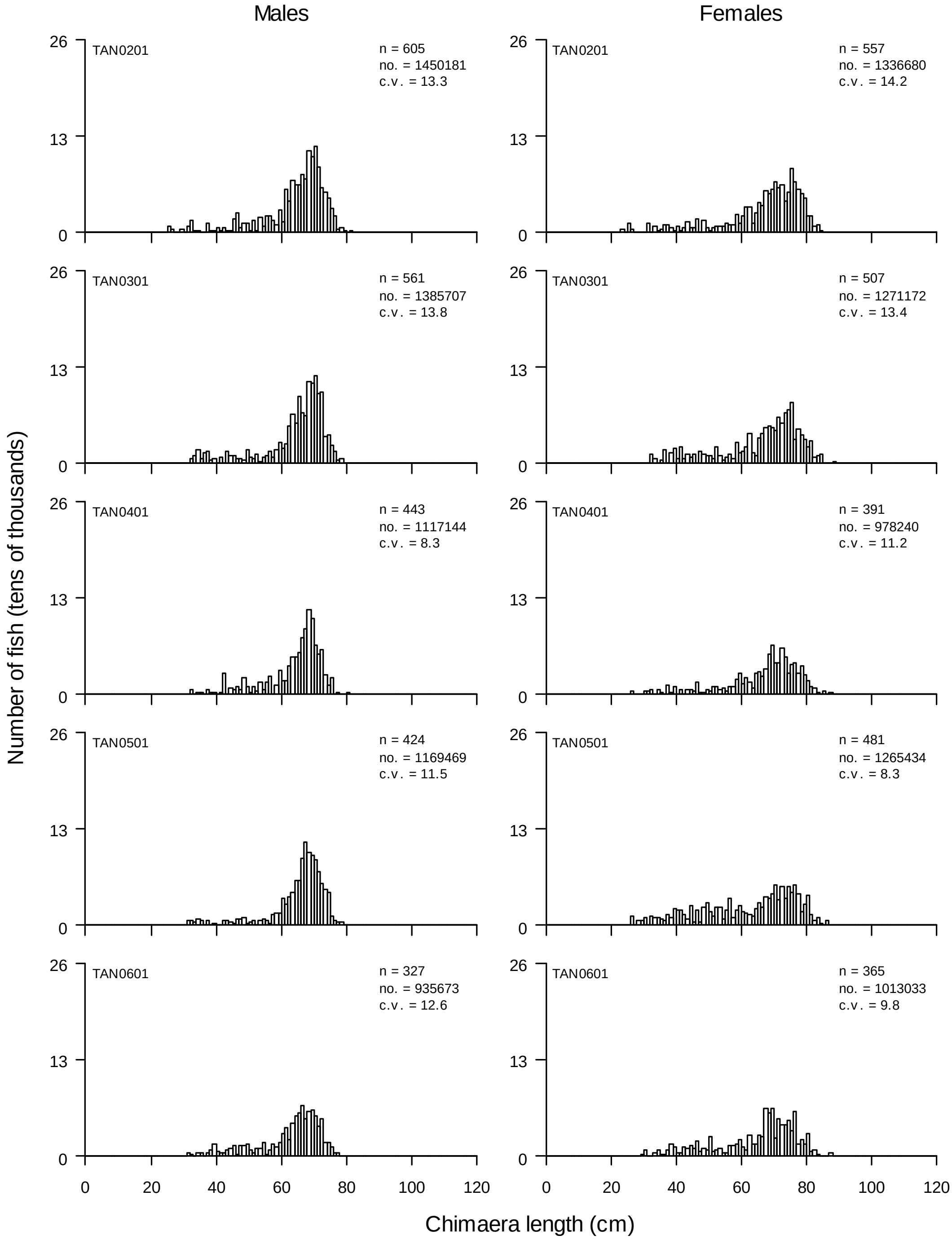



**Figure A5 continued: Scaled population length frequencies by sex of pale ghost shark from the Chatham Rise from *Tangaroa* surveys from 2002 to 2006. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

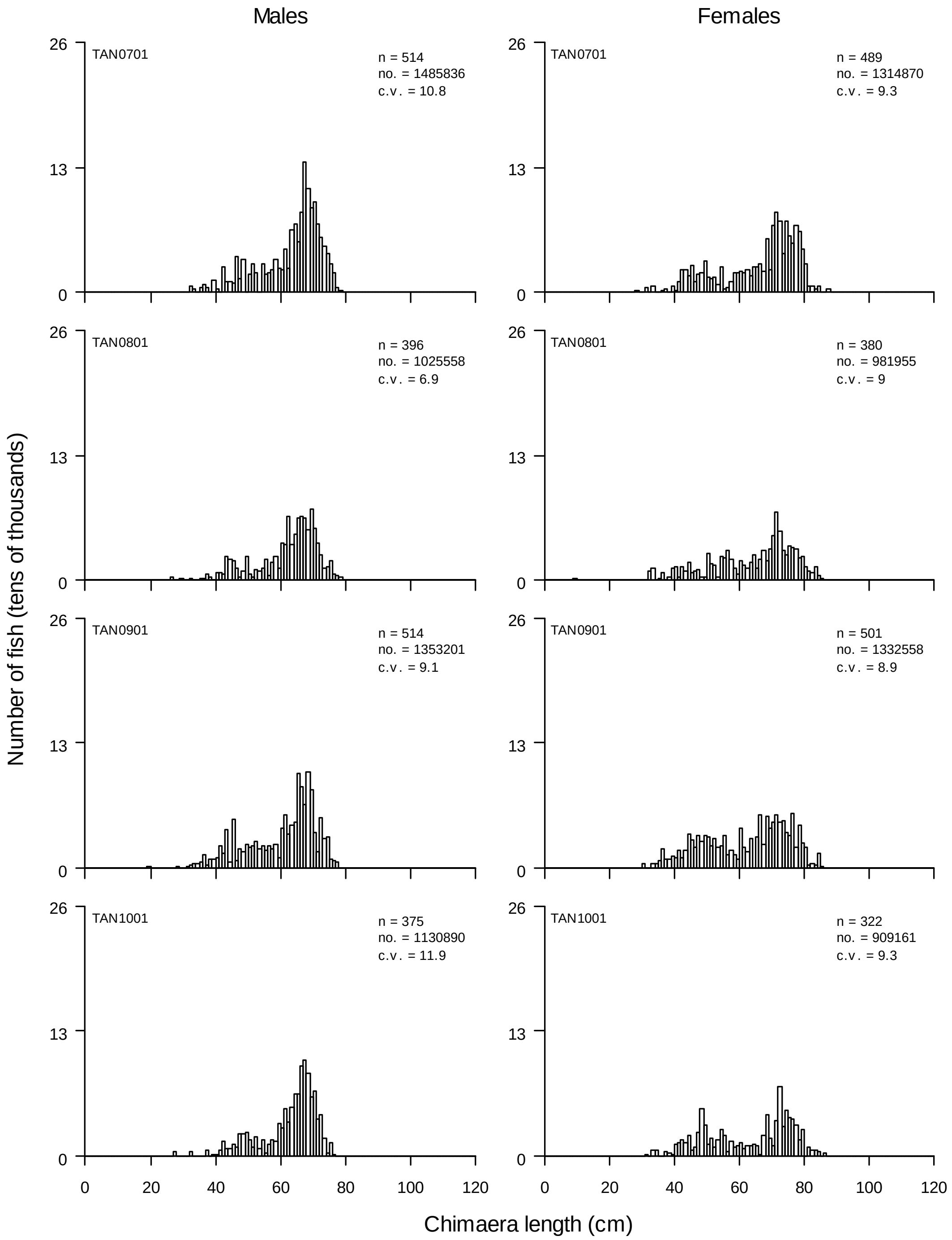



**Figure A5 continued: Scaled population length frequencies by sex of pale ghost shark from the Chatham Rise from *Tangaroa* surveys from 2007 to 2010 (200–800 m core strata only). n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

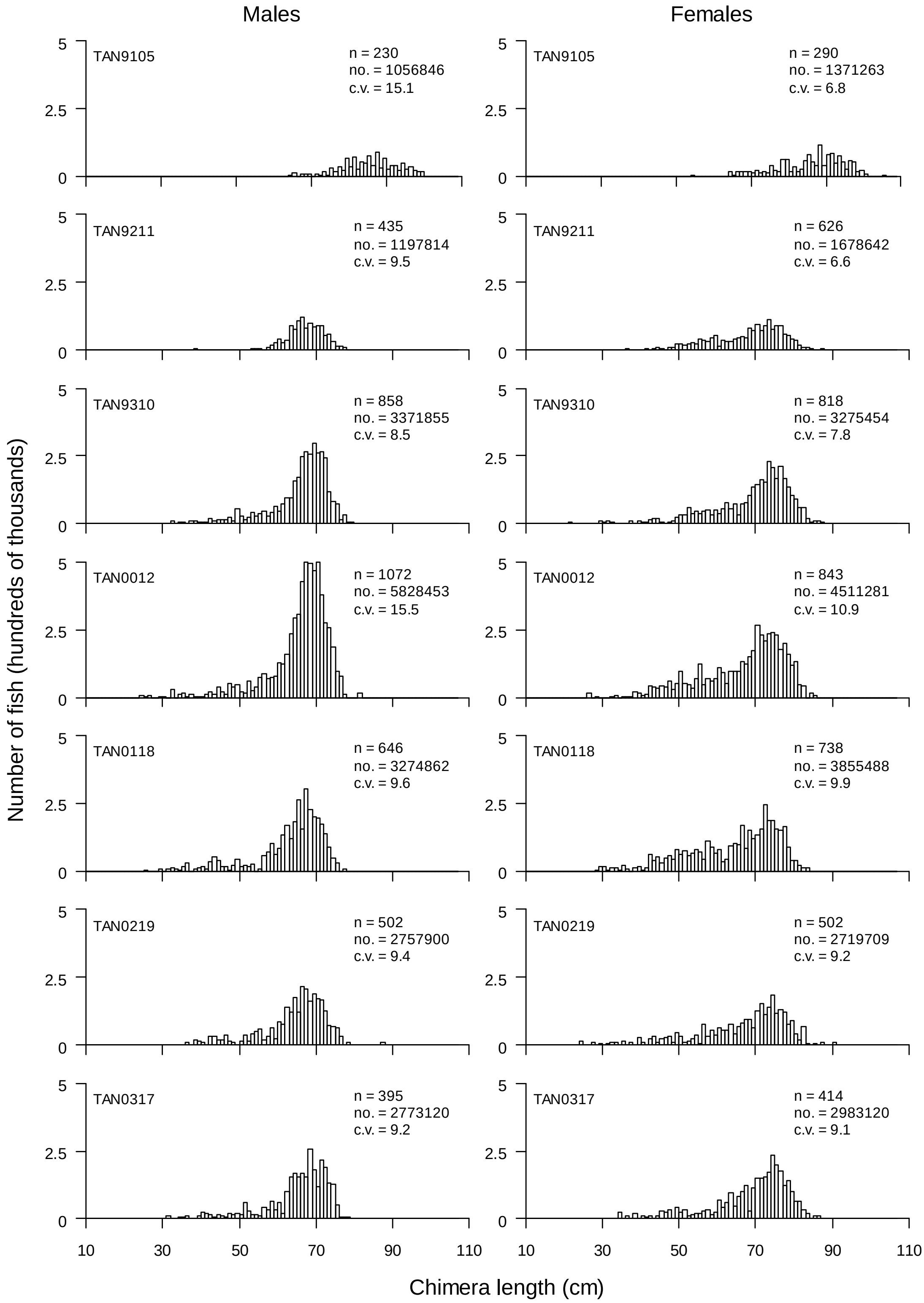



**Figure A6: Scaled population length frequencies by sex of pale ghost shark from Sub-Antarctic (summer series) from *Tangaroa* surveys, 1991–2003. NB: total length was measured for all fish on TAN9105. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

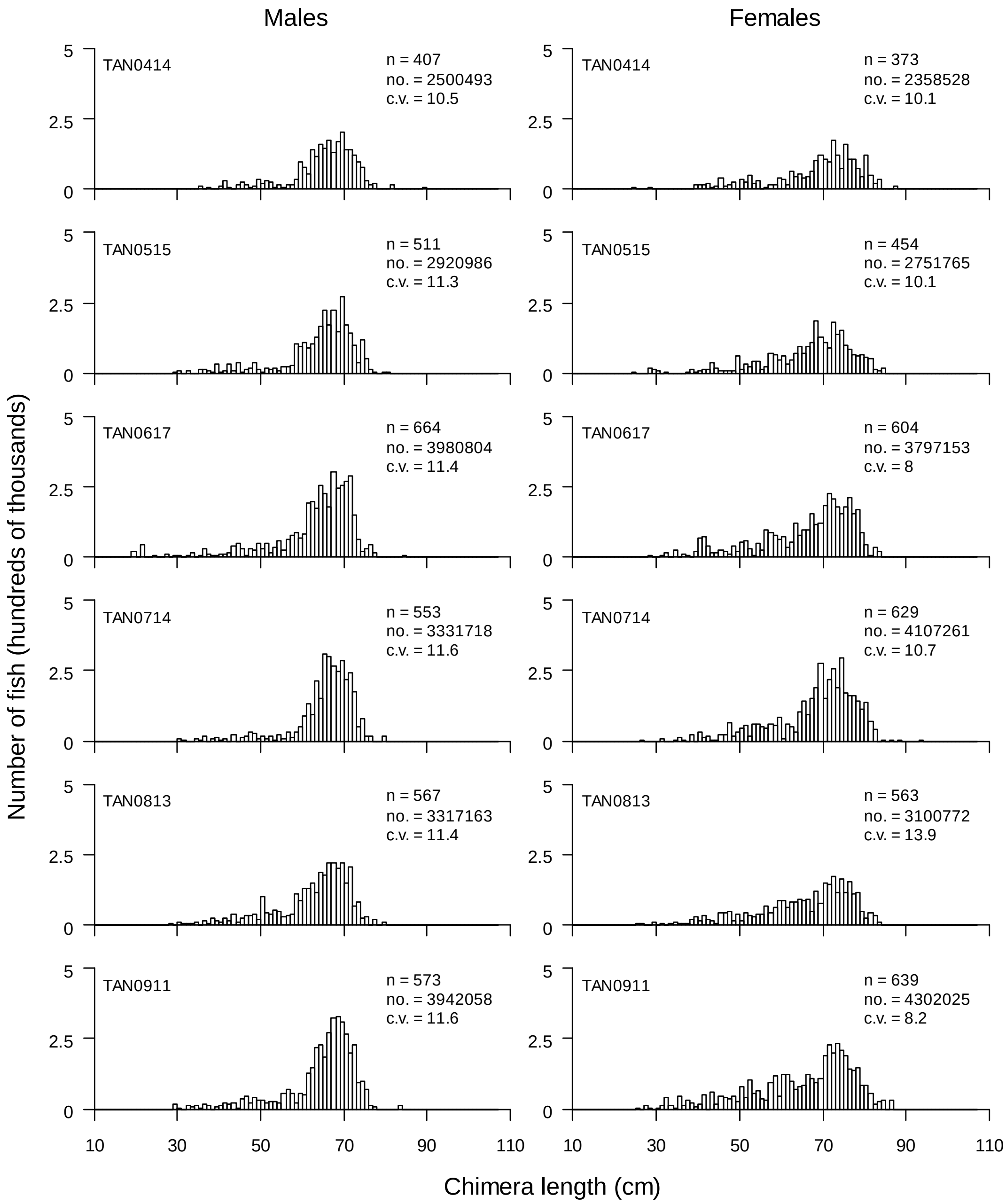



**Figure A6 continued: Scaled population length frequencies by sex of pale ghost shark from Sub-Antarctic (summer series) from *Tangaroa* surveys, 2004–2009. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

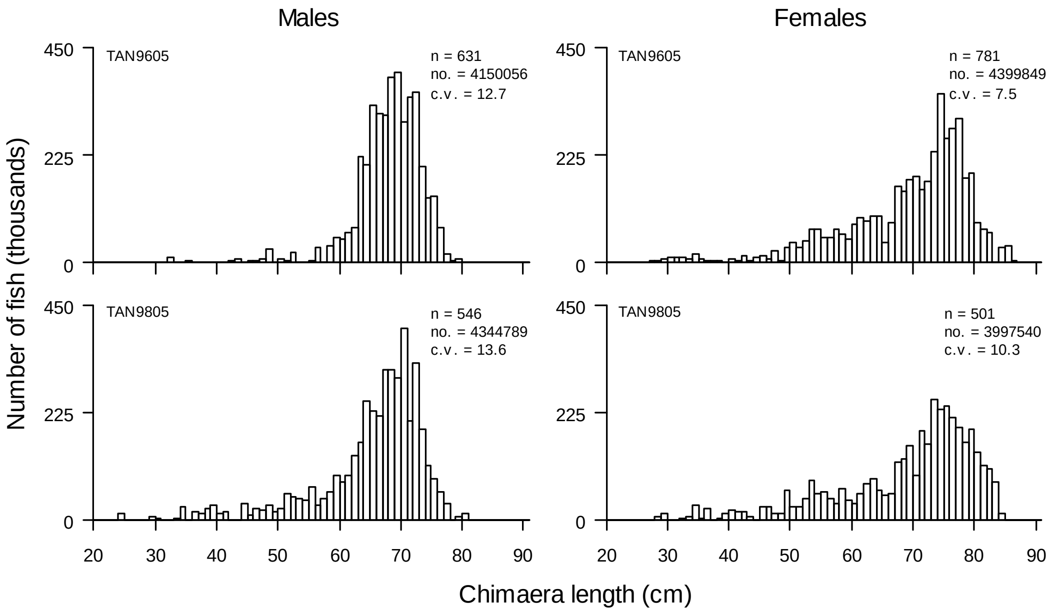



**Figure A7: Scaled population length frequencies by sex of pale ghost shark from autumn Sub-Antarctic surveys by *Tangaroa*, 1996 and 1998. Note: length frequencies from before 1996 were not available. n = number of fish measured, no. = population number, c.v. = coefficient of variation.**

## APPENDIX B. OBSERVER DATA

**Table B1: Percentage of observed catch from each area, for fishing years 2000–2010.**

| Year | ECNI | ECSI/CHAT | SUBA | West Coast | Total |
|---|---|---|---|---|---|
| 2000 | 10.5 | 11.8 | 6.5 | 176.1 | 11 |
| 2001 | 34.9 | 12.2 | 4.7 | 168.8 | 11.3 |
| 2002 | 55.5 | 9.1 | 8 | 89.9 | 9.3 |
| 2003 | 4.6 | 7.3 | 7 | 114.8 | 7.8 |
| 2004 | 3.9 | 16.9 | 3.3 | 343.2 | 14.5 |
| 2005 | 17.7 | 18.8 | 11.4 | 101.9 | 18.6 |
| 2006 | 27 | 13.3 | 9.2 | 72.8 | 12.5 |
| 2007 | 24.7 | 13.7 | 27.7 | 136.7 | 21.1 |
| 2008 | 32.7 | 5.9 | 24.4 | 47.5 | 12.6 |
| 2009 | 28.8 | 9 | 21.3 | 131 | 13.8 |
| 2010 | 28.6 | 11.5 | 11.3 | 139.5 | 12.6 |
| Total | 79.6 | 13.2 | 27.2 | 324.2 | 20.1 |

**Table B2: Number of tows sampled by the observer programme for pale ghost shark length by fishing year and area and by fishing year and month from each area and overall for the fishing years 2000–2010.**

**a) All areas**

| Year | ECNI | ECSI/CHAT | SUBA | West Coast | Total |
|---|---|---|---|---|---|
| 2000 | 0 | 32 | 41 | 3 | 76 |
| 2001 | 0 | 39 | 1 | 3 | 43 |
| 2002 | 2 | 63 | 23 | 42 | 130 |
| 2003 | 1 | 44 | 15 | 20 | 80 |
| 2004 | 2 | 55 | 29 | 20 | 106 |
| 2005 | 0 | 70 | 9 | 19 | 98 |
| 2006 | 0 | 89 | 13 | 28 | 130 |
| 2007 | 0 | 73 | 7 | 32 | 112 |
| 2008 | 3 | 71 | 29 | 10 | 113 |
| 2009 | 5 | 22 | 9 | 10 | 46 |
| 2010 | 0 | 27 | 14 | 4 | 45 |
| Total | 13 | 585 | 190 | 191 | 979 |

**Table B2: Continued**

**b) ECNI**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2001 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2002 | - | - | - | - | - | - | - | - | - | - | 2 | - | 2 |
| 2003 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 2004 | - | - | - | - | - | - | 2 | - | - | - | - | - | 2 |
| 2005 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2006 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2007 | - | 1 | - | - | - | - | 1 | - | - | 1 | - | - | 3 |
| 2008 | - | 3 | - | - | - | - | 1 | - | - | 1 | - | - | 5 |
| 2009 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2010 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Total | - | 4 | - | - | - | - | 4 | - | - | 2 | 2 | 1 | 13 |

**c) ECSI/CHAT**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | 10 | 17 | - | - | 5 | - | - | - | - | 32 |
| 2001 | - | 7 | 17 | - | - | - | 6 | - | 9 | - | - | - | 39 |
| 2002 | 8 | 22 | 15 | 10 | 4 | - | 4 | - | - | - | - | - | 63 |
| 2003 | 3 | 8 | 7 | 7 | 10 | - | - | - | 3 | - | - | 6 | 44 |
| 2004 | - | 3 | 10 | 3 | - | 9 | 8 | 8 | - | 4 | 5 | 5 | 55 |
| 2005 | 2 | 5 | 2 | 7 | 16 | 21 | - | - | 13 | - | 3 | 1 | 70 |
| 2006 | 32 | 3 | - | - | 4 | 6 | 3 | 4 | 28 | 8 | - | 1 | 89 |
| 2007 | - | 6 | 9 | 15 | 6 | - | 6 | 16 | 14 | 1 | - | - | 73 |
| 2008 | 12 | 12 | - | 3 | 11 | - | 4 | 24 | 3 | - | - | 2 | 71 |
| 2009 | 1 | 1 | 1 | - | 3 | 5 | 2 | 9 | - | - | - | - | 22 |
| 2010 | 6 | 3 | 1 | - | - | 1 | - | 10 | 6 | - | - | - | 27 |
| Total | 64 | 70 | 62 | 55 | 71 | 42 | 33 | 76 | 76 | 13 | 8 | 15 | 585 |

**d) Southland/SUBA**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | 10 | 17 | 14 | - | - | - | 41 |
| 2001 | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| 2002 | - | 10 | 11 | - | - | - | 2 | - | - | - | - | - | 23 |
| 2003 | - | - | 2 | 4 | - | 1 | 1 | - | - | - | - | 7 | 15 |
| 2004 | 22 | - | - | 4 | - | - | - | - | 3 | - | - | - | 29 |
| 2005 | 4 | - | - | - | - | - | - | - | - | - | - | 5 | 9 |
| 2006 | 9 | - | - | - | - | - | - | 4 | - | - | - | - | 13 |
| 2007 | - | 1 | - | 1 | - | - | 1 | - | - | - | 3 | 1 | 7 |
| 2008 | 5 | 9 | - | - | - | 13 | 1 | 1 | - | - | - | - | 29 |
| 2009 | 2 | 1 | 1 | - | - | - | 2 | 1 | - | - | - | 2 | 9 |
| 2010 | 1 | - | - | - | 1 | 6 | 4 | - | 2 | - | - | - | 14 |
| Total | 43 | 21 | 14 | 9 | 1 | 20 | 21 | 24 | 19 | - | 3 | 15 | 190 |

**Table B2: Continued**

**e) West Coast**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | 2 | - | - | - | - | 1 | 3 |
| 2001 | - | - | - | - | - | - | 1 | 2 | - | - | - | - | 3 |
| 2002 | - | 3 | 5 | 3 | - | 20 | 2 | 3 | 2 | 1 | 3 | - | 42 |
| 2003 | 6 | 5 | - | - | - | - | - | - | - | 3 | - | 6 | 20 |
| 2004 | 6 | 2 | 1 | 2 | - | - | - | 2 | 3 | - | 2 | 2 | 20 |
| 2005 | 2 | - | - | - | - | - | 9 | 1 | - | - | 4 | 3 | 19 |
| 2006 | - | 4 | - | - | - | 4 | - | 3 | 7 | 6 | 4 | - | 28 |
| 2007 | 21 | 4 | 1 | - | - | - | - | 5 | - | - | 1 | - | 32 |
| 2008 | - | - | 3 | - | - | - | - | - | - | - | 6 | 1 | 10 |
| 2009 | - | 3 | 3 | - | - | - | - | 3 | - | - | - | 1 | 10 |
| 2010 | 1 | - | - | - | 1 | 2 | - | - | - | - | - | - | 4 |
| Total | 36 | 21 | 13 | 5 | 1 | 26 | 14 | 19 | 12 | 10 | 20 | 14 | 191 |

**Table B3: Number of pale ghost shark measured by fishing year and month by area and overall by the observer programme, for fishing years 2000–2010.**

| Year | ECNI | ECSI/CHAT | SUBA | West Coast | Total |
|---|---|---|---|---|---|
| 2000 | - | 281 | 913 | 20 | 1214 |
| 2001 | - | 1311 | 107 | 223 | 1641 |
| 2002 | 5 | 590 | 246 | 315 | 1156 |
| 2003 | 15 | 283 | 217 | 99 | 614 |
| 2004 | 2 | 663 | 389 | 156 | 1210 |
| 2005 | - | 700 | 139 | 205 | 1044 |
| 2006 | - | 1101 | 208 | 147 | 1456 |
| 2007 | - | 810 | 102 | 177 | 1089 |
| 2008 | 17 | 1101 | 458 | 205 | 1781 |
| 2009 | 18 | 236 | 236 | 61 | 551 |
| 2010 | - | 420 | 371 | 139 | 930 |
| Total | 57 | 7496 | 3386 | 1747 | 12686 |

**(a) ECNI**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2001 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2002 | - | - | - | - | - | - | - | - | - | - | 5 | - | 5 |
| 2003 | - | - | - | - | - | - | - | - | - | - | - | 15 | 15 |
| 2004 | - | - | - | - | - | - | 2 | - | - | - | - | - | 2 |
| 2005 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2006 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2007 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2008 | - | 9 | - | - | - | - | 2 | - | - | 6 | - | - | 17 |
| 2009 | - | 7 | - | - | - | - | 1 | - | - | 10 | - | - | 18 |
| 2010 | | | | | | | | | | | | | |
| Total | - | 16 | - | - | - | - | 5 | - | - | 16 | 5 | 15 | 57 |

**(b) ECSI/CHAT**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | 34 | 108 | - | - | 139 | - | - | - | - | 281 |
| 2001 | - | 60 | 342 | - | - | - | 380 | - | 529 | - | - | - | 1311 |
| 2002 | 80 | 255 | 94 | 87 | 35 | - | 39 | - | - | - | - | - | 590 |
| 2003 | 10 | 96 | 84 | 39 | 14 | - | - | - | 4 | - | - | 36 | 283 |
| 2004 | - | 17 | 158 | 52 | - | 104 | 91 | 117 | - | 7 | 76 | 41 | 663 |
| 2005 | 25 | 137 | 39 | 182 | 116 | 113 | - | - | 46 | - | 31 | 11 | 700 |
| 2006 | 320 | 34 | - | - | 50 | 60 | 29 | 83 | 330 | 189 | - | 6 | 1101 |
| 2007 | - | 42 | 176 | 165 | 27 | - | 158 | 180 | 43 | 19 | - | - | 810 |
| 2008 | 194 | 175 | - | 50 | 146 | - | 80 | 372 | 52 | - | - | 32 | 1101 |
| 2009 | 2 | 10 | 6 | - | 16 | 36 | 40 | 126 | - | - | - | - | 236 |
| 2010 | 85 | 60 | 20 | - | - | 32 | - | 158 | 65 | - | - | - | 420 |
| Total | 716 | 886 | 919 | 609 | 512 | 345 | 817 | 1175 | 1069 | 215 | 107 | 126 | 7496 |

**Table B3: Continued**

**(c) Southland/SUBA**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | 212 | 334 | 367 | - | - | - | 913 |
| 2001 | - | - | - | - | - | - | - | 107 | - | - | - | - | 107 |
| 2002 | - | 119 | 114 | - | - | - | 13 | - | - | - | - | - | 246 |
| 2003 | - | - | 13 | 70 | - | 10 | 15 | - | - | - | - | 109 | 217 |
| 2004 | 311 | - | - | 50 | - | - | - | - | 28 | - | - | - | 389 |
| 2005 | 80 | - | - | - | - | - | - | - | - | - | - | 59 | 139 |
| 2006 | 162 | - | - | - | - | - | - | 46 | - | - | - | - | 208 |
| 2007 | - | 8 | - | 24 | - | - | 20 | - | - | - | 30 | 20 | 102 |
| 2008 | 80 | 106 | - | - | - | 254 | 10 | 8 | - | - | - | - | 458 |
| 2009 | 30 | 20 | 20 | - | - | - | 35 | 20 | - | - | - | 111 | 236 |
| 2010 | 22 | - | - | - | 60 | 194 | 80 | - | 15 | - | - | - | 371 |
| Total | 685 | 253 | 147 | 144 | 60 | 458 | 385 | 515 | 410 | - | 30 | 299 | 3386 |

**(d) West Coast**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | - | - | - | - | 19 | - | - | - | - | 1 | 20 |
| 2001 | - | - | - | - | - | - | 46 | 177 | - | - | - | - | 223 |
| 2002 | - | 34 | 50 | 3 | - | 81 | 72 | 22 | 25 | 2 | 26 | - | 315 |
| 2003 | 7 | 31 | - | - | - | - | - | - | - | 6 | - | 55 | 99 |
| 2004 | 10 | 16 | 13 | 28 | - | - | - | 5 | 10 | - | 42 | 32 | 156 |
| 2005 | 40 | - | - | - | - | - | 100 | 1 | - | - | 54 | 10 | 205 |
| 2006 | - | 35 | - | - | - | 19 | - | 7 | 34 | 14 | 38 | - | 147 |
| 2007 | 140 | 8 | 4 | - | - | - | - | 18 | - | - | 7 | - | 177 |
| 2008 | - | - | 140 | - | - | - | - | - | - | - | 48 | 17 | 205 |
| 2009 | - | 19 | 24 | - | - | - | - | 10 | - | - | - | 8 | 61 |
| 2010 | 20 | - | - | - | 41 | 78 | - | - | - | - | - | - | 139 |
| Total | 217 | 143 | 231 | 31 | 41 | 178 | 237 | 240 | 69 | 22 | 215 | 123 | 1747 |

**Table B4: Number of female pale ghost shark gonads staged by fishing year and month by area and overall by the observer programme for fishing years 2000–2010.**

| Year | ECNI | ECSI/CHAT | SUBA | West Coast | Total |
|---|---|---|---|---|---|
| 2000 | - | 1 | 1 | - | - |
| 2001 | - | - | - | - | - |
| 2002 | - | - | 10 | - | - |
| 2003 | - | - | - | - | - |
| 2004 | - | - | - | 31 | - |
| 2005 | - | - | - | - | - |
| 2006 | - | - | - | - | - |
| 2007 | - | - | - | - | - |
| 2008 | - | - | - | - | - |
| 2009 | 1 | - | - | 2 | - |
| 2010 | - | - | - | - | - |
| Total | 1 | 1 | 11 | 33 | 46 |

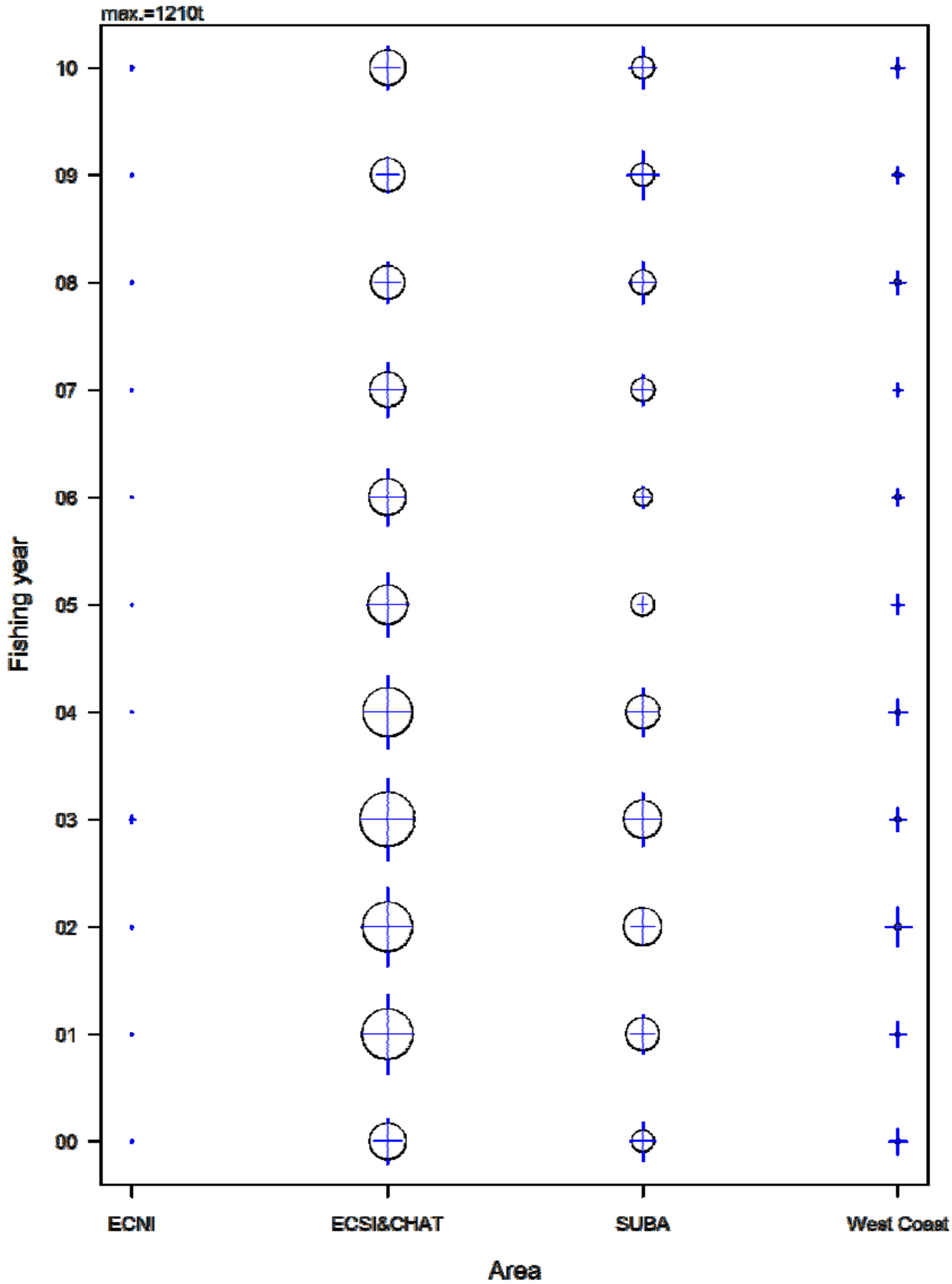



**Figure B1: Representativeness of observer sampling of pale ghost shark catch by fishing year and area for the East Coast North Island (ECNI), ECSI and Chatham Islands (ECSI&CHAT), Southland/Sub-Antarctic (SUBA), and West Coast regions, for fishing years 2000–2010. Circles show the proportion of target catch by area within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.**

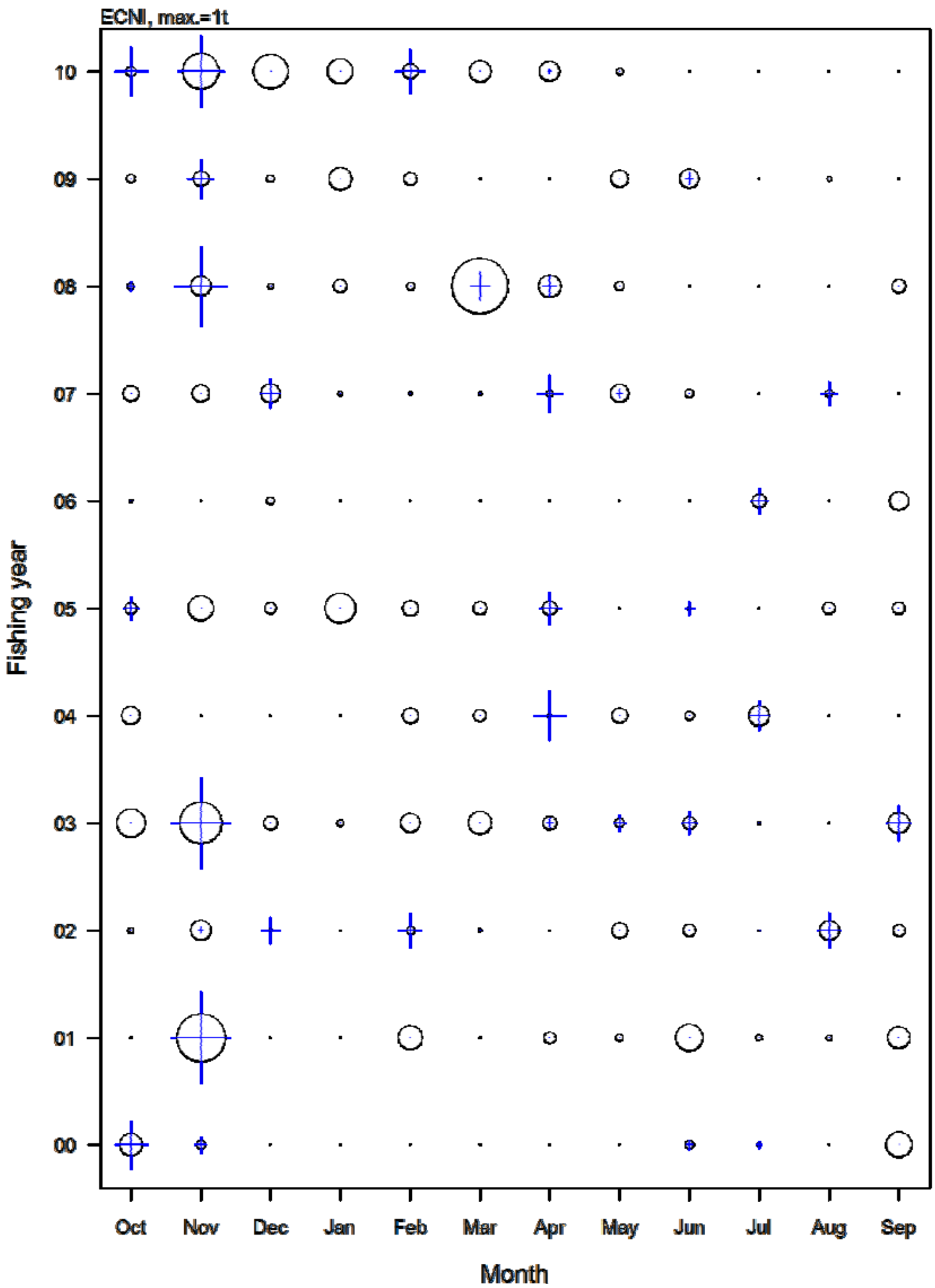



**Figure B2: Representativeness of observer sampling of pale ghost shark catch by fishing year and month for the East Coast North Island, for fishing years 2000–2010. Circles show the proportion of target catch by month within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.**

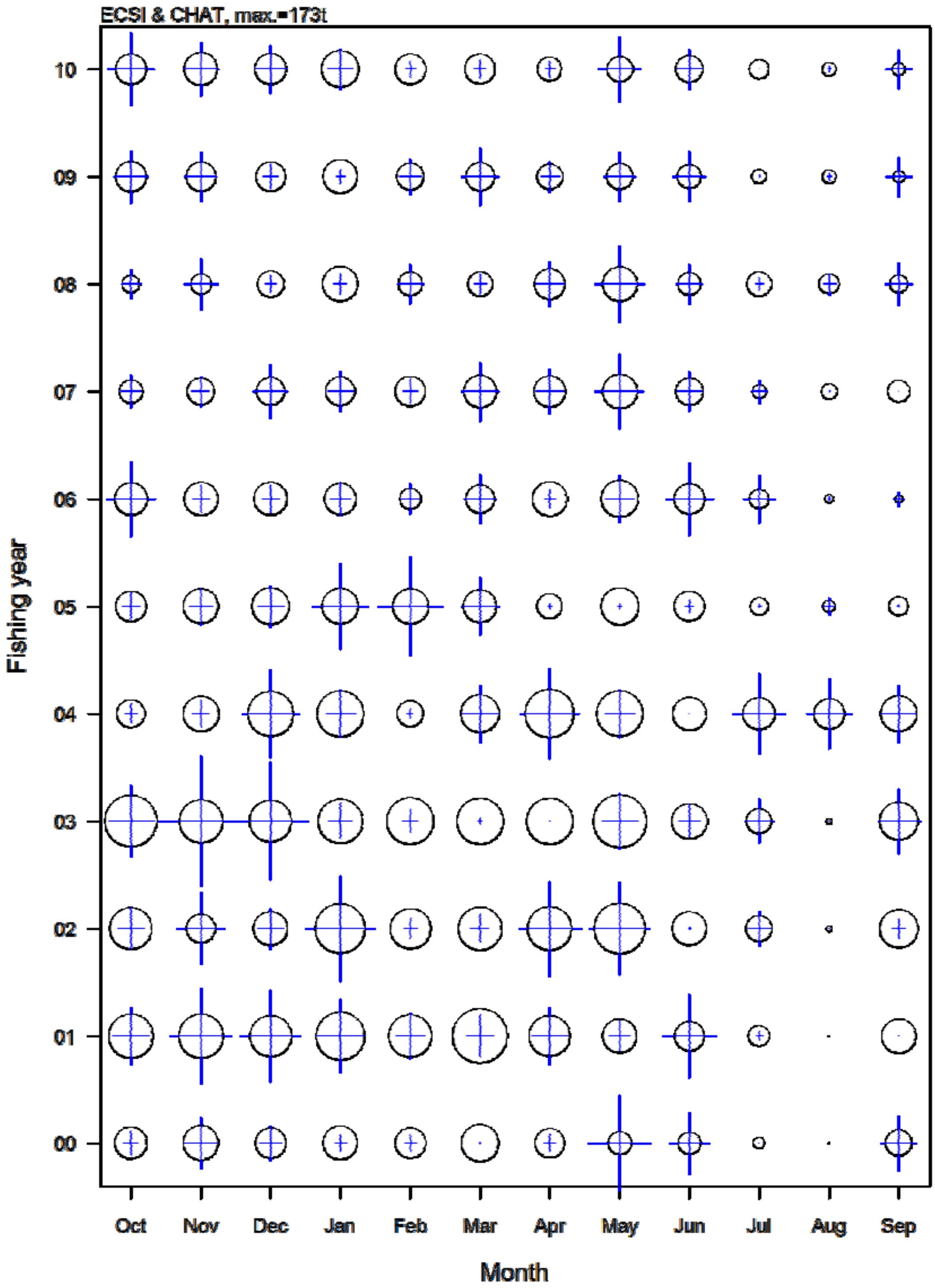



**Figure B3: Representativeness of observer sampling of pale ghost shark catch by fishing year and month for the East Coast South Island and Chatham Rise region, for fishing years 2000–2010. Circles show the proportion of target catch by month within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.**

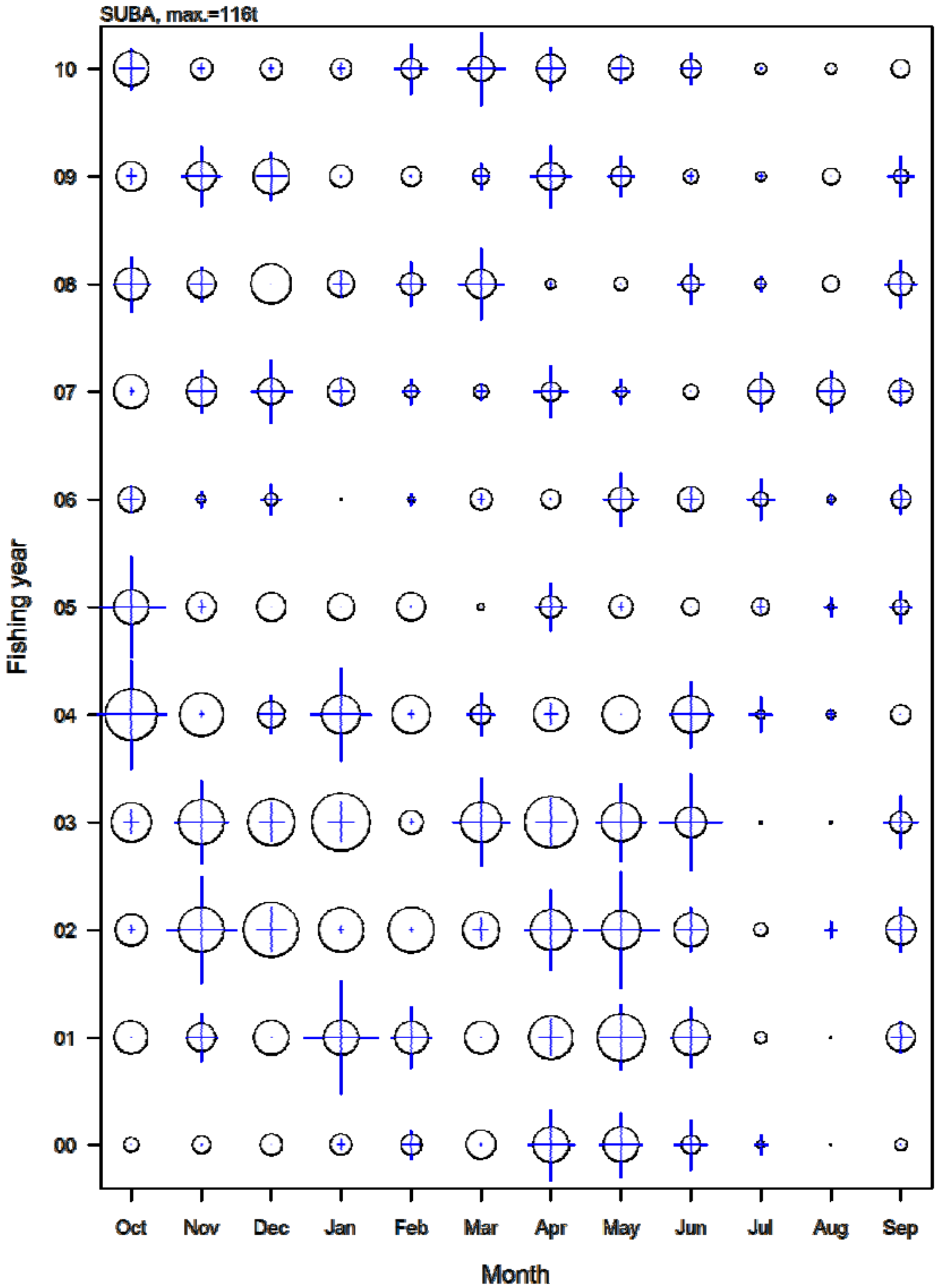



**Figure B4: Representativeness of observer sampling of pale ghost shark catch by fishing year and month for the Sub-Antarctic region, for fishing years 2000–2010. Circles show the proportion of target catch by month within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.**

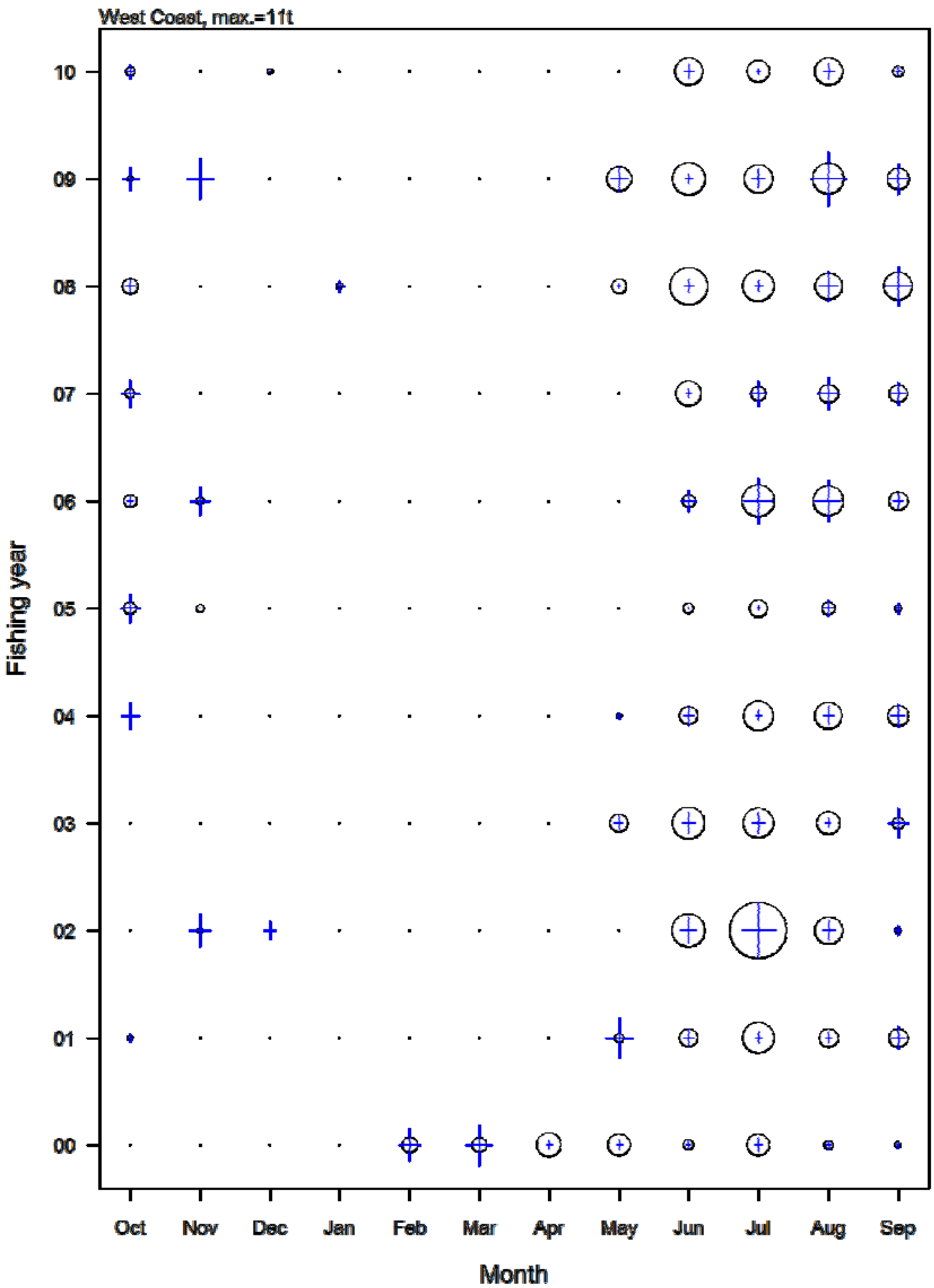



**Figure B5: Representativeness of observer sampling of pale ghost shark catch by fishing year and month for the West Coast region, for fishing years 2000–2010. Circles show the proportion of target catch by month within a year; crosses show the proportion of observed target catch for the same cells. Representation is demonstrated by how closely the cross matches the circle diameter.**

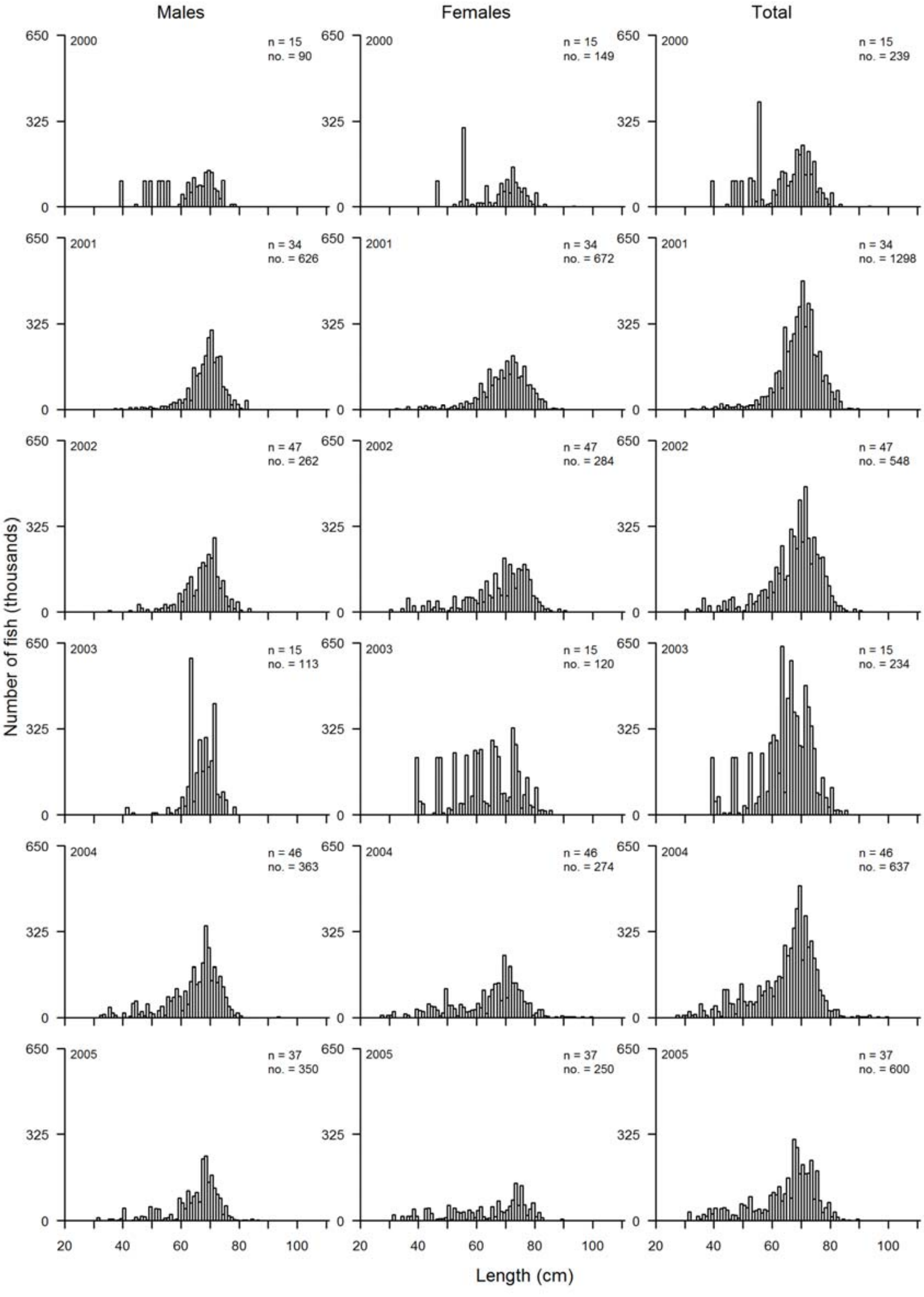



**Figure B6: Scaled length frequency of pale ghost shark taken in commercial catches from the East Coast South Island and Chatham Rise fishery by fishing year sampled by the Observer Programme, for fishing years 2000–2005. n, number of tows sampled; no., number of fish sampled.**

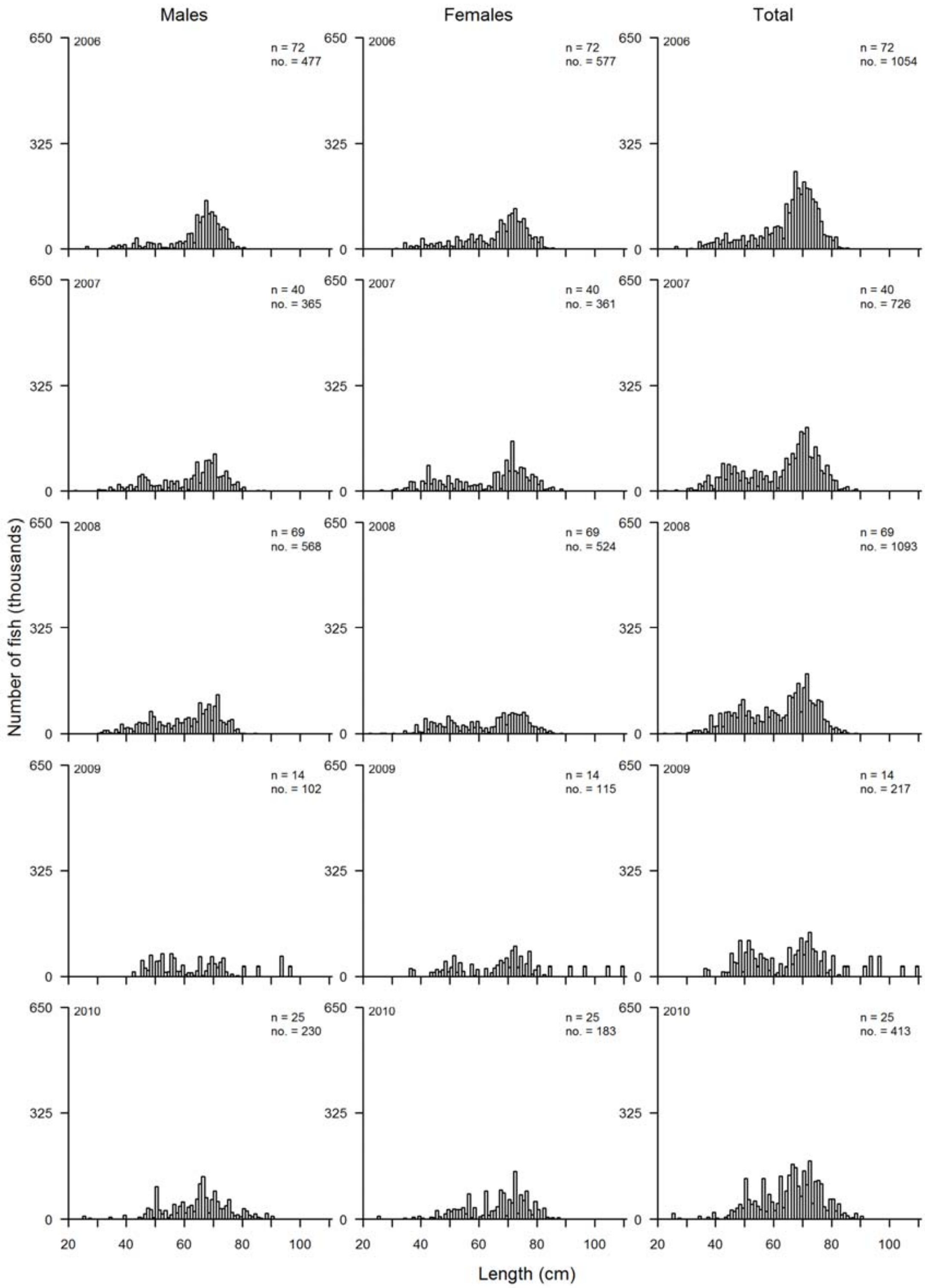



**Figure B7: Scaled length frequency of pale ghost shark taken in commercial catches from the East Coast South Island and Chatham Rise fishery by fishing year sampled by the Observer Programme, for fishing years 2006–2010. n, number of tows sampled; no., number of fish sampled.**

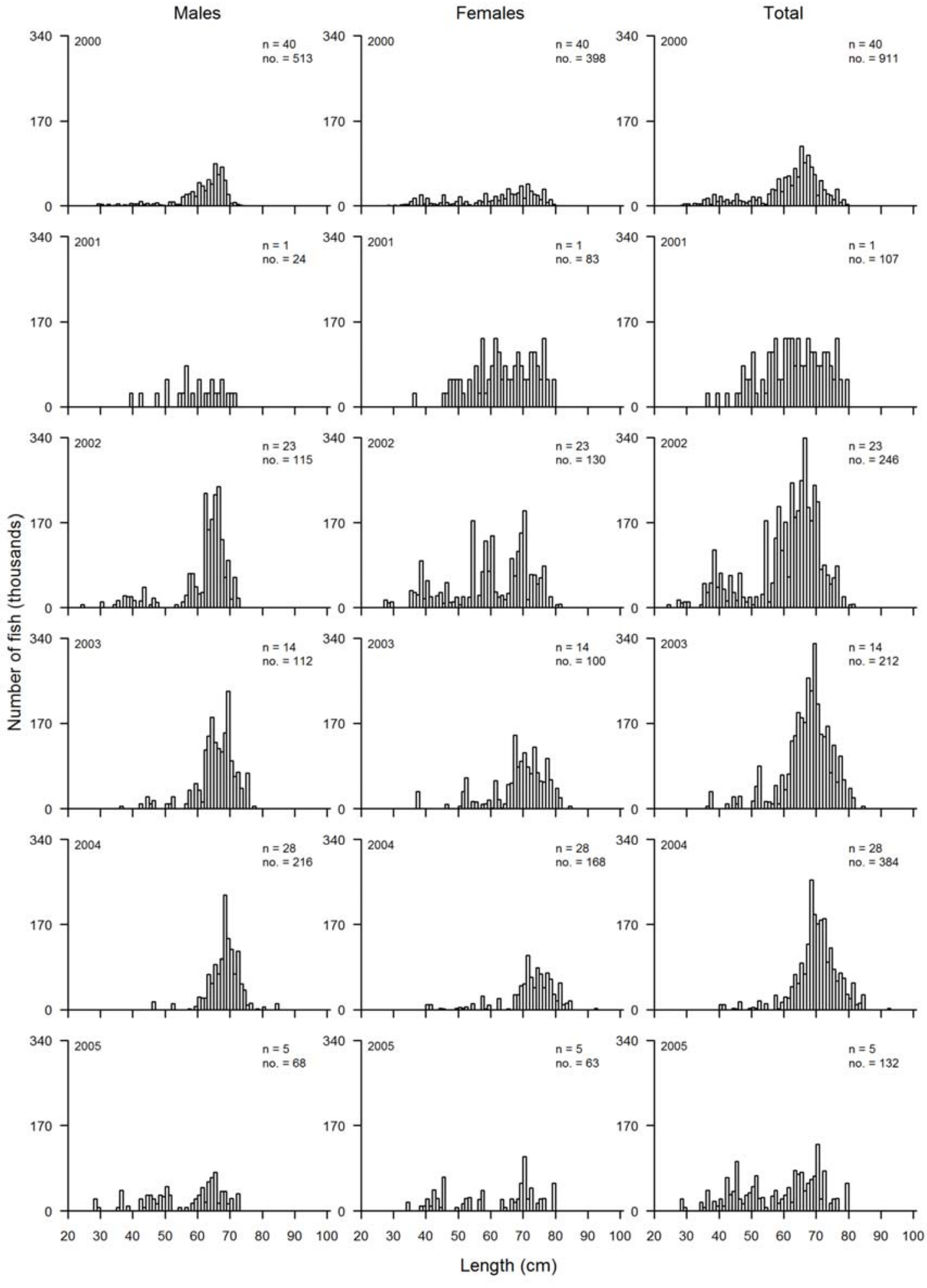



**Figure B8: Scaled length frequency of pale ghost shark taken in commercial catches from the Sub-Antarctic fishery by fishing year sampled by the Observer Programme, for fishing years 2000–2005. n, number of tows sampled; no., number of fish sampled.**

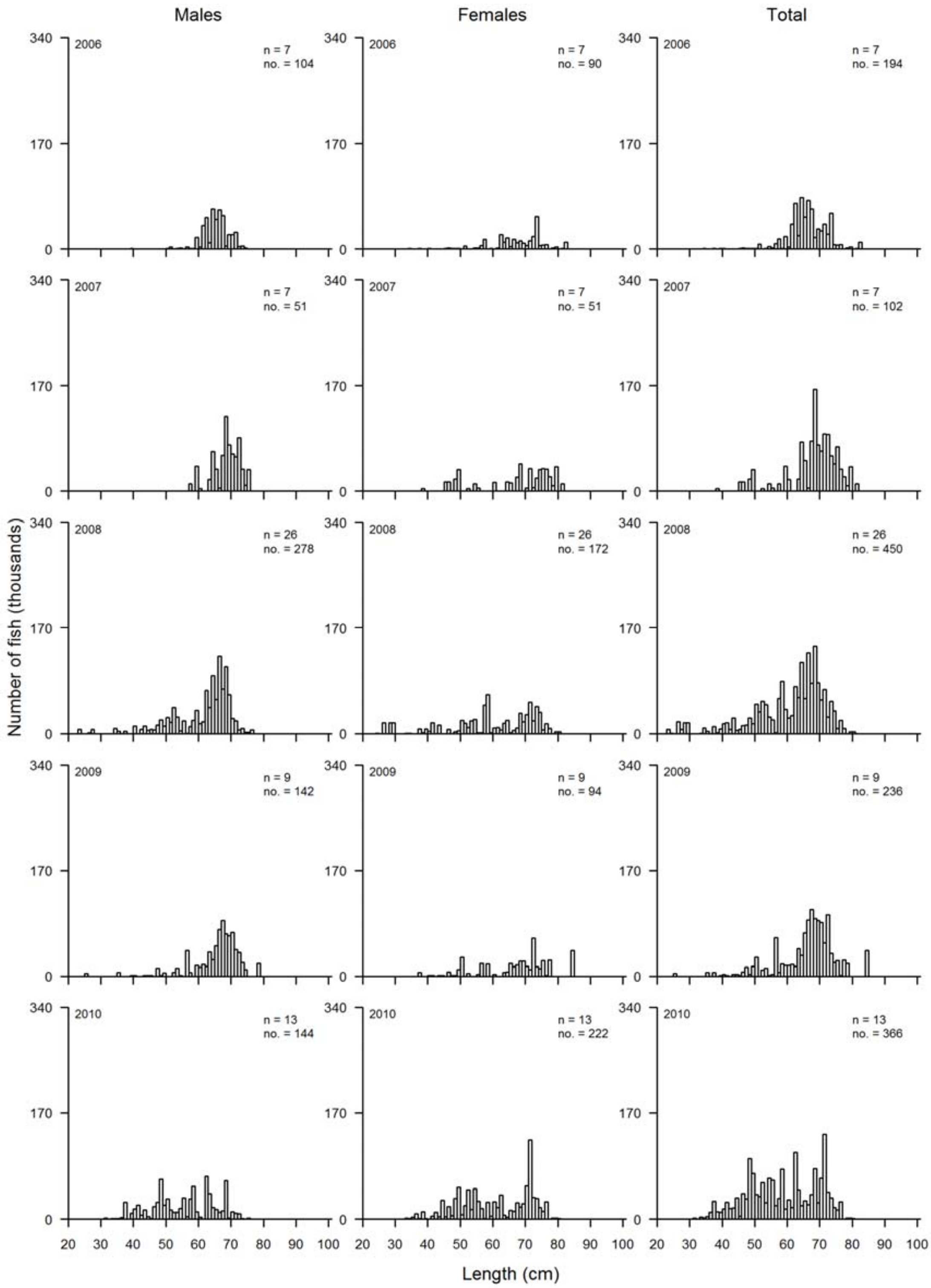



**Figure B9: Scaled length frequency of pale ghost shark taken in commercial catches from the Sub-Antarctic fishery by fishing year sampled by the Observer Programme, for fishing years 2006–2010. n, number of tows sampled; no., number of fish sampled.**

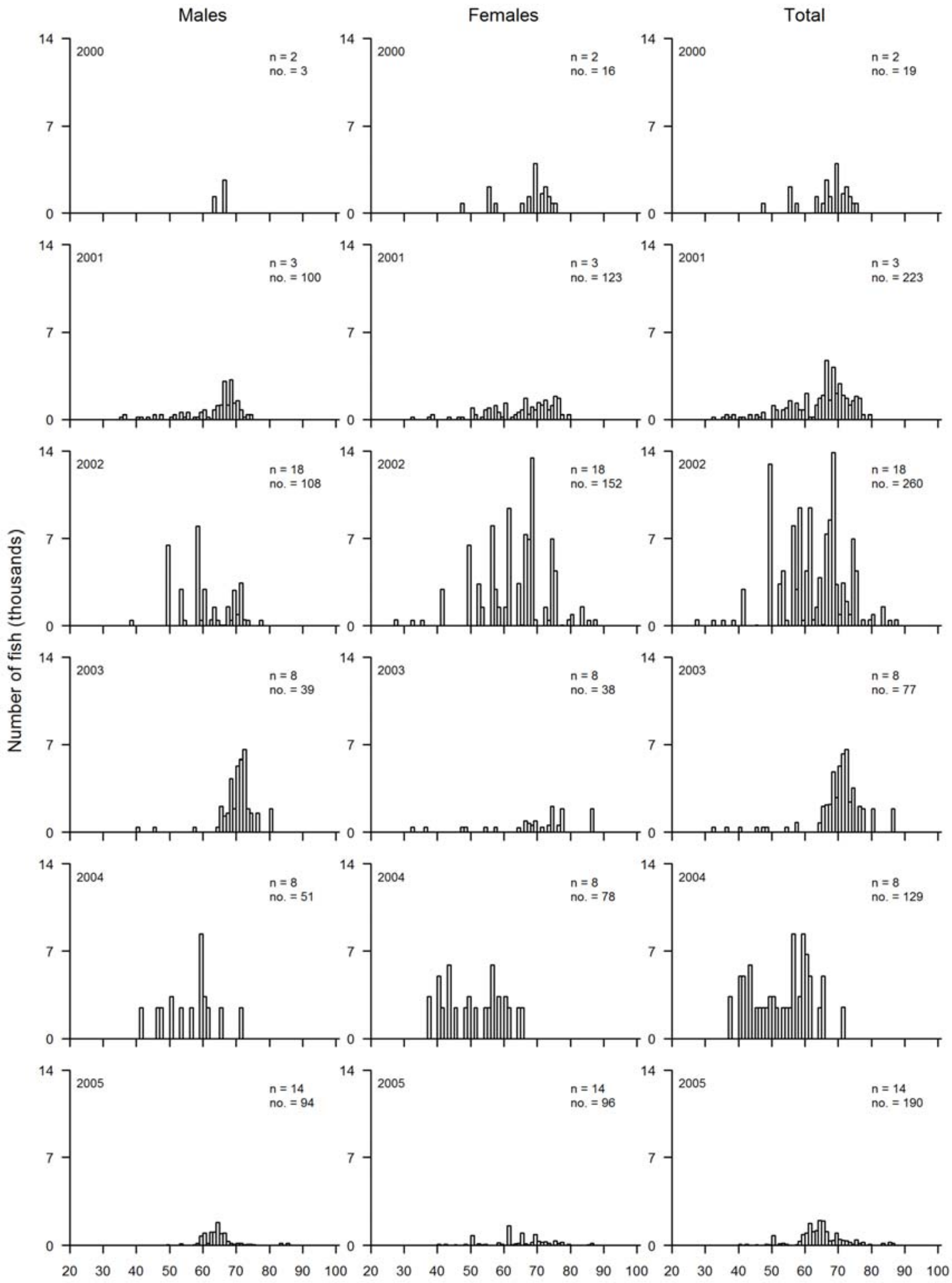



**Figure B10: Scaled length frequency of pale ghost shark taken in commercial catches from the West Coast fishery by fishing year sampled by the Observer Programme, for fishing years 2000–2005. n, number of tows sampled; no., number of fish sampled.**

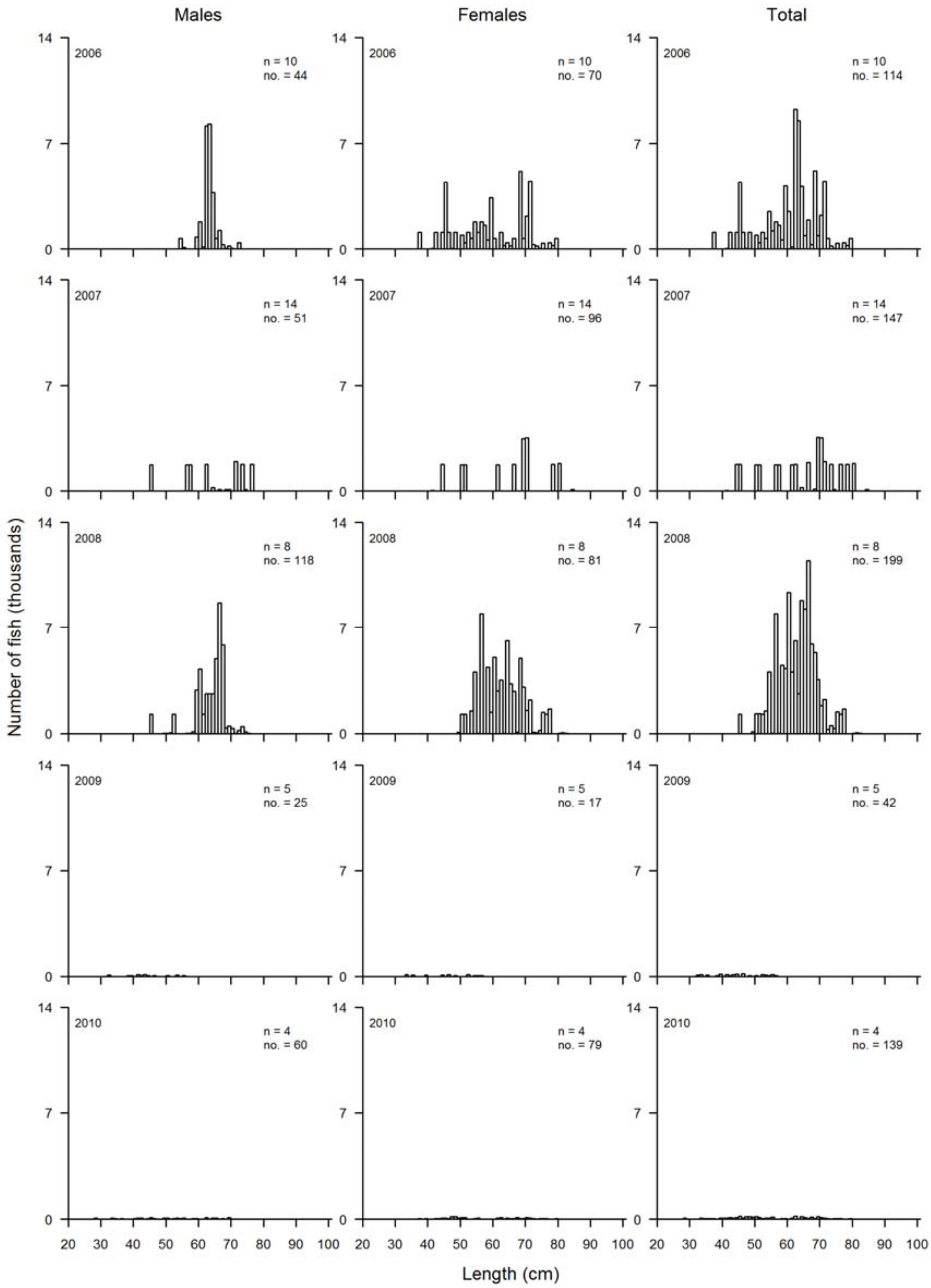



**Figure B11: Scaled length frequency of pale ghost shark taken in commercial catches from the West Coast fishery by fishing year sampled by the Observer Programme, for fishing years 2006–2010. n, number of tows sampled; no., number of fish sampled.**

## APPENDIX C: CHARACTERISATION

**Table C1. List of tables and fields requested in the *Warehou* extract 8208.**

**Fishing_events table**

| | | |
|---|---|---|
| Event_Key | Effort_total_num | Column_a |
| Version_seqno | Effort_width | Column_b |
| DCF_key | Effort_speed | Column_c |
| Start_datetime | Total_net_length | Column_d |
| End_datetime | Total_hook_num | Display_fishyear |
| Primary_method | Set_end_datetime | Start_stats_area_code |
| Target_species | Haul_start_datetime | Vessel_key |
| Fishing_duration | Start_latitude (full accuracy) | Form_type |
| Catch_weight | Start_longitude (full | Trip |
| Effort_depth | accuracy) | Literal_yn |
| Effort_height | End_latitude (full accuracy) | Interp_yn |
| Effort_num | End_longitude (full accuracy) | Resrch_yn |
| Effort_num_2 | Pair_trawl_yn | |
| Effort_seqno | Bottom_depth | |

**Landing_events table**

| | | |
|---|---|---|
| Event_Key | Destination_type | Trip_key |
| Version_seqno | Unit_type | Trip_start_datetime |
| DCF_key | Unit_num | Trip_end_datetime |
| Landing_datetime | Unit_weight | Vessel_key |
| Landing_name | Conv_factor | Form_type |
| Species_code | Green_weight | Literal_yn |
| Species_name | Green_weight_type | Interp_yn |
| Fishstock_code (ALL fish | Processed_weight | Resrch_yn |
| stocks) | Processed_weight_type | |
| State_code | Form_type | |

**Estimated subcatch table**

| | | |
|---|---|---|
| Event_Key | Species_code (ALL species | Literal_yn |
| Version_seqno | for each fishing event) | Interp_yn |
| DCF_key | Catch_weight | Resrch_yn |

**Process data table**

| | | |
|---|---|---|
| Event_Key | Unit_type | Processed_weight_type |
| Version_seqno | Unit_num | Vessel_key |
| DCF_key | Unit_weight | Form_type |
| Spec_prod_action_type | Conv_factor | Trip_key |
| Processed_datatime | Green_weight | Literal_yn |
| Species_code | Green_weight_type | Interp_yn |
| State_code | Processed_weight | Resrch_yn |

**Vessel_history table**

| | |
|---|---|
| Vessel_key | Gross_tonnes |
| Flag_nationality_code | Overall_length_metres |
| Built_year | History_start_datetime |
| Engine_kilowatts | History_end_datetime |

**Table C2: Number of landing events by major destination code and form type for GSP 1–7 from 2000 to 2010. "L" refers to "landed to NZ"; "R" refers to "retained on board"; "A" refers to "Accidental loss"; "D" refers to "Discarded"; "E" refers to "Eaten"; "T" refers to "transferred to another vessel".**

| | CLR form | | | | | | CELR form | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSP 1 | L | R | A | D | E | Other | L | R | A | D | E | Other | Total |
| 2000 | 292 | 29 | 1 | 3 | 3 | - | 40 | 2 | 4 | 1 | - | - | 375 |
| 2001 | 316 | 27 | 7 | - | 3 | - | 49 | 1 | 1 | - | - | - | 404 |
| 2002 | 301 | 30 | - | - | 4 | - | 37 | 3 | 6 | 2 | - | 1 | 384 |
| 2003 | 371 | 44 | 1 | 2 | 4 | - | 37 | 7 | 6 | 2 | - | - | 474 |
| 2004 | 307 | 54 | 3 | 3 | 2 | 8 | 26 | 2 | 2 | - | - | - | 407 |
| 2005 | 274 | 19 | 12 | - | 6 | - | 19 | 1 | - | - | - | - | 331 |
| 2006 | 260 | 18 | 5 | - | 3 | 3 | 150 | - | - | - | - | - | 439 |
| 2007 | 332 | 24 | 13 | 1 | 16 | - | 12 | - | - | - | - | - | 401 |
| 2008 | 321 | 34 | 8 | - | 16 | 1 | 2 | - | - | - | - | - | 386 |
| 2009 | 304 | 22 | 6 | - | 23 | 9 | - | - | - | - | - | - | 369 |
| 2010 | 280 | 18 | 10 | - | 22 | 33 | 1 | - | - | - | - | - | 366 |
| Total | 3358 | 319 | 66 | 9 | 102 | 54 | 373 | 16 | 19 | 5 | 0 | 1 | 4 336 |

| | CLR form | | | | | | CELR form | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSP 5 | L | R | A | T | E | Other | L | R | A | T | E | Other | Total |
| 2000 | 121 | 11 | 1 | - | 2 | - | 10 | - | 1 | - | - | - | 146 |
| 2001 | 128 | 14 | 1 | 1 | - | - | 11 | 1 | - | - | - | 1 | 157 |
| 2002 | 163 | 10 | - | - | 3 | - | 13 | - | 3 | - | - | - | 192 |
| 2003 | 156 | 13 | - | - | 3 | 3 | 14 | - | 6 | - | 1 | 3 | 199 |
| 2004 | 172 | 13 | 9 | - | 5 | 2 | 13 | 1 | 8 | - | - | - | 223 |
| 2005 | 109 | 13 | 7 | - | 3 | 2 | 12 | 1 | 1 | - | - | - | 148 |
| 2006 | 104 | 16 | 6 | - | 4 | - | 4 | - | - | - | - | - | 134 |
| 2007 | 116 | 16 | 7 | - | 17 | - | 1 | - | - | - | - | - | 157 |
| 2008 | 128 | 10 | 10 | - | 17 | - | - | - | - | - | - | - | 165 |
| 2009 | 113 | 11 | 6 | - | 14 | 1 | - | - | - | - | - | - | 148 |
| 2010 | 122 | 13 | 10 | - | 15 | - | - | - | - | - | - | - | 161 |
| Total | 1 432 | 140 | 57 | 1 | 83 | 8 | 78 | 3 | 19 | 0 | 1 | 4 | 1 830 |

**Table C2 continued.**

| | CLR form | | | | | | CELR form | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GSP 7 | L | R | E | D | A | Other | L | R | E | D | A | Other | Total |
| 2000 | 57 | 2 | 2 | 1 | - | - | 21 | - | - | - | - | - | 83 |
| 2001 | 59 | 4 | - | - | 1 | 1 | 8 | - | - | - | - | - | 73 |
| 2002 | 77 | 6 | 6 | 1 | 1 | - | 55 | - | - | - | - | - | 146 |
| 2003 | 67 | 5 | 3 | 3 | - | - | 15 | - | - | - | - | 1 | 94 |
| 2004 | 45 | 2 | 4 | 1 | 2 | - | 22 | - | - | - | - | - | 76 |
| 2005 | 35 | 6 | 7 | - | - | - | 9 | - | - | - | - | - | 57 |
| 2006 | 32 | 8 | 13 | - | 1 | - | - | - | - | - | - | - | 54 |
| 2007 | 41 | 2 | 12 | - | - | - | 13 | - | - | - | - | - | 68 |
| 2008 | 44 | 4 | 14 | - | 2 | - | - | - | - | - | - | - | 64 |
| 2009 | 45 | 4 | 16 | - | 2 | - | - | - | - | - | - | - | 68 |
| 2010 | 36 | 1 | 12 | - | 2 | - | - | - | - | 1 | - | 2 | 54 |
| Total | 538 | 44 | 89 | 6 | 11 | 1 | 143 | 0 | 0 | 1 | 0 | 3 | 837 |

**Table C3: Destination codes, total landing weight, number of landings and whether the records were kept or discarded for all pale ghost shark catch 2000–2010 for GSP 1–7.**

| Destination code | Greenweight (t) | No. records | Description | Action |
|---|---|---|---|---|
| GSP 1 | | | | |
| L | 8 204.46 | 3 744 | Landed in New Zealand to a Licensed Fish Receiver | Keep |
| A | 6.33 | 85 | Accidental loss | Keep |
| D | 3.68 | 14 | Discarded | Keep |
| E | 1.79 | 102 | Eaten | Keep |
| U | 1.30 | 19 | Used as bait | Keep |
| T | 0.59 | 7 | Transferred to another vessel | Keep |
| O | 0.55 | 1 | Conveyed outside New Zealand | Keep |
| S | 0.01 | 4 | Seized by the Crown | Keep |
| R | 813.40 | 336 | Retained on board | Drop |
| B | 0.90 | 23 | Stored as bait | Drop |
| GSP 5 | | | | |
| L | 3 748.95 | 1 514 | Landed in New Zealand to a Licensed Fish Receiver | Keep |
| A | 15.74 | 76 | Accidental loss | Keep |
| T | 1.68 | 1 | Transferred to another vessel | Keep |
| E | 1.36 | 84 | Eaten | Keep |
| D | 1.21 | 8 | Discarded | Keep |
| O | 1.20 | 3 | Conveyed outside New Zealand | Keep |
| R | 175.86 | 143 | Retained on board | Drop |
| B | 0.03 | 1 | Stored as bait | Drop |
| GSP 7 | | | | |
| L | 222.45 | 682 | Landed in New Zealand to a Licensed Fish Receiver | Keep |
| E | 2.19 | 89 | Eaten | Keep |
| D | 0.31 | 7 | Discarded | Keep |
| A | 0.29 | 11 | Accidental loss | Keep |
| T | 0.03 | 1 | Transferred to another vessel | Keep |
| F | 0.01 | 2 | Recreational catch | Keep |
| R | 7.33 | 44 | Retained on board | Drop |
| Null | 0.00 | 1 | Missing destination type code | Drop |

**Table C4: The reported MHR catch, annual retained landings in the groomed and unmerged dataset, and retained landings in the groomed and merged dataset, and estimated catches in the groomed and merged dataset for GSP 1–7 from 2000 to 2010. Units for catch and landings are tonnes.**

| | | | | | GSP 1 | | | | | GSP 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Merged estimated | | | | | Merged estimated | |
| Year | MHR | Un-merged landings | Merged landings | Catch | % MHR | MHR | Un-merged landings | Merged landings | Catch | % MHR |
| 2000 | 577 | 515 | 300 | 539 | 93 | 216 | 210 | 107 | 196 | 91 |
| 2001 | 1 142 | 1 058 | 1 051 | 1 046 | 92 | 454 | 438 | 435 | 437 | 96 |
| 2002 | 1 033 | 1 031 | 998 | 1 014 | 98 | 545 | 543 | 514 | 575 | 106 |
| 2003 | 1 277 | 1 252 | 1 199 | 1 212 | 95 | 602 | 601 | 583 | 582 | 97 |
| 2004 | 1 009 | 1 017 | 975 | 993 | 98 | 529 | 502 | 448 | 448 | 85 |
| 2005 | 635 | 678 | 602 | 626 | 99 | 247 | 243 | 220 | 215 | 87 |
| 2006 | 565 | 555 | 541 | 546 | 97 | 134 | 119 | 120 | 121 | 90 |
| 2007 | 553 | 535 | 528 | 499 | 90 | 226 | 222 | 207 | 218 | 96 |
| 2008 | 473 | 479 | 464 | 449 | 95 | 329 | 321 | 237 | 238 | 72 |
| 2009 | 486 | 485 | 459 | 445 | 92 | 294 | 289 | 195 | 209 | 71 |
| 2010 | 534 | 531 | 1 100 | 506 | 95 | 206 | 209 | 192 | 202 | 98 |
| Totals | 8 284 | 8 136 | 8 217 | 7 875 | 95 | 3 782 | 3 697 | 3 258 | 3 441 | 91 |

| | | | | | GSP 7 |
|---|---|---|---|---|---|
| | | | | Merged estimated | |
| Year | MHR | Un-merged landings | Merged landings | Catch | % MHR |
| 2000 | 35 | 32 | 9 | 8 | 23 |
| 2001 | 16 | 15 | 9 | 7 | 44 |
| 2002 | 71 | 71 | 19 | 18 | 25 |
| 2003 | 16 | 16 | 10 | 10 | 63 |
| 2004 | 15 | 17 | 7 | 8 | 53 |
| 2005 | 5 | 7 | 4 | 3 | 60 |
| 2006 | 9 | 8 | 9 | 9 | 100 |
| 2007 | 15 | 8 | 4 | 5 | 33 |
| 2008 | 16 | 15 | 15 | 15 | 94 |
| 2009 | 15 | 14 | 14 | 13 | 87 |
| 2010 | 11 | 11 | 8 | 8 | 73 |
| Totals | 224 | 214 | 108 | 104 | 46 |

**Table C5: Total number of trips that reported landing pale ghost shark, number of trips that reported landing pale ghost shark with zero daily processed catch and proportion with zero daily processed catch, for TCEPR forms for GSP 1–7 from 2000 to 2010.**

| | TCEPR | | | | TCEPR | | |
|---|---|---|---|---|---|---|---|
| GSP 1 | Total | Zero Trips | Proportion | GSP 5 | Total | Zero Trips | Proportion |
| 2000 | 145 | 37 | 0.26 | | 67 | 4 | 0.06 |
| 2001 | 160 | 31 | 0.19 | | 85 | 4 | 0.05 |
| 2002 | 148 | 25 | 0.17 | | 88 | 5 | 0.06 |
| 2003 | 198 | 42 | 0.21 | | 93 | - | - |
| 2004 | 166 | 35 | 0.21 | | 83 | 1 | 0.01 |
| 2005 | 153 | 45 | 0.29 | | 69 | 4 | 0.06 |
| 2006 | 148 | 40 | 0.27 | | 62 | 2 | 0.03 |
| 2007 | 189 | 40 | 0.21 | | 91 | 4 | 0.04 |
| 2008 | 189 | 36 | 0.19 | | 78 | 5 | 0.06 |
| 2009 | 166 | 26 | 0.16 | | 76 | 4 | 0.05 |
| 2010 | 163 | 23 | 0.14 | | 86 | 3 | 0.03 |

| | TCEPR | | |
|---|---|---|---|
| GSP 7 | Total | Zero trips | Proportion |
| 2000 | 34 | 7 | 0.21 |
| 2001 | 41 | 5 | 0.12 |
| 2002 | 44 | 7 | 0.16 |
| 2003 | 44 | 9 | 0.20 |
| 2004 | 35 | 2 | 0.06 |
| 2005 | 27 | 3 | 0.11 |
| 2006 | 40 | 1 | 0.03 |
| 2007 | 31 | 3 | 0.10 |
| 2008 | 35 | 2 | 0.06 |
| 2009 | 41 | 3 | 0.07 |
| 2010 | 24 | 1 | 0.04 |

**Table C6: Total processed catch (t) for each region from groomed and merged data for fishing years 2000 – 2010.**

| Year | ECNI | ECSI/CHAT | Sub-Antarctic | West Coast | Total |
|---|---|---|---|---|---|
| 2000 | 1 | 298 | 107 | 9 | 415 |
| 2001 | 9 | 1 042 | 435 | 9 | 1 496 |
| 2002 | 1 | 997 | 514 | 19 | 1 531 |
| 2003 | 3 | 1 196 | 583 | 10 | 1 792 |
| 2004 | 2 | 973 | 448 | 7 | 1 430 |
| 2005 | 2 | 600 | 220 | 4 | 826 |
| 2006 | 1 | 540 | 120 | 9 | 670 |
| 2007 | 2 | 526 | 207 | 4 | 739 |
| 2008 | 5 | 458 | 237 | 15 | 716 |
| 2009 | 1 | 458 | 195 | 14 | 668 |
| 2010 | 2 | 1 098 | 192 | 8 | 1 300 |
| Total | 28 | 8 187 | 3 259 | 108 | 11 582 |

**Table C7: Total catch (t) by vessel nationality from groomed and merged data for fishing years 2000–2010.**

| Year | NZ | Korea | Panama | Cyprus | Malta | Japan | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 343 | 11 | 32 | 27 | - | - | 2 | 415 |
| 2001 | 1 137 | 52 | 168 | 76 | 1 | 61 | - | 1 496 |
| 2002 | 1 190 | 86 | 134 | 76 | 4 | 40 | - | 1 531 |
| 2003 | 1 444 | 73 | 124 | 60 | 41 | 50 | - | 1 792 |
| 2004 | 1 202 | 82 | 108 | 2 | 34 | 2 | - | 1 430 |
| 2005 | 673 | 65 | 72 | - | 14 | 2 | - | 826 |
| 2006 | 537 | 21 | 79 | - | 30 | 2 | - | 670 |
| 2007 | 569 | 147 | - | - | 22 | - | - | 739 |
| 2008 | 551 | 141 | - | - | 21 | 3 | - | 716 |
| 2009 | 448 | 218 | - | - | - | 2 | - | 668 |
| 2010 | 1 137 | 161 | - | - | - | 2 | - | 1 300 |
| Total | 9 231 | 1 057 | 718 | 241 | 167 | 164 | 3 | 11 582 |

**Table C8a: Proportion of pale ghost shark catch reported each month from the ECSI/CHAT area for fishing years 2000–2010.**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0.13 | 0.12 | 0.09 | 0.12 | 0.08 | 0.12 | 0.10 | 0.06 | 0.05 | 0.01 | - | 0.13 | 298 |
| 2001 | 0.12 | 0.09 | 0.09 | 0.13 | 0.1 | 0.18 | 0.09 | 0.06 | 0.06 | 0.02 | - | 0.07 | 1 042 |
| 2002 | 0.11 | 0.05 | 0.07 | 0.15 | 0.09 | 0.11 | 0.11 | 0.14 | 0.06 | 0.02 | - | 0.09 | 997 |
| 2003 | 0.13 | 0.08 | 0.07 | 0.09 | 0.11 | 0.10 | 0.10 | 0.14 | 0.06 | 0.03 | - | 0.07 | 1 196 |
| 2004 | 0.05 | 0.07 | 0.13 | 0.13 | 0.04 | 0.08 | 0.11 | 0.13 | 0.07 | 0.06 | 0.05 | 0.08 | 973 |
| 2005 | 0.09 | 0.12 | 0.13 | 0.12 | 0.12 | 0.11 | 0.06 | 0.11 | 0.08 | 0.03 | 0.01 | 0.04 | 600 |
| 2006 | 0.11 | 0.12 | 0.12 | 0.11 | 0.05 | 0.08 | 0.10 | 0.16 | 0.10 | 0.04 | 0.01 | 0.01 | 540 |
| 2007 | 0.06 | 0.09 | 0.09 | 0.10 | 0.11 | 0.12 | 0.11 | 0.13 | 0.08 | 0.02 | 0.03 | 0.06 | 526 |
| 2008 | 0.04 | 0.05 | 0.13 | 0.16 | 0.07 | 0.07 | 0.12 | 0.15 | 0.07 | 0.07 | 0.03 | 0.04 | 458 |
| 2009 | 0.12 | 0.12 | 0.11 | 0.15 | 0.09 | 0.11 | 0.08 | 0.09 | 0.06 | 0.02 | 0.02 | 0.02 | 458 |
| 2010 | 0.05 | 0.06 | 0.05 | 0.07 | 0.29 | 0.34 | 0.03 | 0.03 | 0.04 | 0.02 | 0.01 | 0.01 | 1 098 |
| Total | 0.09 | 0.08 | 0.09 | 0.12 | 0.11 | 0.14 | 0.09 | 0.11 | 0.06 | 0.03 | 0.01 | 0.05 | 8 187 |

**Table C8b: Proportion of pale ghost shark catch reported for each statistical area from the ECSI/CHAT area for fishing years 2000–2010.**

| Year | 020 | 021 | 022 | 023 | 401 | 402 | 407 | 408 | 409 | 410 | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0.17 | 0.03 | 0.16 | 0.17 | 0.07 | 0.05 | 0.07 | 0.11 | 0.06 | 0.04 | 0.08 | 298 |
| 2001 | 0.16 | 0.04 | 0.10 | 0.24 | 0.06 | 0.04 | 0.11 | 0.08 | 0.05 | 0.02 | 0.11 | 1 042 |
| 2002 | 0.20 | 0.03 | 0.03 | 0.26 | 0.05 | 0.05 | 0.10 | 0.10 | 0.05 | 0.04 | 0.09 | 997 |
| 2003 | 0.17 | 0.04 | 0.07 | 0.22 | 0.07 | 0.04 | 0.11 | 0.10 | 0.07 | 0.03 | 0.08 | 1 196 |
| 2004 | 0.26 | 0.03 | 0.07 | 0.18 | 0.05 | 0.05 | 0.05 | 0.11 | 0.08 | 0.05 | 0.09 | 973 |
| 2005 | 0.21 | 0.01 | 0.07 | 0.18 | 0.04 | 0.03 | 0.09 | 0.16 | 0.07 | 0.05 | 0.09 | 600 |
| 2006 | 0.20 | 0.02 | 0.12 | 0.25 | 0.04 | 0.05 | 0.08 | 0.14 | 0.04 | 0.03 | 0.04 | 540 |
| 2007 | 0.17 | 0.02 | 0.11 | 0.25 | 0.03 | 0.07 | 0.06 | 0.09 | 0.07 | 0.03 | 0.11 | 526 |
| 2008 | 0.22 | 0.03 | 0.08 | 0.17 | 0.03 | 0.05 | 0.04 | 0.12 | 0.07 | 0.05 | 0.15 | 458 |
| 2009 | 0.29 | 0.01 | 0.14 | 0.18 | 0.02 | 0.03 | 0.03 | 0.11 | 0.05 | 0.04 | 0.10 | 458 |
| 2010 | 0.14 | 0.01 | 0.06 | 0.34 | 0.01 | 0.01 | 0.09 | 0.17 | 0.09 | 0.04 | 0.04 | 1 098 |
| Total | 0.19 | 0.03 | 0.08 | 0.23 | 0.04 | 0.04 | 0.08 | 0.12 | 0.06 | 0.04 | 0.08 | 8 187 |

**Table C8c: Proportion of pale ghost shark catch reported by gear type from the ECSI/CHAT area for fishing years 2000–2010. NB: The category 'Other' includes fishing days where method was either midwater trawl or an even split of midwater and bottom trawling.**

| Year | BT | Other | Total |
|---|---|---|---|
| 2000 | 0.99 | 0.01 | 298 |
| 2001 | 0.99 | 0.01 | 1 042 |
| 2002 | 1.00 | - | 997 |
| 2003 | 0.99 | 0.01 | 1 196 |
| 2004 | 1.00 | - | 973 |
| 2005 | 0.99 | 0.01 | 600 |
| 2006 | 1.00 | - | 540 |
| 2007 | 1.00 | - | 526 |
| 2008 | 1.00 | - | 458 |
| 2009 | 1.00 | - | 458 |
| 2010 | 1.00 | - | 1 098 |
| Total | >0.99 | <0.01 | 8 187 |

**Table C8d: Proportion of pale ghost shark catch reported by target species from the ECSI/CHAT area for fishing years 2000–2010.**

| Year | HAK | HOK | SWA | Other | Total |
|---|---|---|---|---|---|
| 2000 | - | 0.98 | - | 0.02 | 298 |
| 2001 | 0.01 | 0.97 | - | 0.02 | 1 042 |
| 2002 | 0.01 | 0.97 | - | 0.02 | 997 |
| 2003 | 0.01 | 0.98 | - | 0.02 | 1 196 |
| 2004 | 0.03 | 0.95 | - | 0.02 | 973 |
| 2005 | 0.03 | 0.93 | 0.01 | 0.03 | 600 |
| 2006 | - | 0.96 | 0.01 | 0.03 | 540 |
| 2007 | 0.03 | 0.88 | 0.02 | 0.07 | 526 |
| 2008 | 0.03 | 0.81 | 0.06 | 0.09 | 458 |
| 2009 | 0.06 | 0.73 | 0.08 | 0.13 | 458 |
| 2010 | - | 0.93 | 0.02 | 0.05 | 1 098 |
| Total | 0.02 | 0.93 | 0.01 | 0.04 | 8 187 |

**Table C9a: Proportion of pale ghost shark catch reported each month from the Sub-Antarctic area for fishing years 2000–2010.**

| Year | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0.07 | 0.04 | 0.08 | 0.08 | 0.06 | 0.14 | 0.23 | 0.20 | 0.06 | 0.01 | - | 0.03 | 107 |
| 2001 | 0.08 | 0.08 | 0.08 | 0.10 | 0.10 | 0.10 | 0.15 | 0.17 | 0.07 | - | - | 0.06 | 435 |
| 2002 | 0.03 | 0.11 | 0.18 | 0.12 | 0.11 | 0.09 | 0.11 | 0.10 | 0.08 | 0.01 | - | 0.07 | 514 |
| 2003 | 0.10 | 0.13 | 0.13 | 0.20 | 0.03 | 0.10 | 0.15 | 0.07 | 0.05 | - | - | 0.03 | 583 |
| 2004 | 0.20 | 0.15 | 0.05 | 0.11 | 0.11 | 0.03 | 0.09 | 0.11 | 0.11 | 0.01 | - | 0.03 | 448 |
| 2005 | 0.19 | 0.13 | 0.13 | 0.11 | 0.12 | 0.01 | 0.08 | 0.09 | 0.05 | 0.05 | - | 0.04 | 220 |
| 2006 | 0.19 | 0.02 | 0.05 | - | 0.01 | 0.13 | 0.10 | 0.15 | 0.17 | 0.06 | 0.02 | 0.10 | 120 |
| 2007 | 0.20 | 0.14 | 0.11 | 0.10 | 0.03 | 0.02 | 0.03 | 0.01 | 0.03 | 0.11 | 0.12 | 0.09 | 207 |
| 2008 | 0.15 | 0.11 | 0.23 | 0.11 | 0.08 | 0.12 | 0.01 | 0.03 | 0.04 | 0.01 | 0.03 | 0.07 | 237 |
| 2009 | 0.08 | 0.15 | 0.22 | 0.09 | 0.07 | 0.05 | 0.13 | 0.07 | 0.04 | 0.02 | 0.05 | 0.04 | 195 |
| 2010 | 0.21 | 0.08 | 0.09 | 0.07 | 0.07 | 0.11 | 0.10 | 0.11 | 0.06 | 0.02 | 0.02 | 0.05 | 192 |
| Total | 0.13 | 0.11 | 0.12 | 0.12 | 0.08 | 0.08 | 0.11 | 0.10 | 0.07 | 0.02 | 0.02 | 0.05 | 3 259 |

**Table C9b: Proportion of catch reported for each statistical area from the Sub-Antarctic area for fishing years 2000–2010.**

| Year | 027 | 028 | 602 | 603 | 610 | 618 | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 0.24 | 0.12 | 0.30 | 0.09 | 0.04 | 0.10 | 0.10 | 107 |
| 2001 | 0.17 | 0.12 | 0.31 | 0.19 | 0.09 | 0.05 | 0.06 | 435 |
| 2002 | 0.12 | 0.07 | 0.25 | 0.32 | 0.09 | 0.06 | 0.08 | 514 |
| 2003 | 0.10 | 0.05 | 0.21 | 0.38 | 0.06 | 0.14 | 0.06 | 583 |
| 2004 | 0.07 | 0.06 | 0.27 | 0.43 | 0.05 | 0.07 | 0.05 | 448 |
| 2005 | 0.10 | 0.12 | 0.23 | 0.35 | 0.07 | 0.04 | 0.10 | 220 |
| 2006 | 0.28 | 0.12 | 0.26 | 0.19 | 0.03 | 0.01 | 0.11 | 120 |
| 2007 | 0.23 | 0.10 | 0.16 | 0.39 | 0.07 | - | 0.05 | 207 |
| 2008 | 0.20 | 0.08 | 0.18 | 0.41 | 0.09 | - | 0.04 | 237 |
| 2009 | 0.23 | 0.10 | 0.14 | 0.38 | 0.08 | - | 0.07 | 195 |
| 2010 | 0.20 | 0.12 | 0.14 | 0.34 | 0.11 | - | 0.09 | 192 |
| Total | 0.15 | 0.09 | 0.23 | 0.33 | 0.07 | 0.06 | 0.07 | 3 259 |

**Table C9c: Proportion of pale ghost shark catch reported by gear type from the Sub-Antarctic area for fishing years 2000–2010.**

| Year | BT | Other | Total |
|---|---|---|---|
| 2000 | 1.00 | - | 107 |
| 2001 | 1.00 | - | 435 |
| 2002 | 1.00 | - | 514 |
| 2003 | 1.00 | - | 583 |
| 2004 | 1.00 | - | 448 |
| 2005 | 0.99 | 0.01 | 220 |
| 2006 | 0.99 | 0.01 | 120 |
| 2007 | 1.00 | - | 207 |
| 2008 | 1.00 | - | 237 |
| 2009 | 0.99 | 0.01 | 195 |
| 2010 | 1.00 | - | 192 |
| Total | >0.99 | <0.01 | 3 259 |

**Table C9d: Proportion of pale ghost shark catch reported by target species from the Sub-Antarctic area for fishing years 2000–2010.**

| Year | HOK | LIN | Other | Total |
|---|---|---|---|---|
| 2000 | 0.97 | 0.02 | 0.01 | 107 |
| 2001 | 0.94 | 0.05 | 0.01 | 435 |
| 2002 | 0.94 | 0.03 | 0.03 | 514 |
| 2003 | 0.92 | 0.02 | 0.05 | 583 |
| 2004 | 0.90 | 0.05 | 0.05 | 448 |
| 2005 | 0.79 | 0.12 | 0.10 | 220 |
| 2006 | 0.73 | 0.18 | 0.09 | 120 |
| 2007 | 0.45 | 0.38 | 0.17 | 207 |
| 2008 | 0.62 | 0.30 | 0.08 | 237 |
| 2009 | 0.56 | 0.23 | 0.21 | 195 |
| 2010 | 0.72 | 0.09 | 0.18 | 192 |
| Total | 0.82 | 0.10 | 0.07 | 3 259 |

**Table C10: Species codes used in the report.**

| Code | Common name | Scientific name |
|---|---|---|
| GSP | Pale ghost shark | *Hydrolagus bemisi* |
| HAK | Hake | *Merluccius australis* |
| HOK | Hoki | *Macruronus novaezelandiae* |
| LIN | Ling | *Genypterus blacodes* |
| SWA | Silver warehou | *Seriolella punctata* |

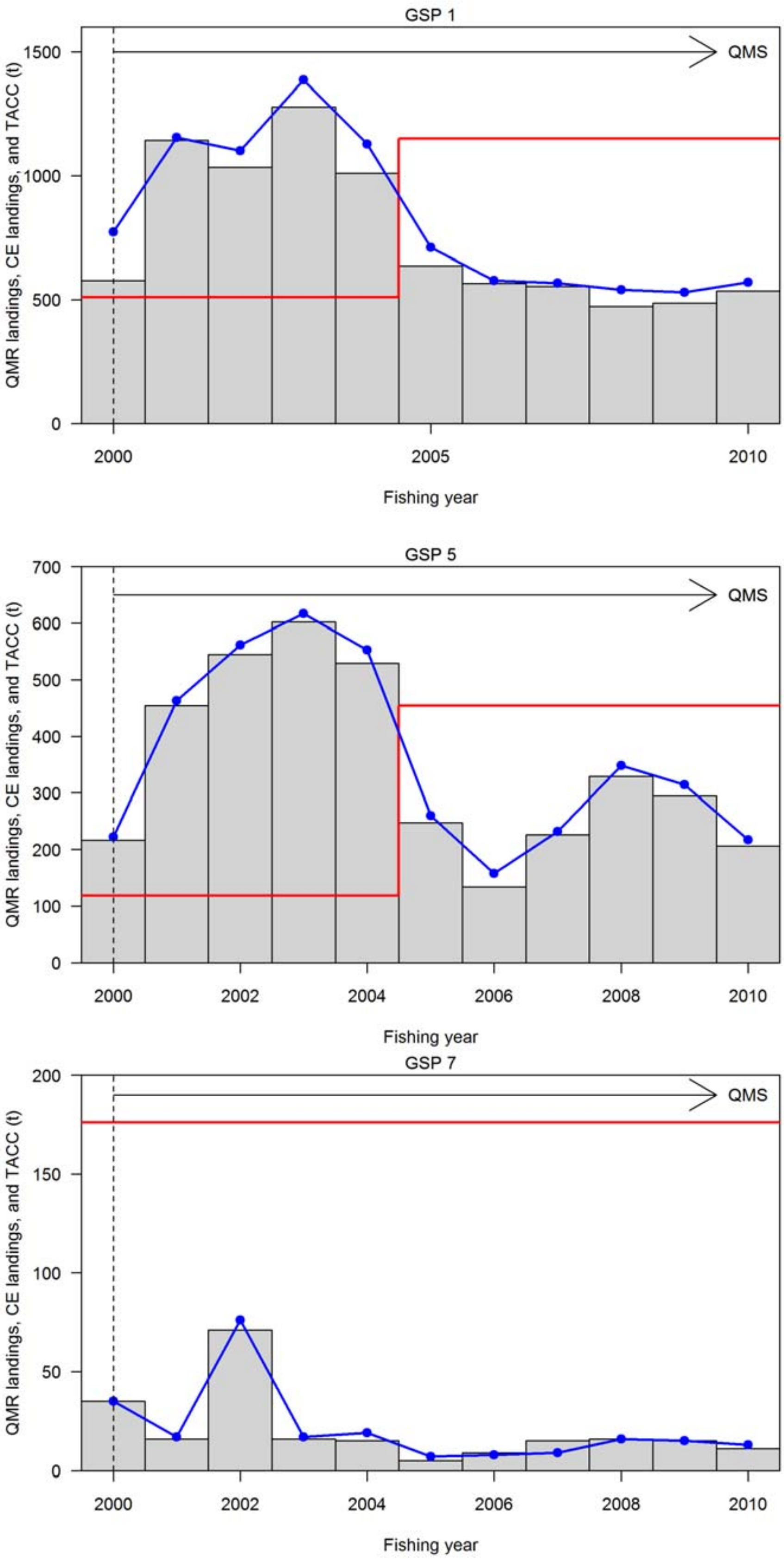



**Figure C1:The QMR/MHR landings (gray bars), un-groomed catch effort landings (dotted blue line), and TACC (red line) for GSP 1, 5 and 7 from the 2000 to 2010 fishing year.**

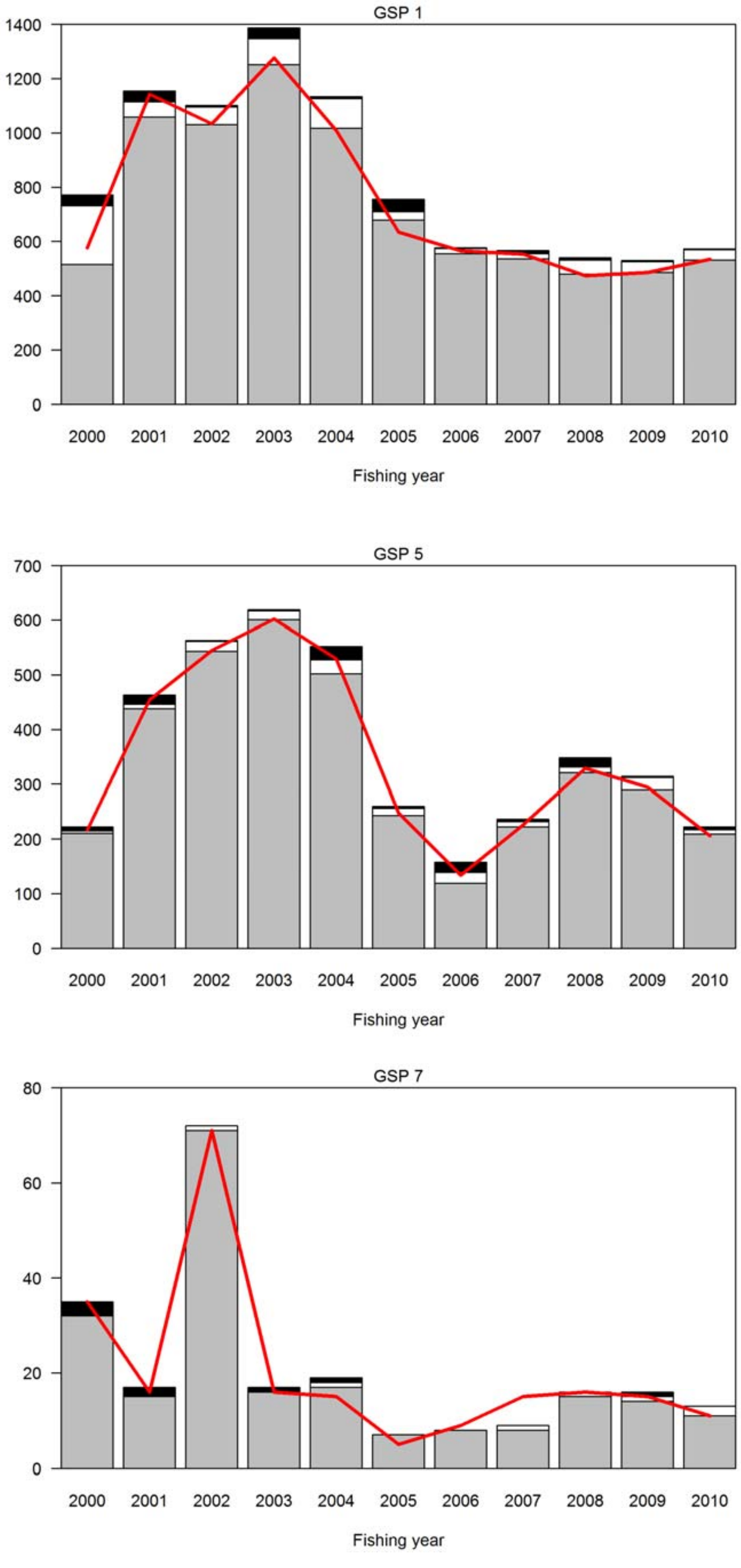



**Figure C2: The retained landings (gray bars), interim landings (white bars), and landings dropped during data grooming (black bars), and MHR landings (red line) for GSP 1, 5, and 7 from the 2000 to 2010 fishing year.**

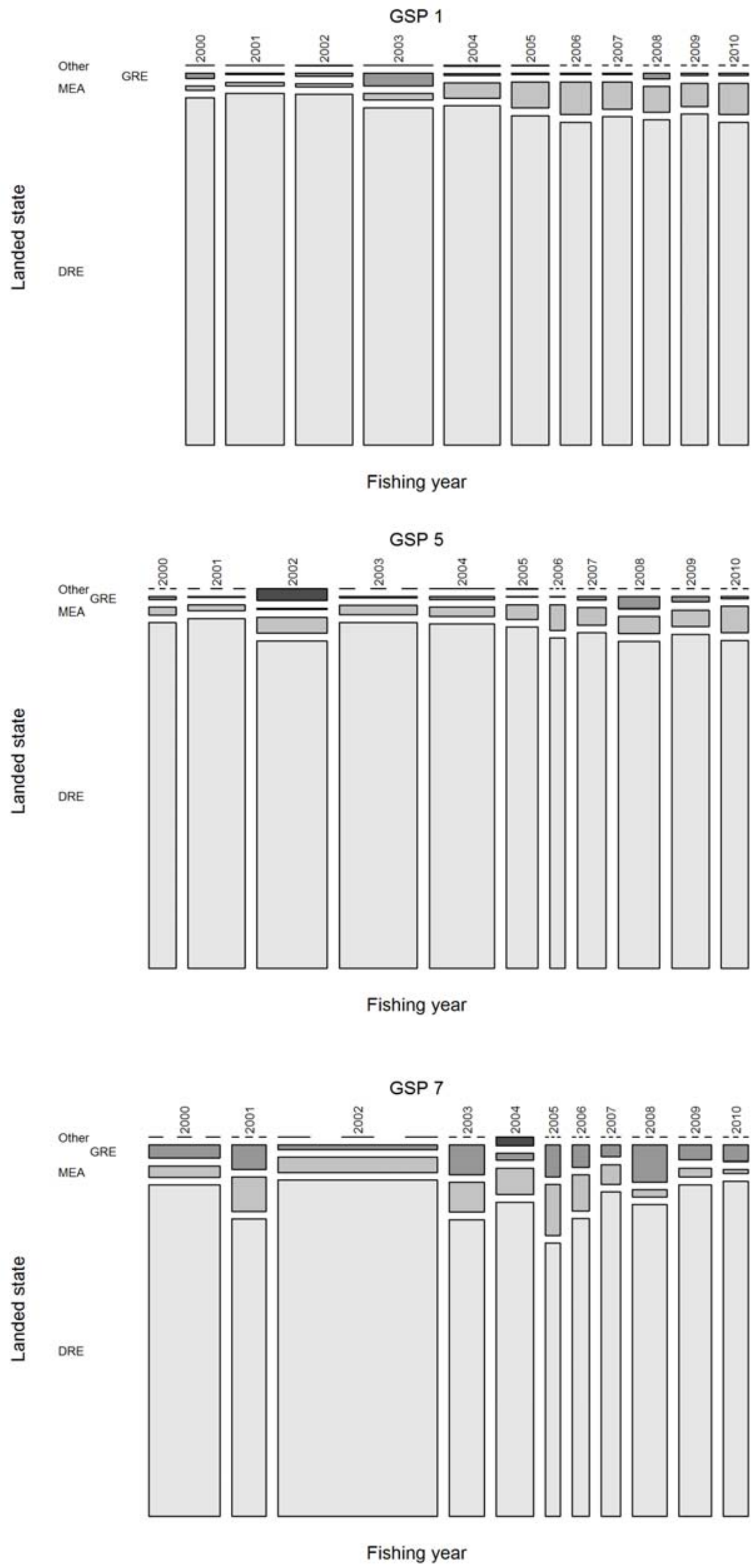



**Figure C3: The proportion of retained landings (greenweight) by processed state for GSP 1, 5, and 7 from the 2000 to 2010 fishing year in the groomed and unmerged dataset. GRE = "Green"; MEA = "Mealed"; DRE = "Dressed" and also includes "Headed, gutted, and tailed", Other = All other processed states.**

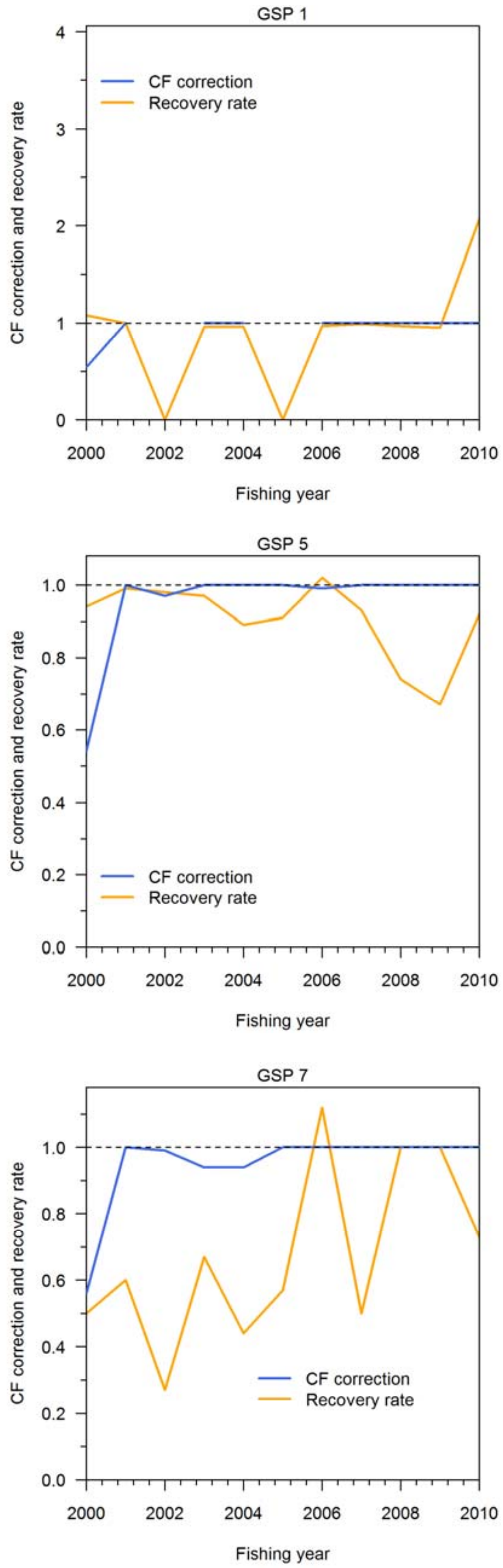



**Figure C4: Conversion factor (CF) corrections, defined as the ratio of annual green weight recalculated using the most recent correction factors for each processed state to the reported green weight, and the recovery rate, defined as the ratio of annual landings in the groomed and merged dataset to those in the groomed and unmerged dataset, for GSP 1, 5, and 7 from the 2000 to 2010 fishing year.**

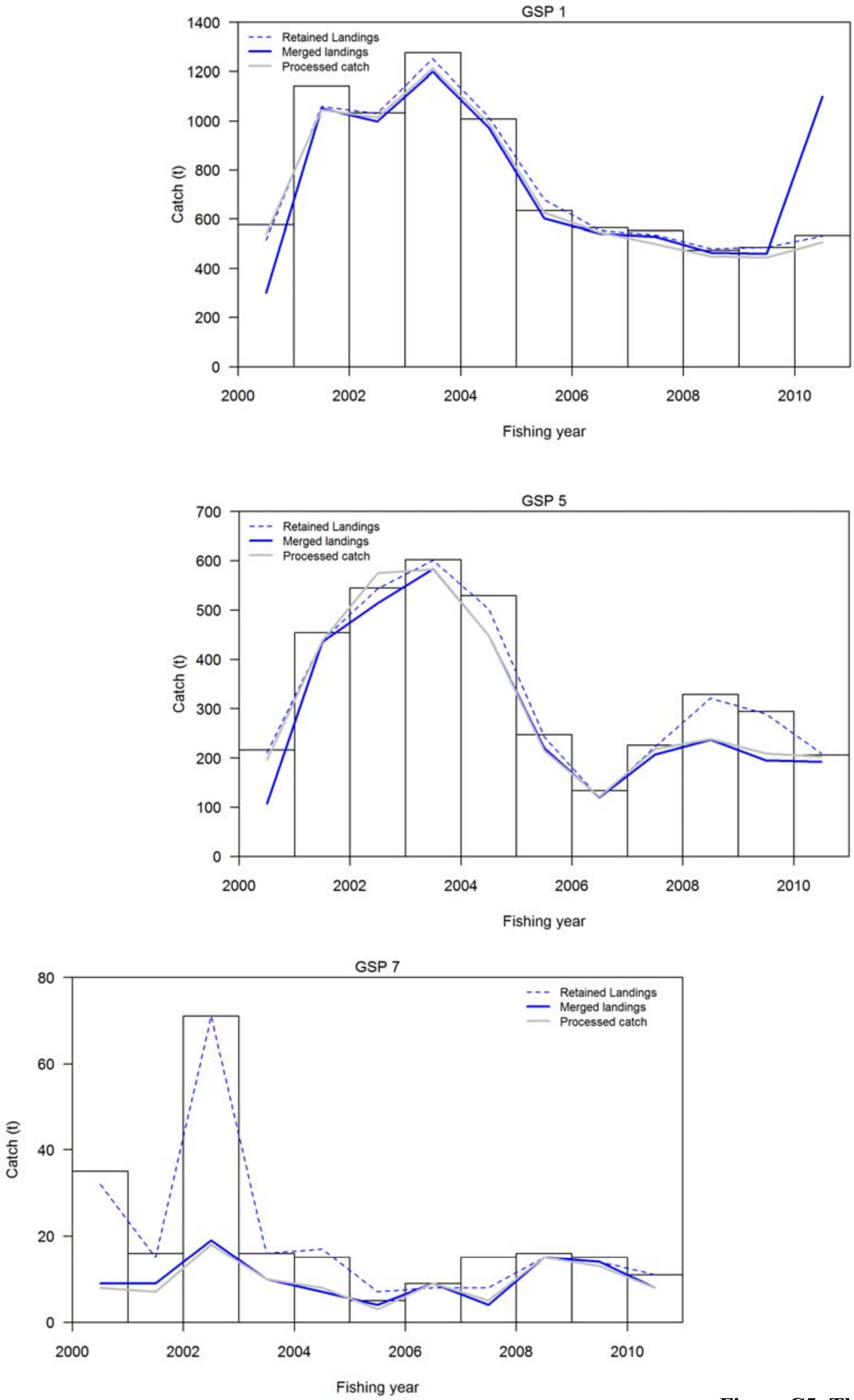



**Figure C5: The QMR/MHR landings (white bars), retained landings in the groomed and unmerged dataset (green dashed line), retained landings in groomed and merged dataset (green solid line), and daily processed catch in the groomed and merged dataset (red solid line), using the centroid method, for GSP 1–7 from the 2000 to 2010 fishing year.**

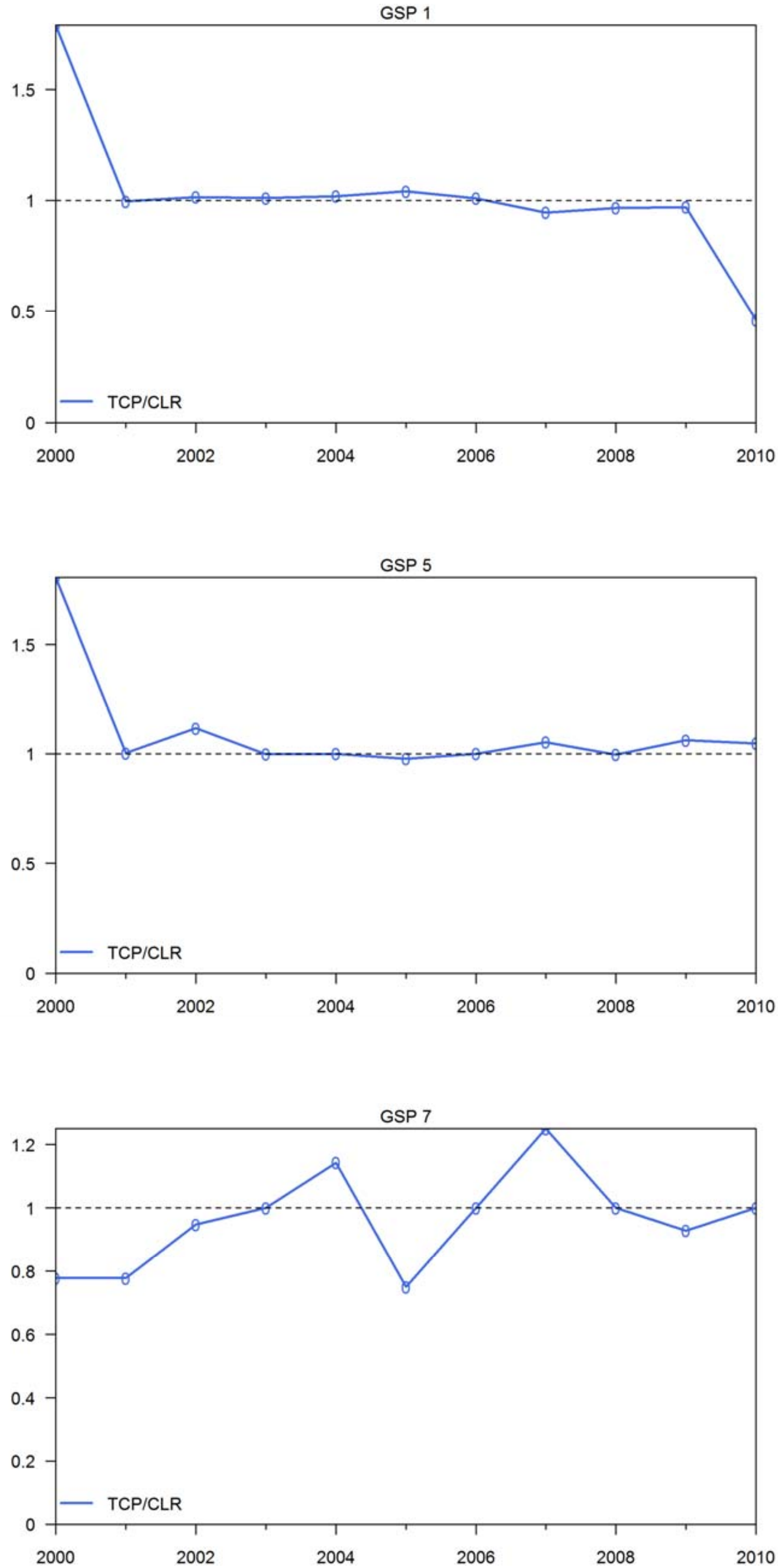
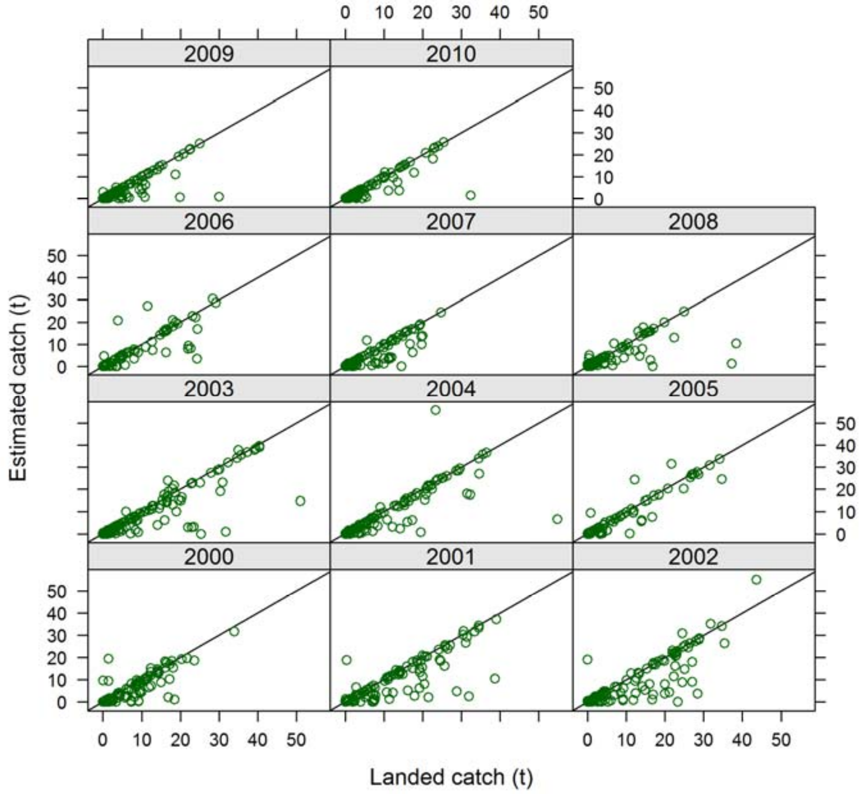



**Figure C6: The reporting rate, defined as the ratio of greenweight calculated from annual processed catch as a proportion of retained landings in the groomed and merged dataset, for GSP 1, 5, and 7 from the 2000 to 2010 fishing year.**



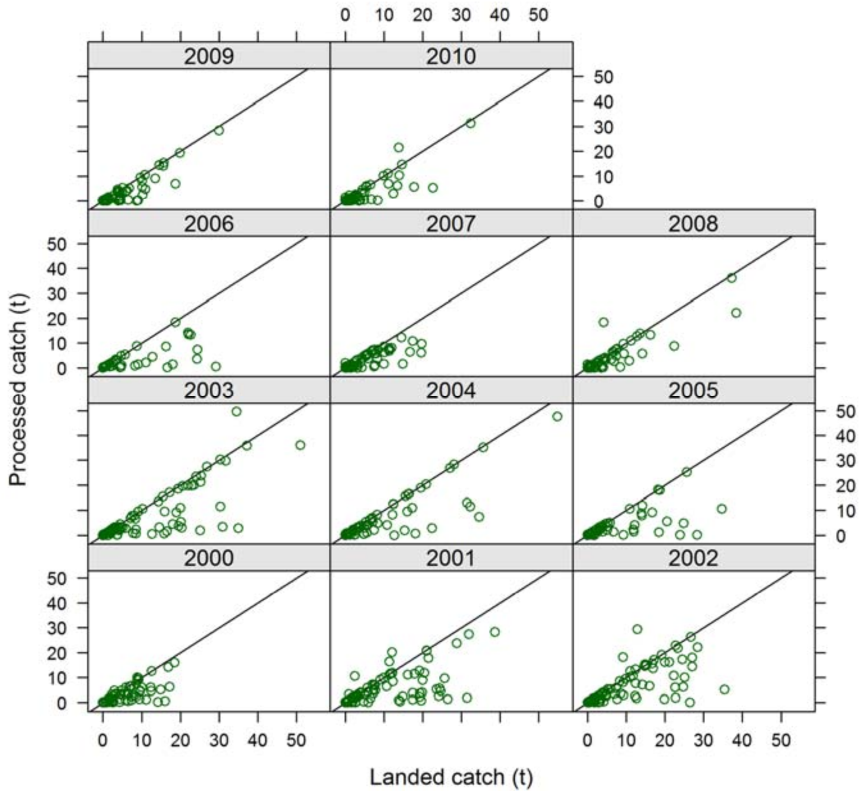




**Figure C7: Processed catch versus reported landings on a trip basis in the groomed and merged dataset, for GSP 1 (top) and GSP 5 (bottom) from the 2000 to 2010 fishing year.**

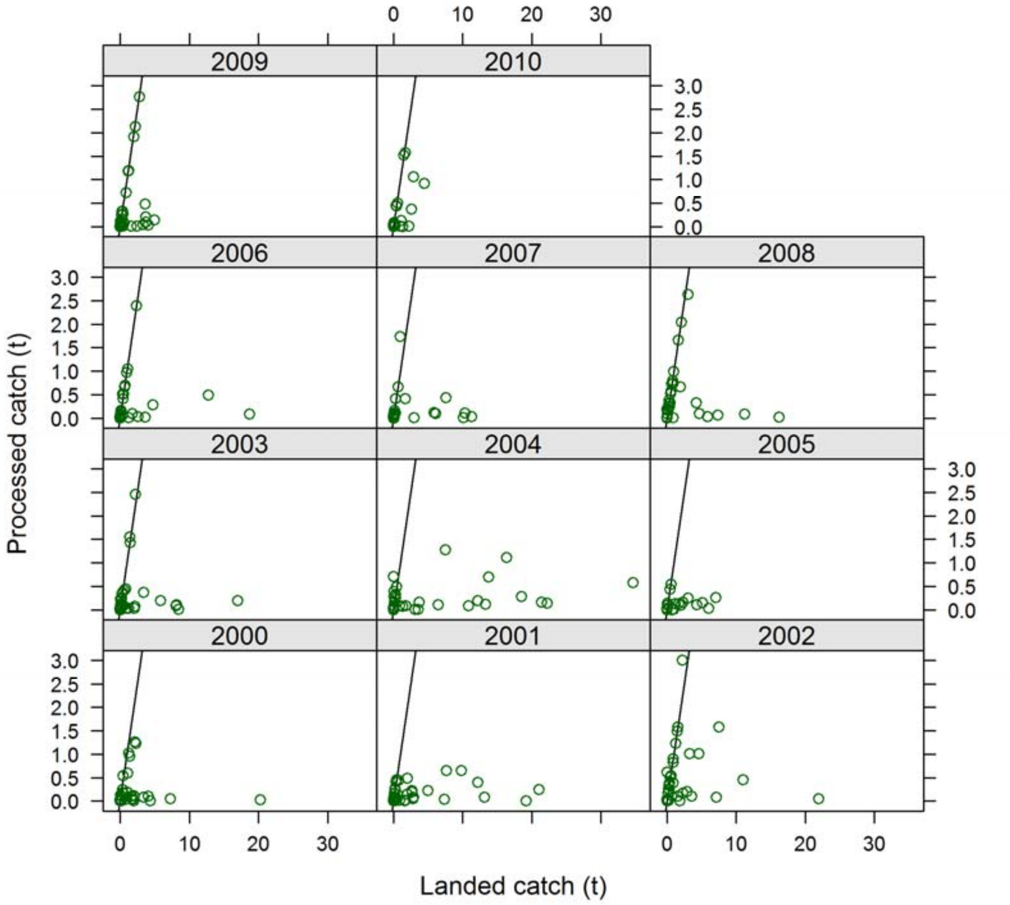



**Figure C7 continued: Processed catch versus reported landings on a trip basis in the groomed and merged dataset, for GSP 7 from the 2000 to 2010 fishing year.**

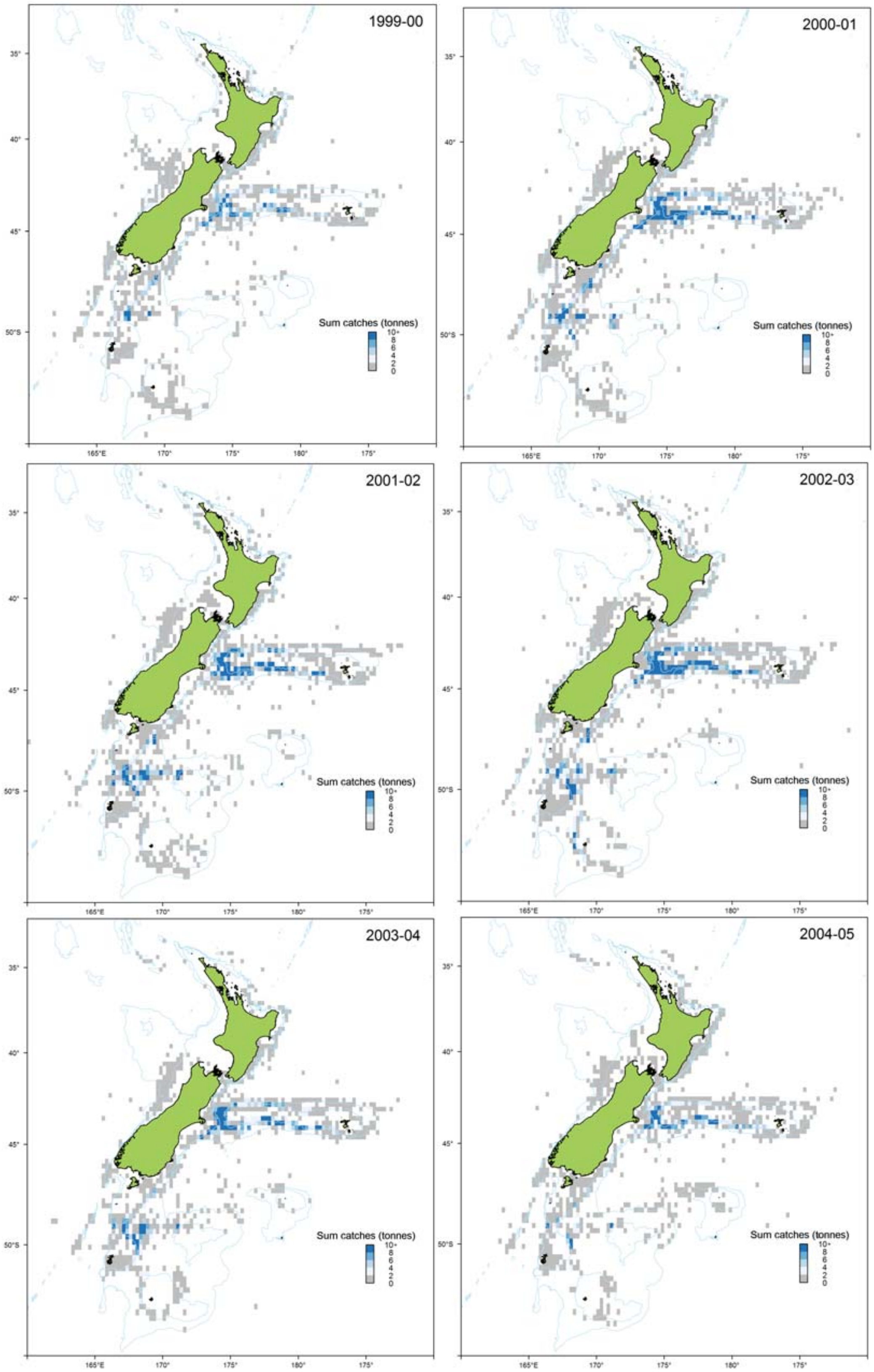



**Figure C8: Annual catch (in tonnes) of all commercial pale ghost shark catches from TCEPR records by fishing year (1 October to 30 September) 2000 to 2010.**

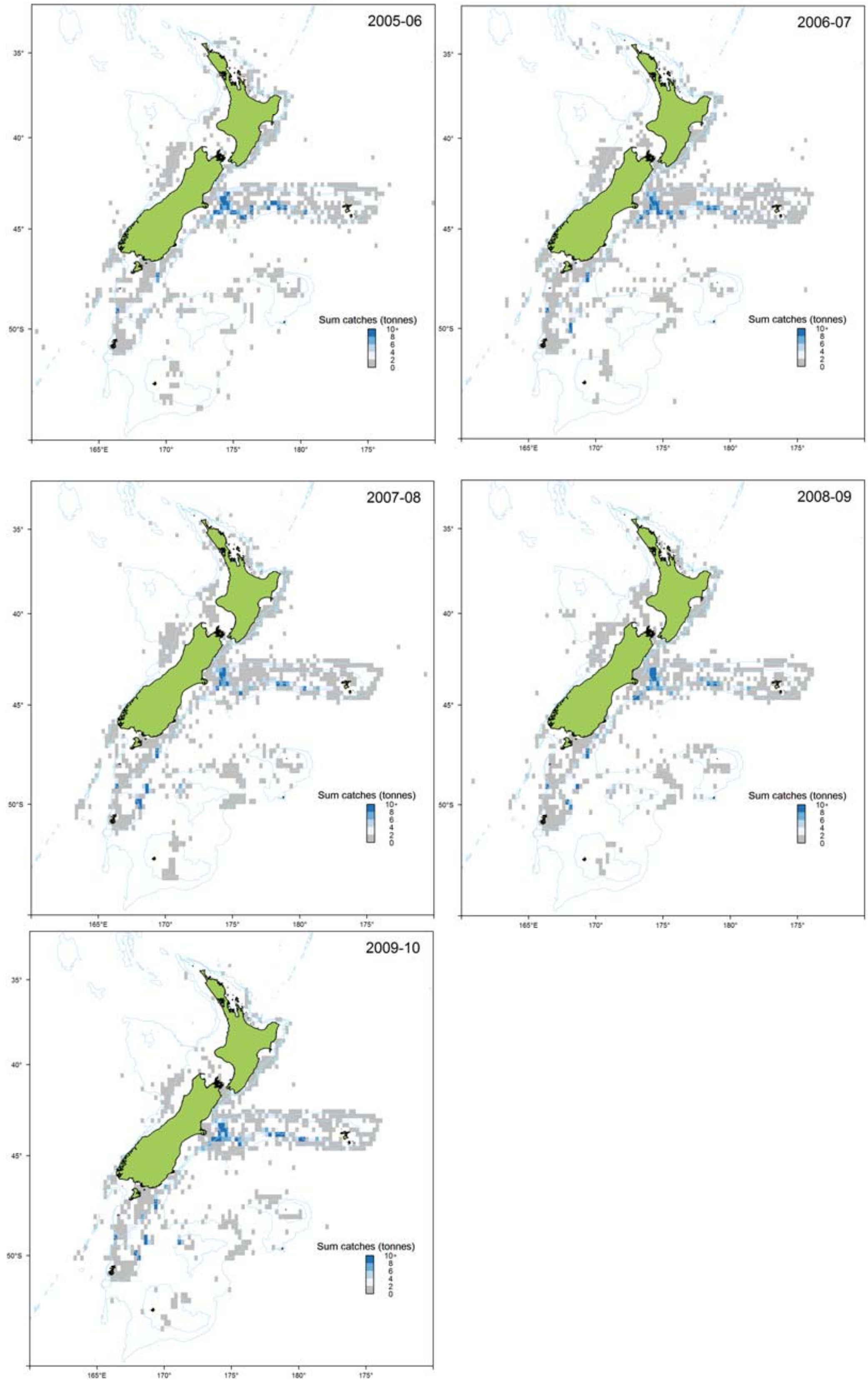



**Figure C8 continued.**

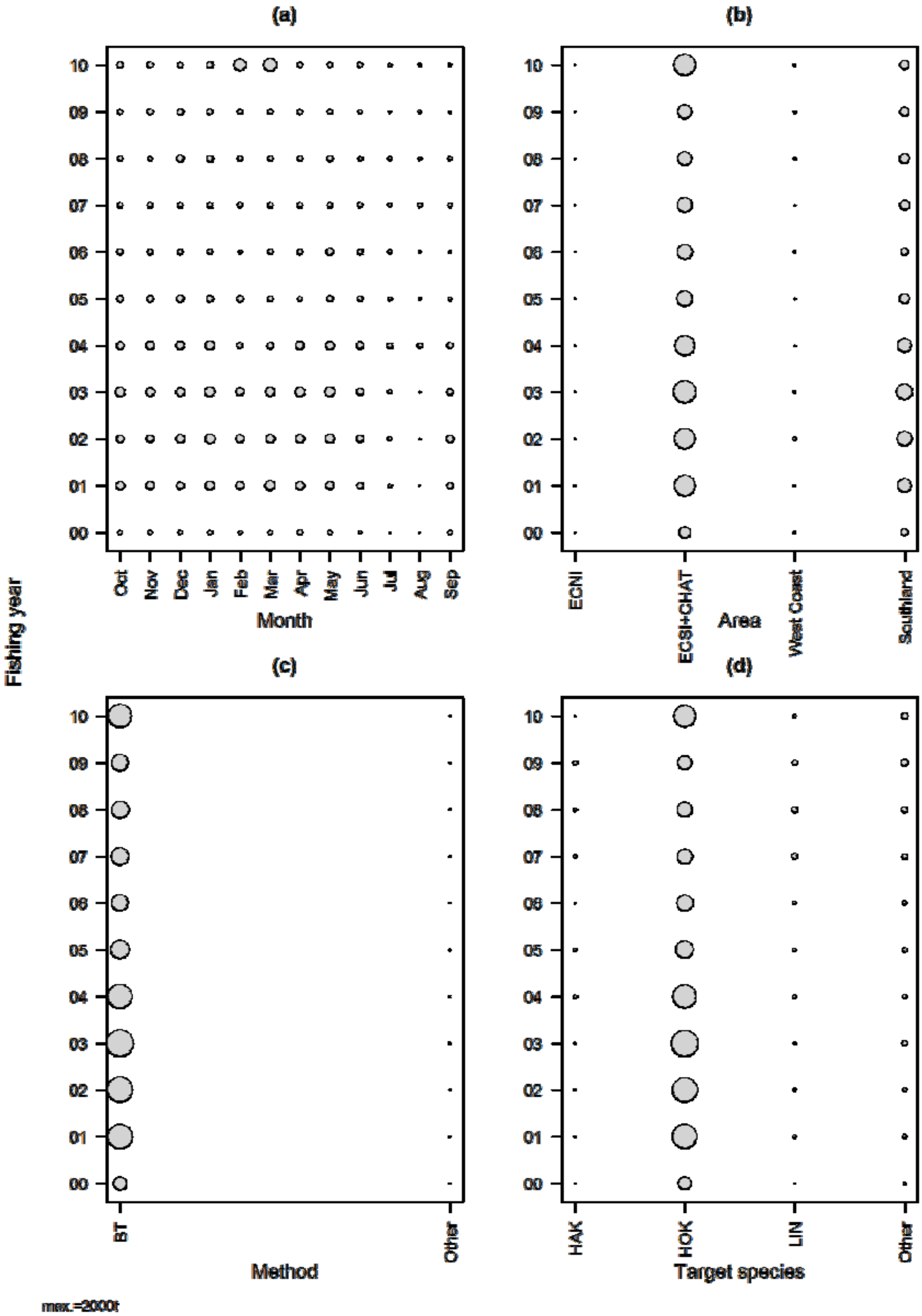



**Figure C9: Distribution of annual catch by month, area, method, and target species for all merged data. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**

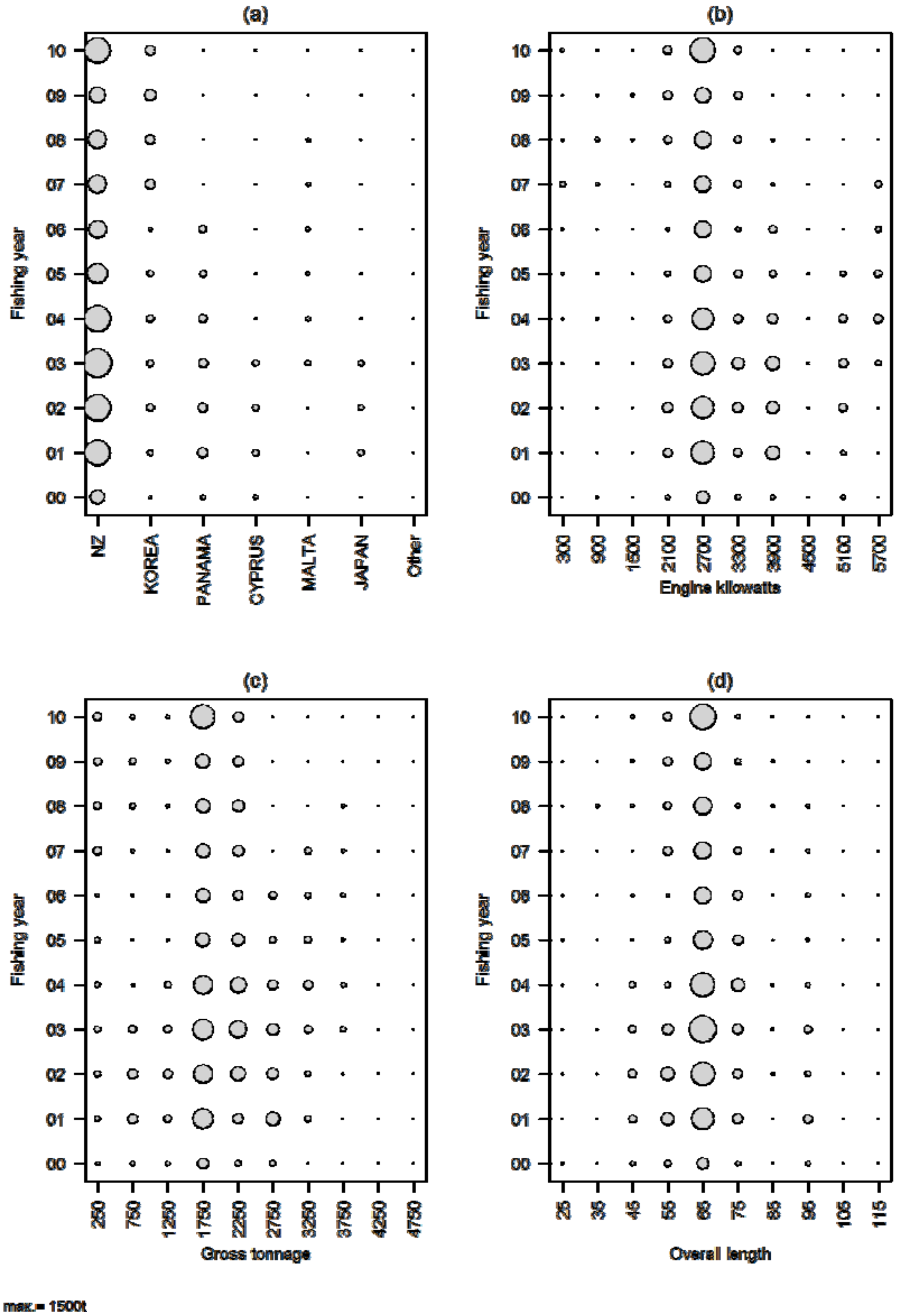



**Figure C10: Distribution of annual catch by nationality, vessel power, gross tonnage, and length (m) for all merged data. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**

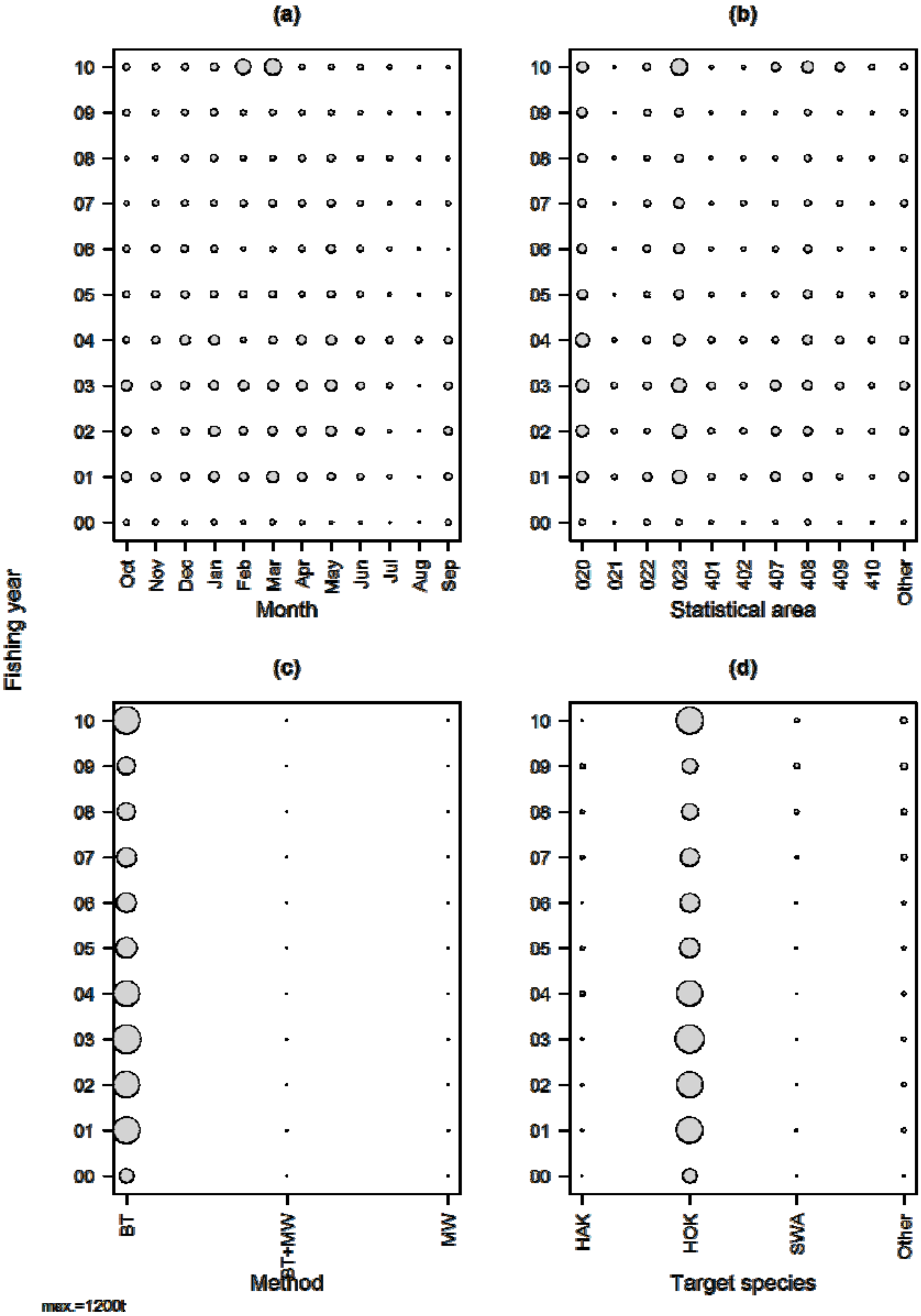



**Figure C11: Distribution of annual catch by month, statistical area, method, and target species for ECSI/CHAT merged data. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner. NB: BT+MW fishing method are days where there was an even split between the number of bottom and midwater tows.**

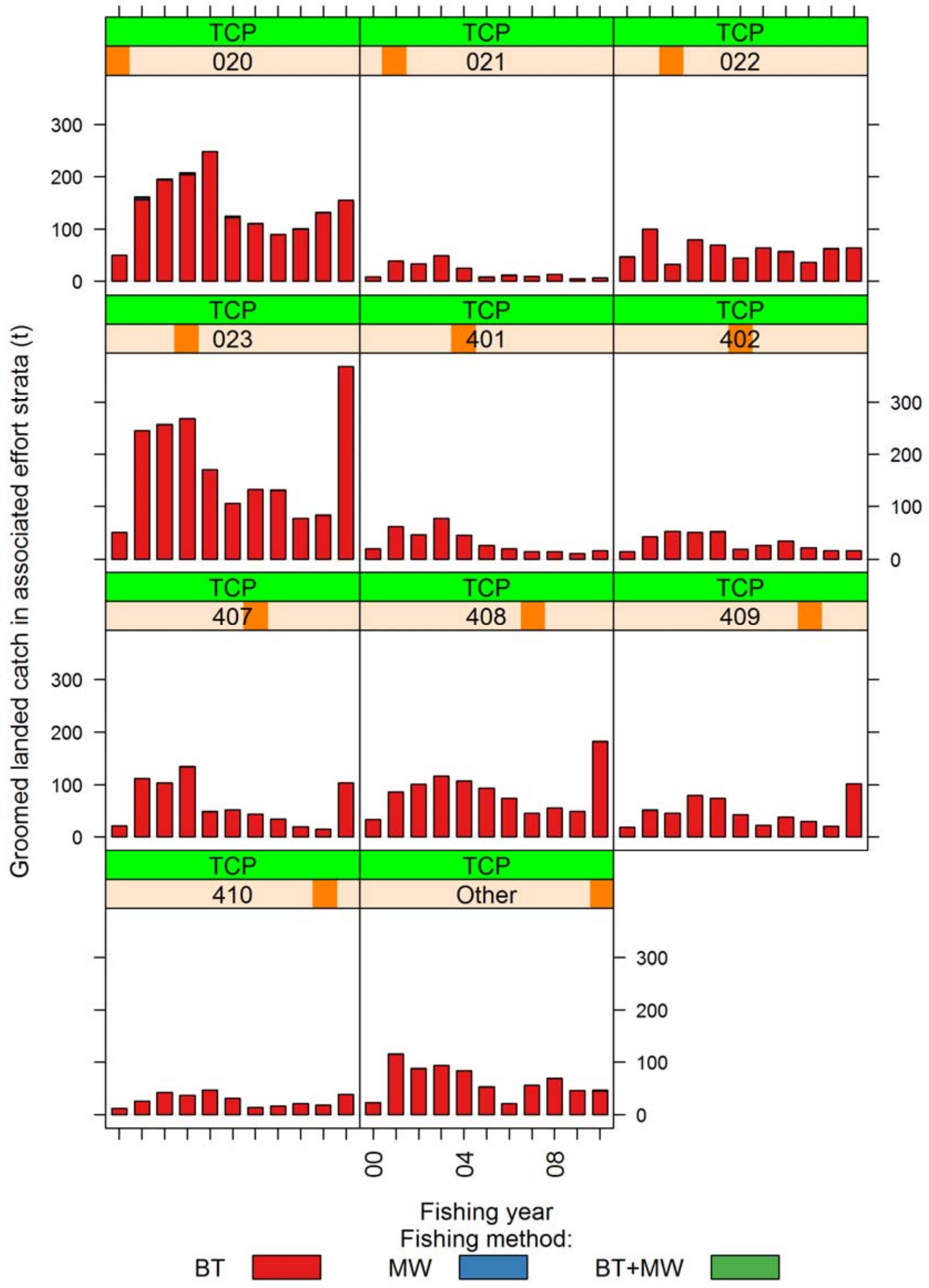



**Figure C12a: Distribution of pale ghost shark catch in the ECSI/CHAT region in relation to form type and statistical area for fishing years 2000–2010 taken by midwater and bottom trawl gear. NB: BT+MW fishing method are days where there was an even split between the number of bottom and midwater tows.**

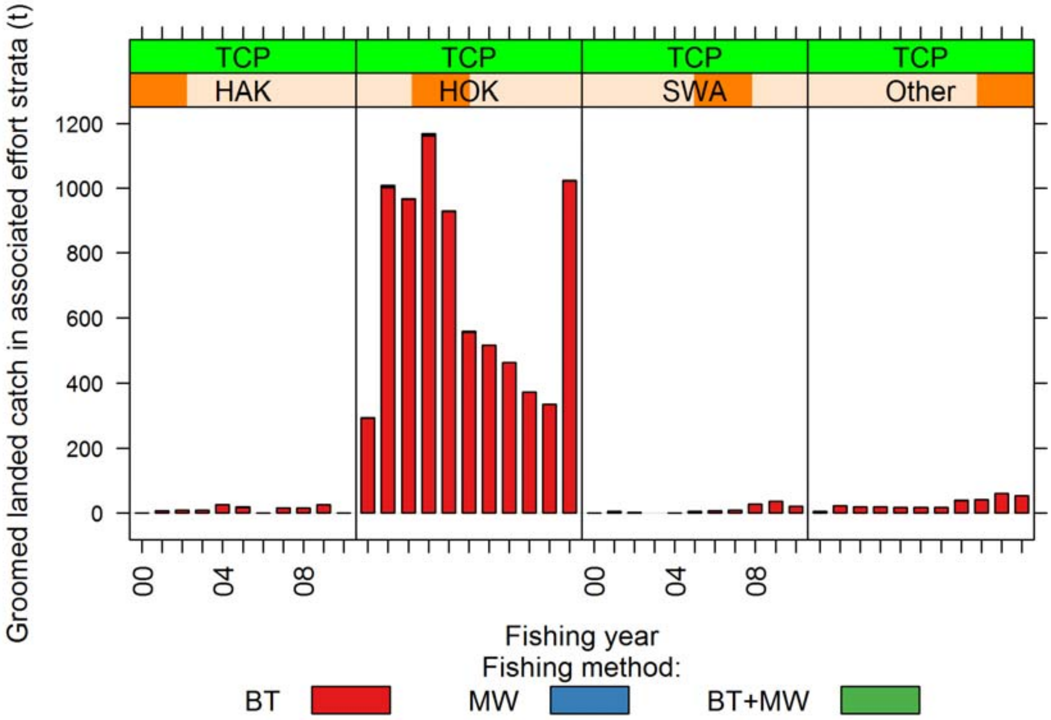



**Figure C12b: Distribution of pale ghost shark catch in the ECSI/CHAT region in relation to form type and target species for fishing years 2000–2010 taken by midwater and bottom trawl gear. NB: BT+MW fishing method are days where there was an even split between the number of bottom and midwater tows.**

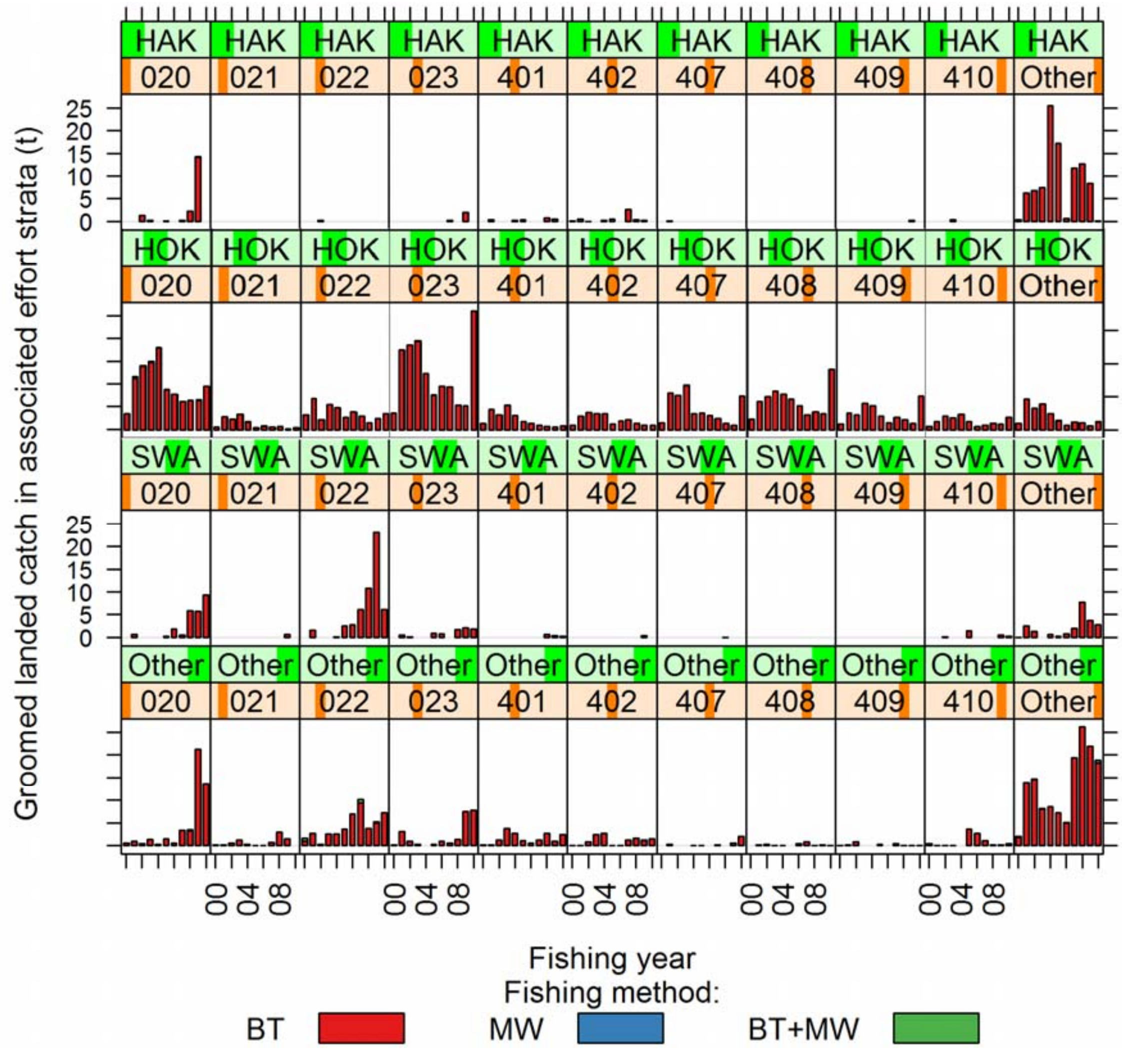



**Figure C12c: Distribution of pale ghost shark catch in the ECSI/CHAT region in relation to target species and statistical area by fishing method for fishing years 2000–2010 taken by midwater and bottom trawl gear. NB: BT+MW fishing method are days where there was an even split between the number of bottom and midwater tows. Note the difference in scale for the y-axis in HOK.**

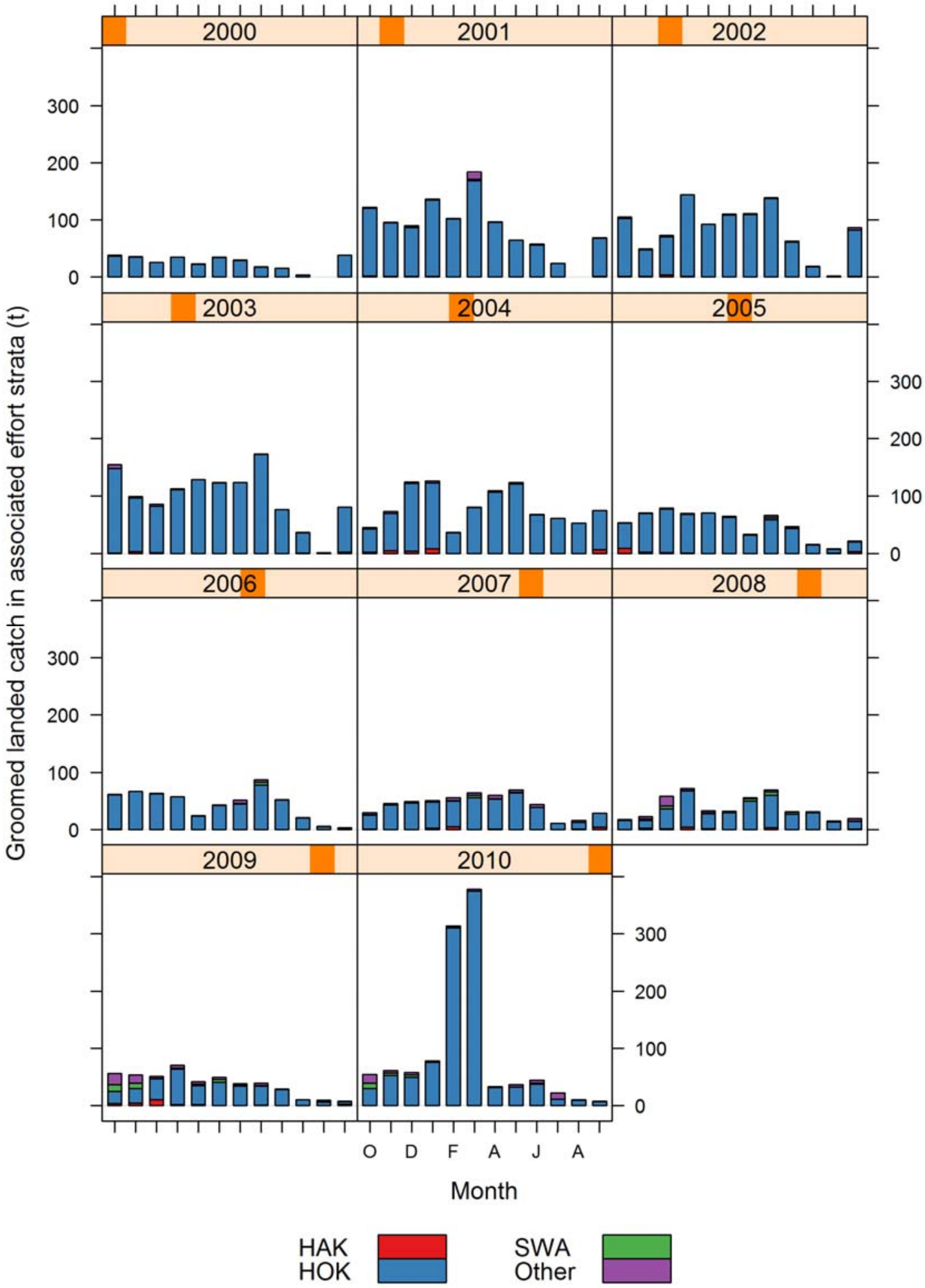



**Figure C12d: Distribution of pale ghost shark catch in the ECSI/CHAT region in relation to fishing year, month, and target species for fishing years 2000–2010 taken by bottom trawl gear.**

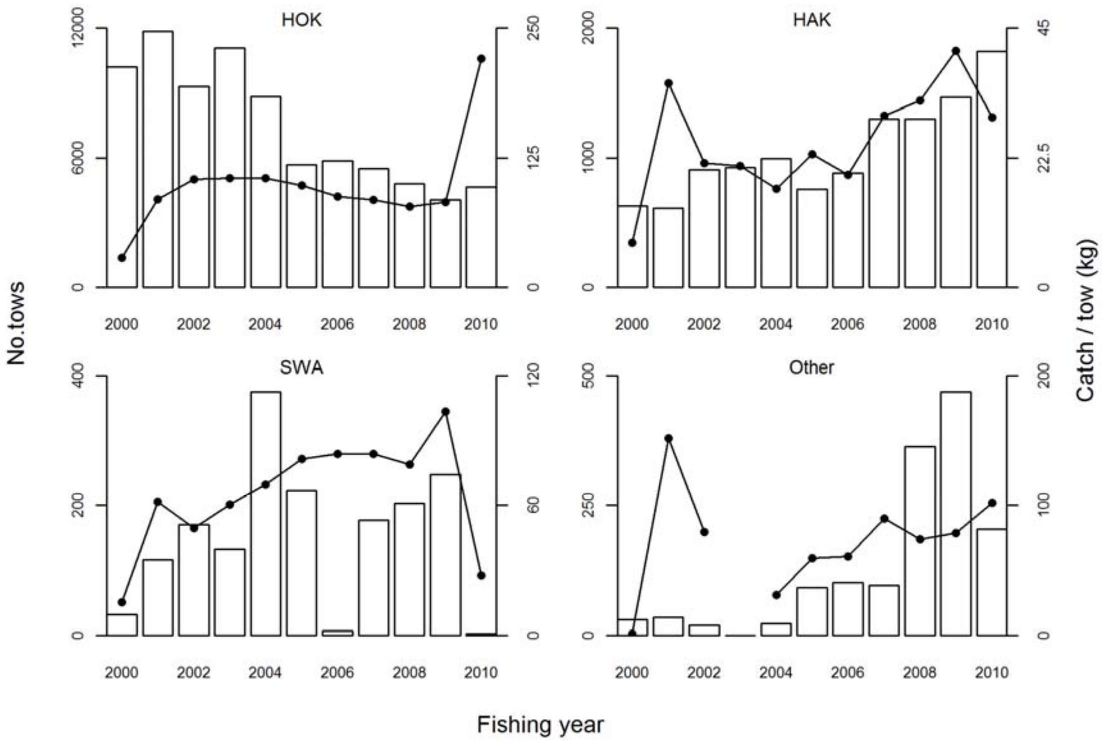



**Figure C13: Unstandardised catch rate (kg/tow) of pale ghost shark for various target species and the number of tows for the ECSI/CHAT region taken by bottom trawl gear.**

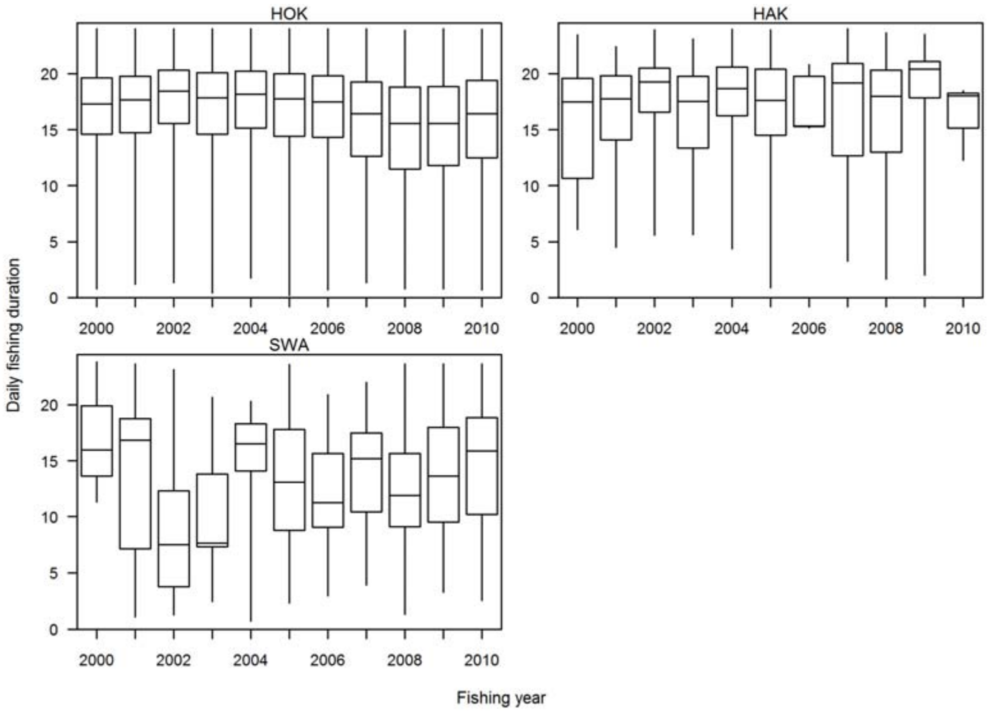



**Figure C14: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for summed daily tow durations (hours) reported for various target species capturing pale ghost shark in the ECSI/CHAT region using bottom trawl gear.**

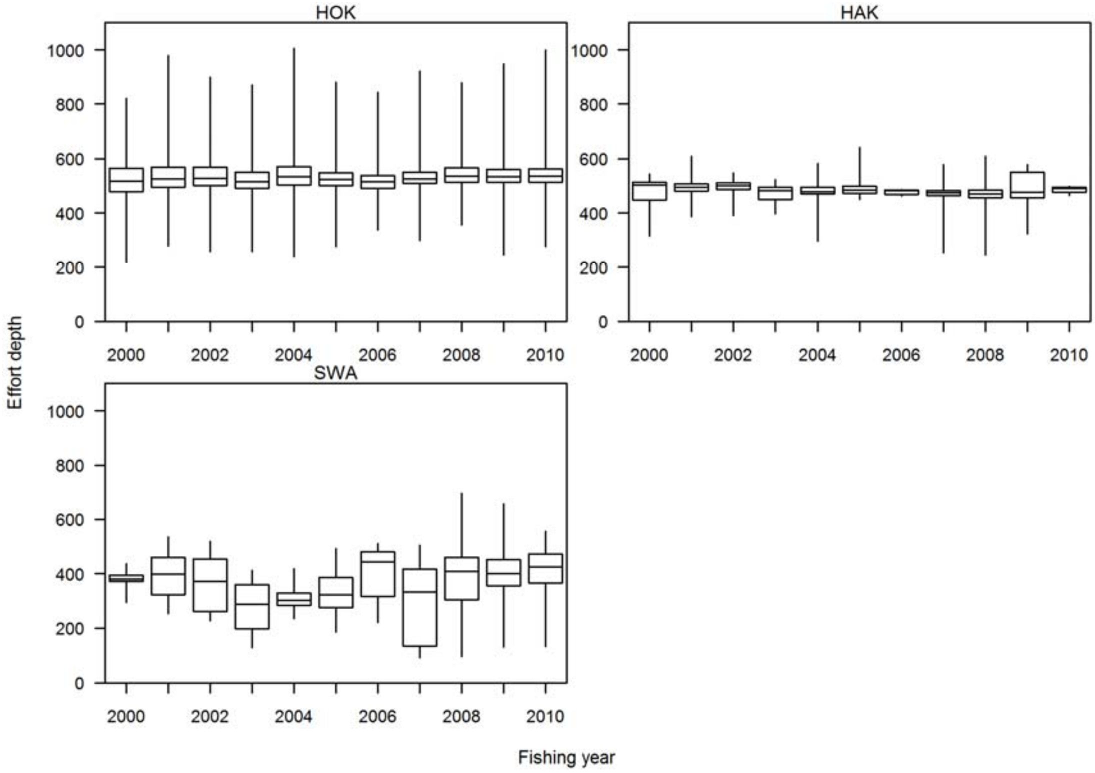



**Figure C15: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for various target species capturing pale ghost shark in the ECSI/CHAT region using bottom trawl gear.**

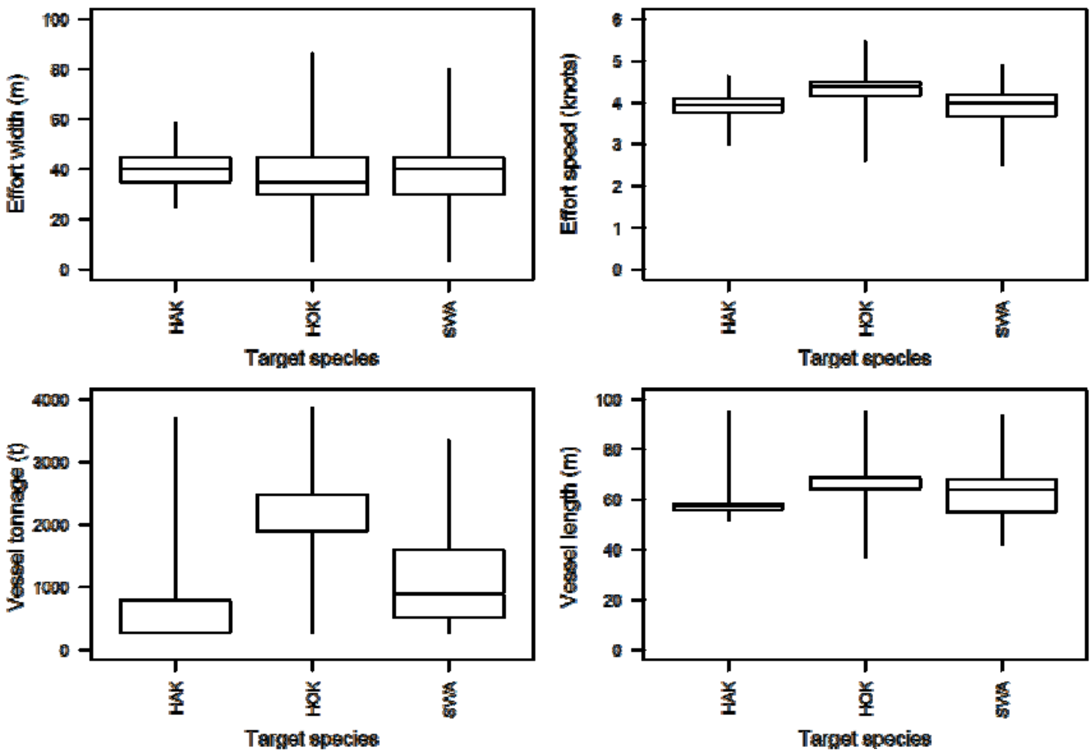



**Figure C16: Distribution of fishing effort variables and vessel characteristics for the ECSI/CHAT area for major target species catching pale ghost shark using bottom trawl gear.**

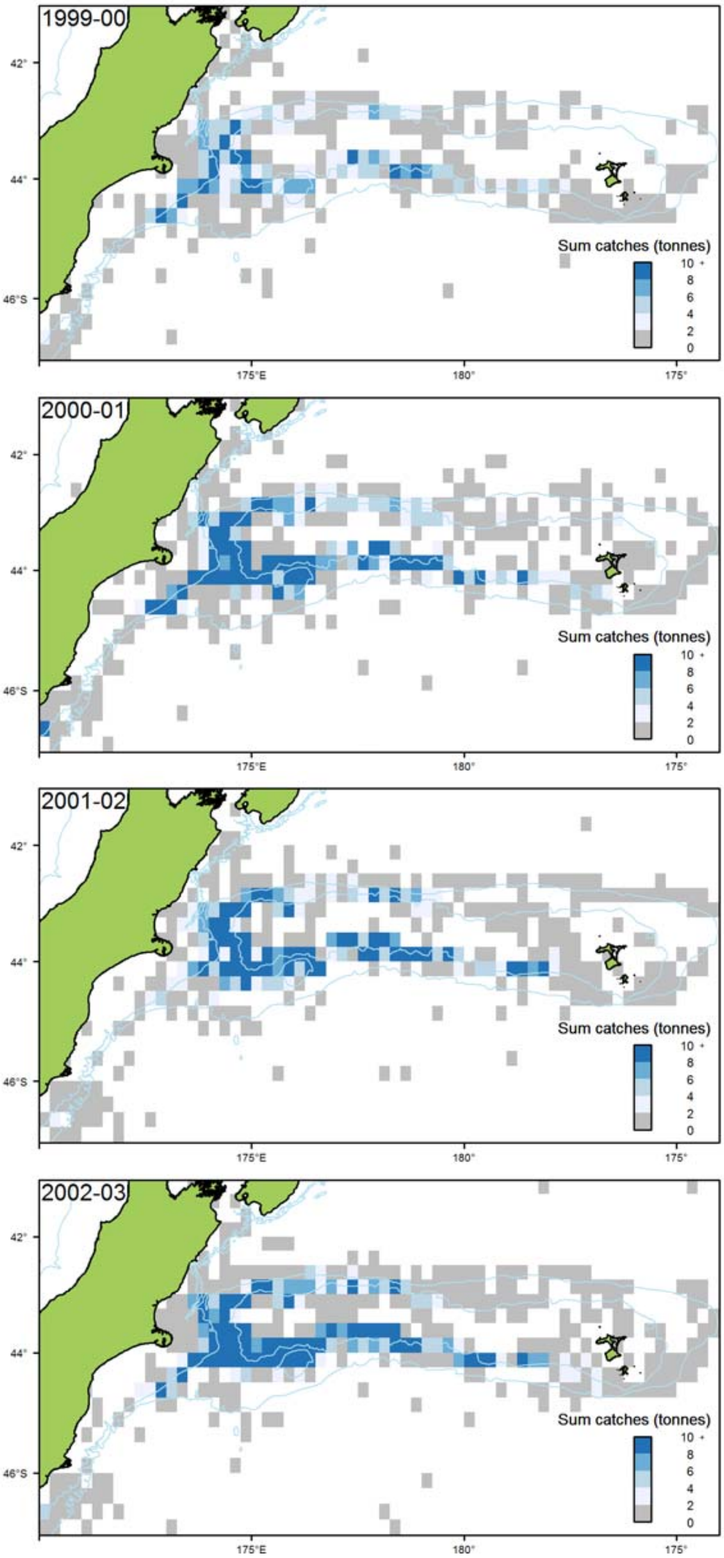



**Figure C17: Distribution of pale ghost shark catch taken by bottom trawl gear within the ECSI/CHAT region aggregated into 0.2 degree spatial blocks for fishing years 2000–2003 from the TCEPR form.**

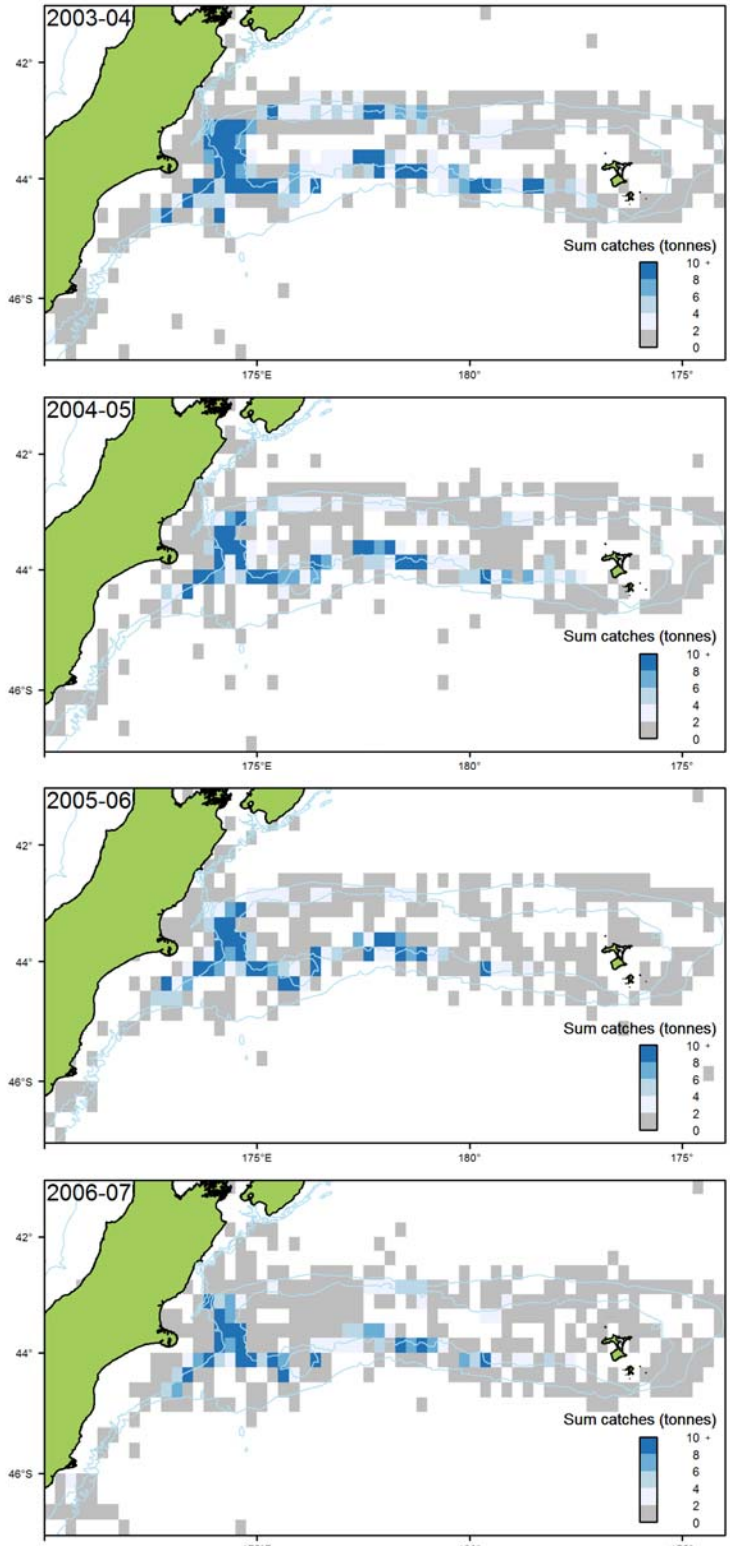



**Figure C17 continued: Distribution of pale ghost shark catch taken by bottom trawl gear within the ECSI/CHAT region aggregated into 0.2 degree spatial blocks for fishing years 2004–2007 from the TCEPR form.**

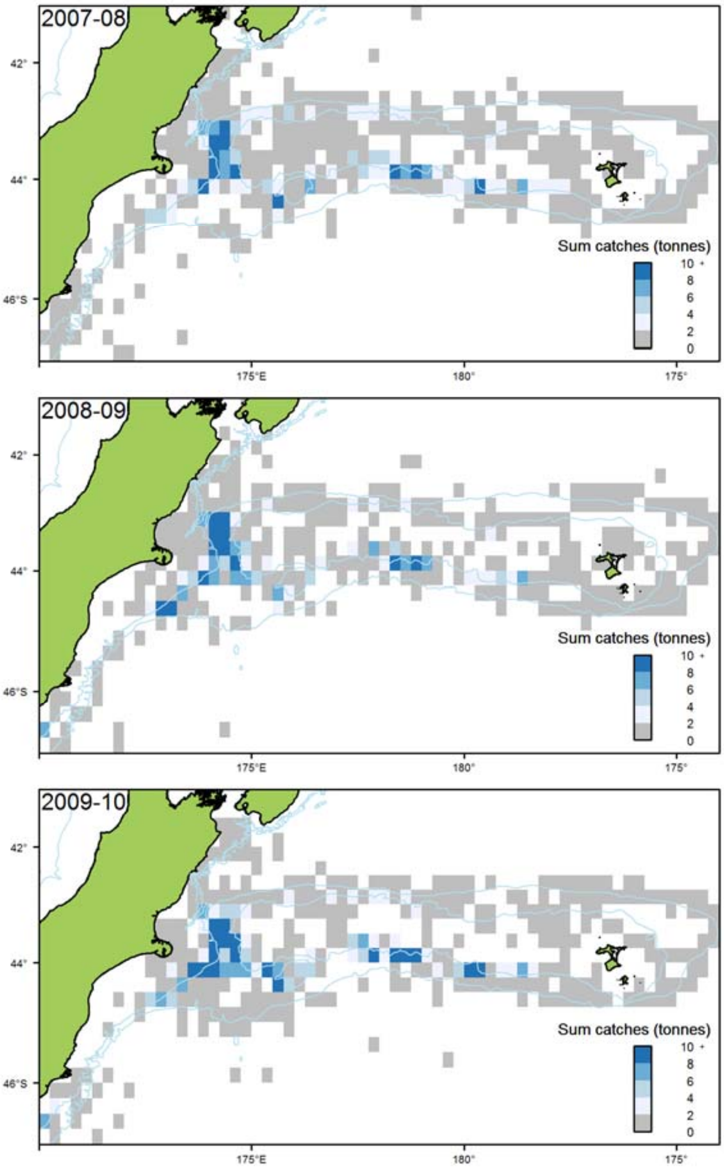



**Figure C17 continued: Distribution of pale ghost shark catch taken by bottom trawl gear within the ECSI/CHAT region aggregated into 0.2 degree spatial blocks for fishing years 2008–2010 from the TCEPR form.**

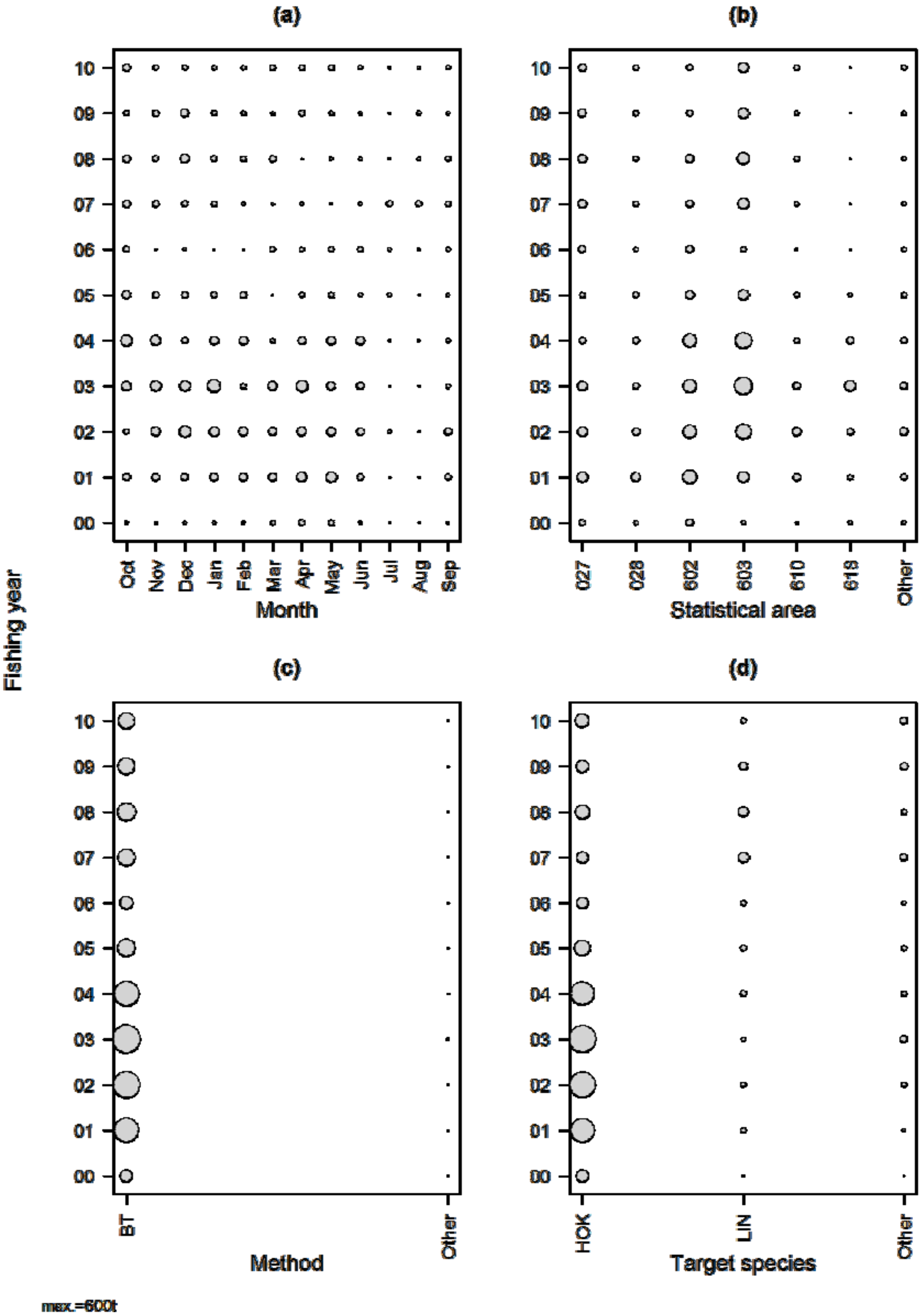



**Figure C18: Distribution of pale ghost shark catch in the Southland/SUBA region (circle size is proportional to catch) for 2000–2010 fishing years in relation to a) month, b) statistical area, c) fishing method, and d) target species. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**

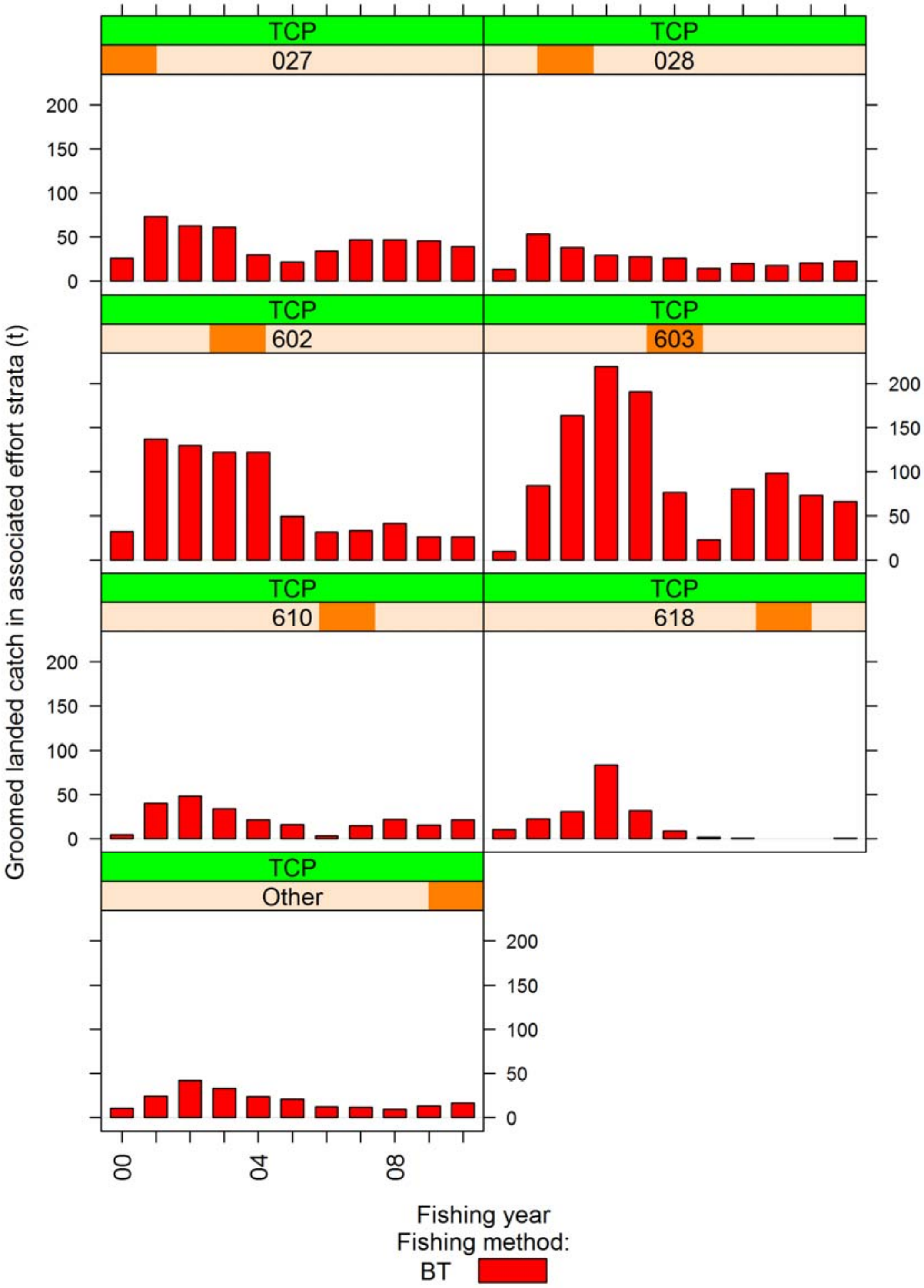



**Figure C19a: Distribution of pale ghost shark catch in the Southland/SUBA region in relation to form type and statistical area by fishing method for fishing years 2000–2010 taken by bottom trawl gear.**

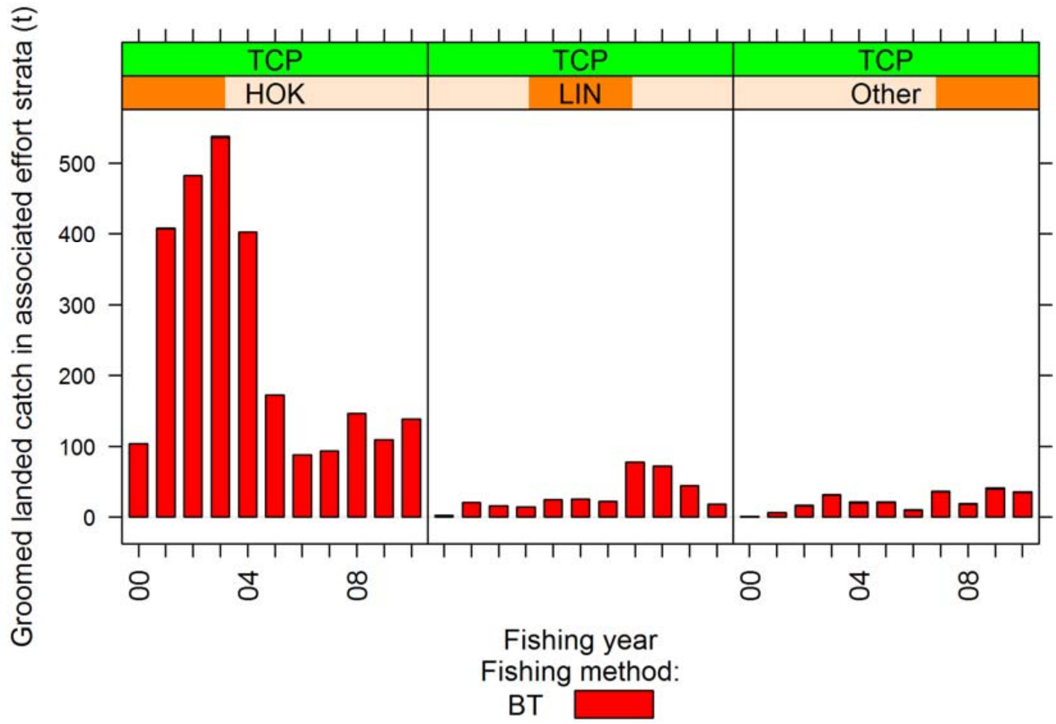



**Figure C19b: Distribution of pale ghost shark catch in the Southland/SUBA region in relation to form type and target species by fishing method for fishing years 2000–2010 taken by bottom trawl gear.**

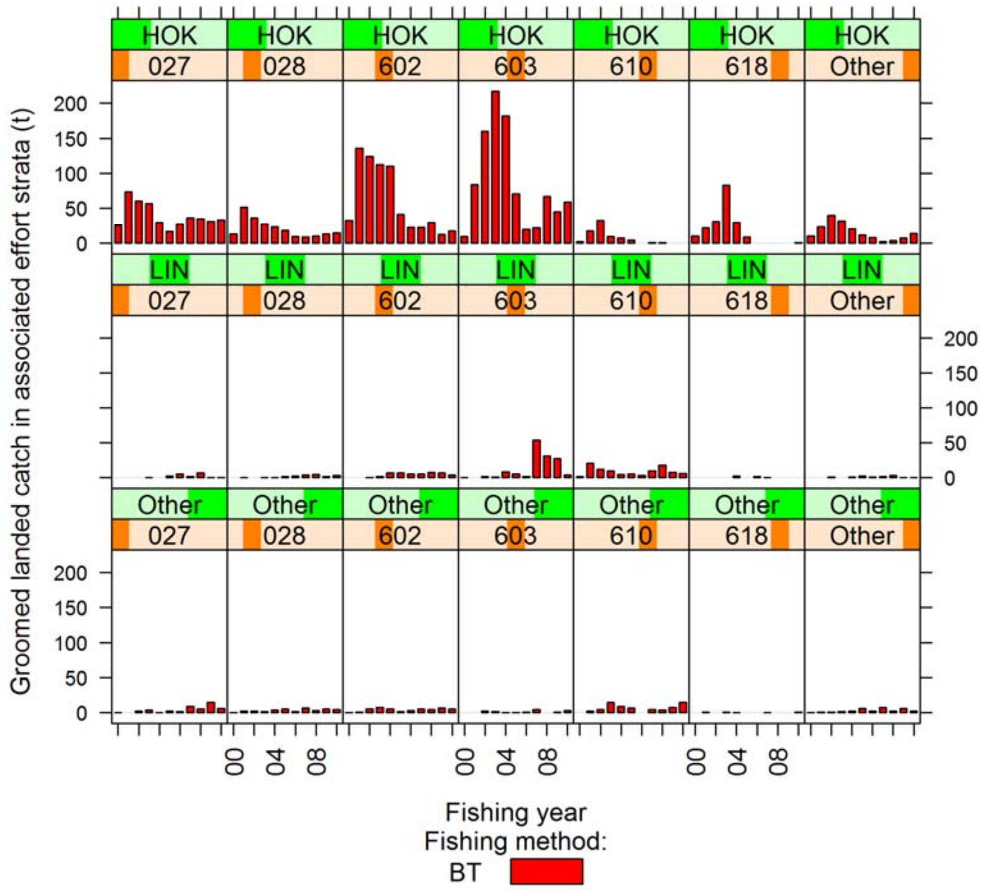



**Figure C19c: Distribution of pale ghost shark catch in the Southland/SUBA region in relation to target species and statistical area by fishing method for fishing years 2000–2010 taken by bottom trawl gear.**

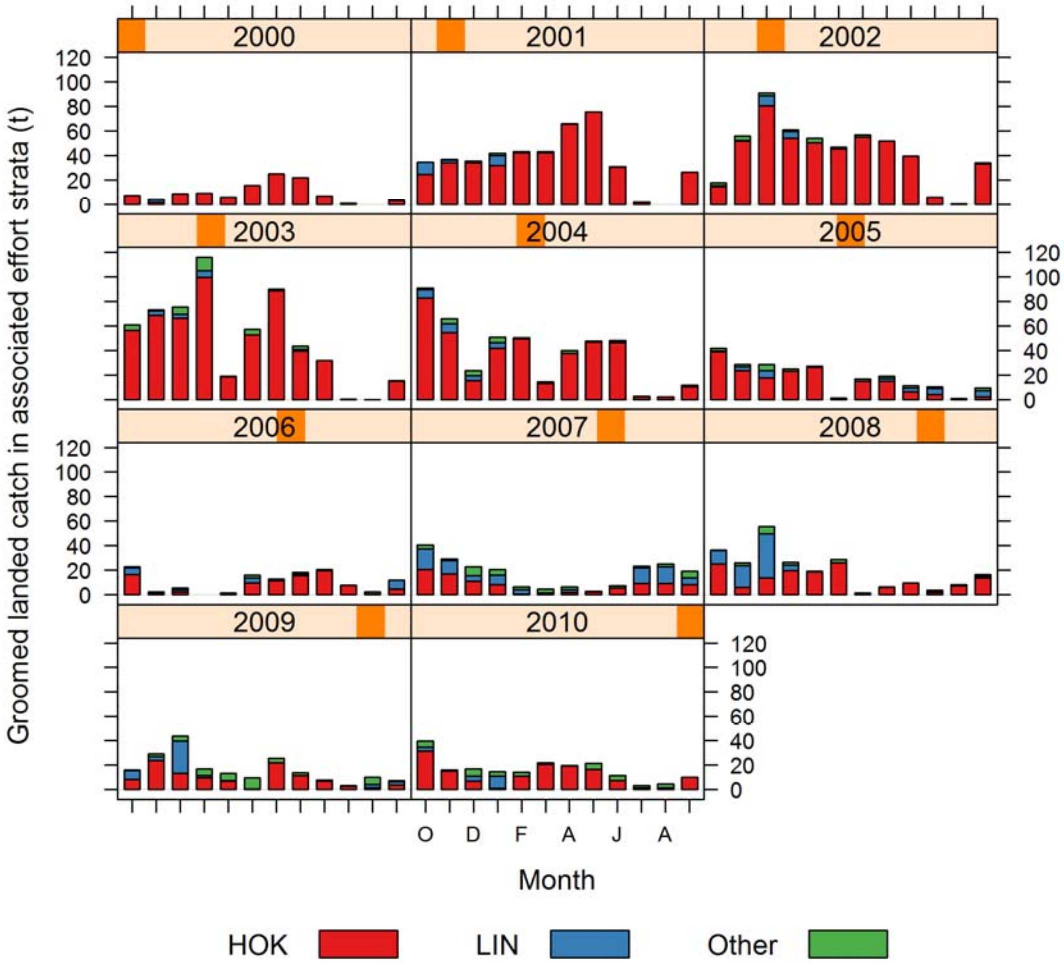



**Figure C19d: Distribution of pale ghost shark catch in the Southland/SUBA region in relation to fishing year by target species and month for fishing years 2000–2010 taken by bottom trawl gear.**

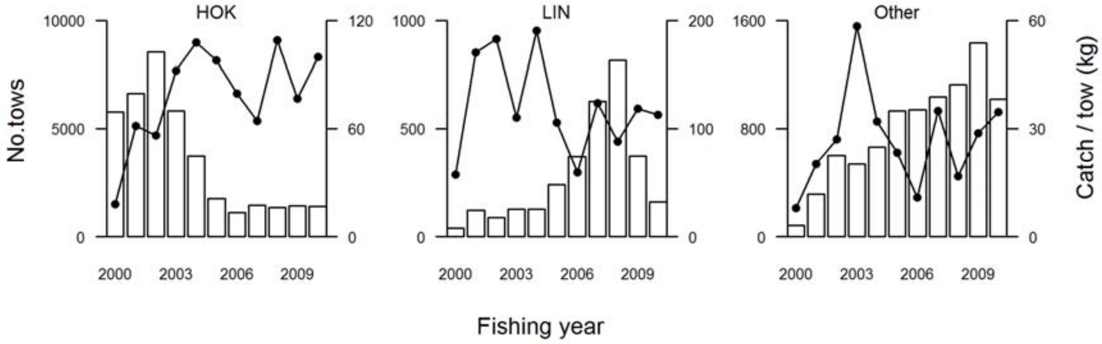



**Figure C20: Unstandardised catch rates of pale ghost shark for various target species tows in kg (catch/tow) and the number of tows for the Southland/SUBA region using bottom trawl gear.**

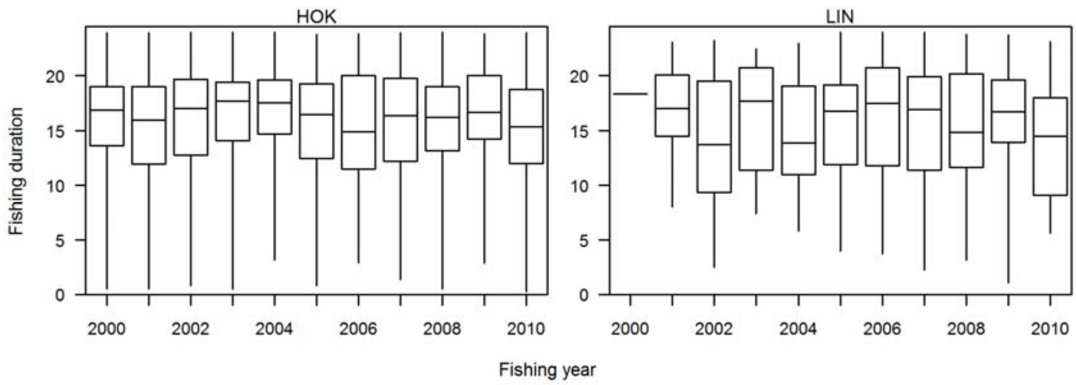



**Figure C21: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for daily tow durations reported for hoki and ling targeted tows capturing pale ghost shark in the Southland/SUBA region using bottom trawl gear.**

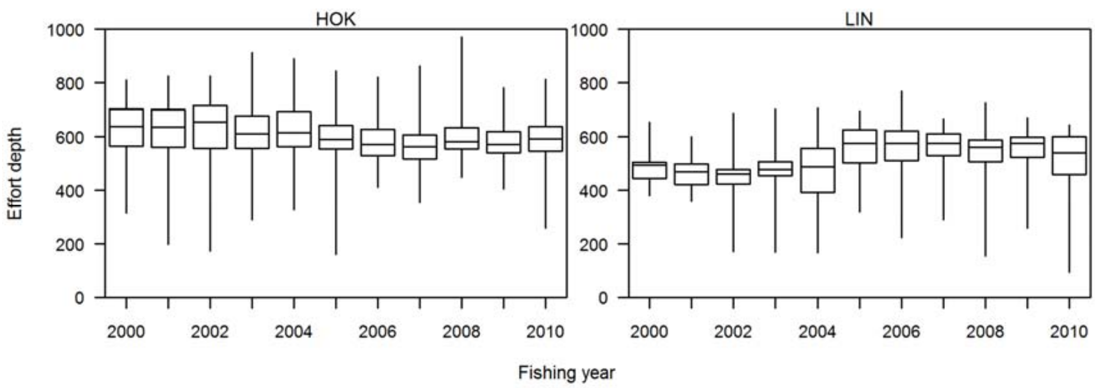



**Figure C22: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for various target species capturing pale ghost shark in the Southland/SUBA region using bottom trawl gear.**

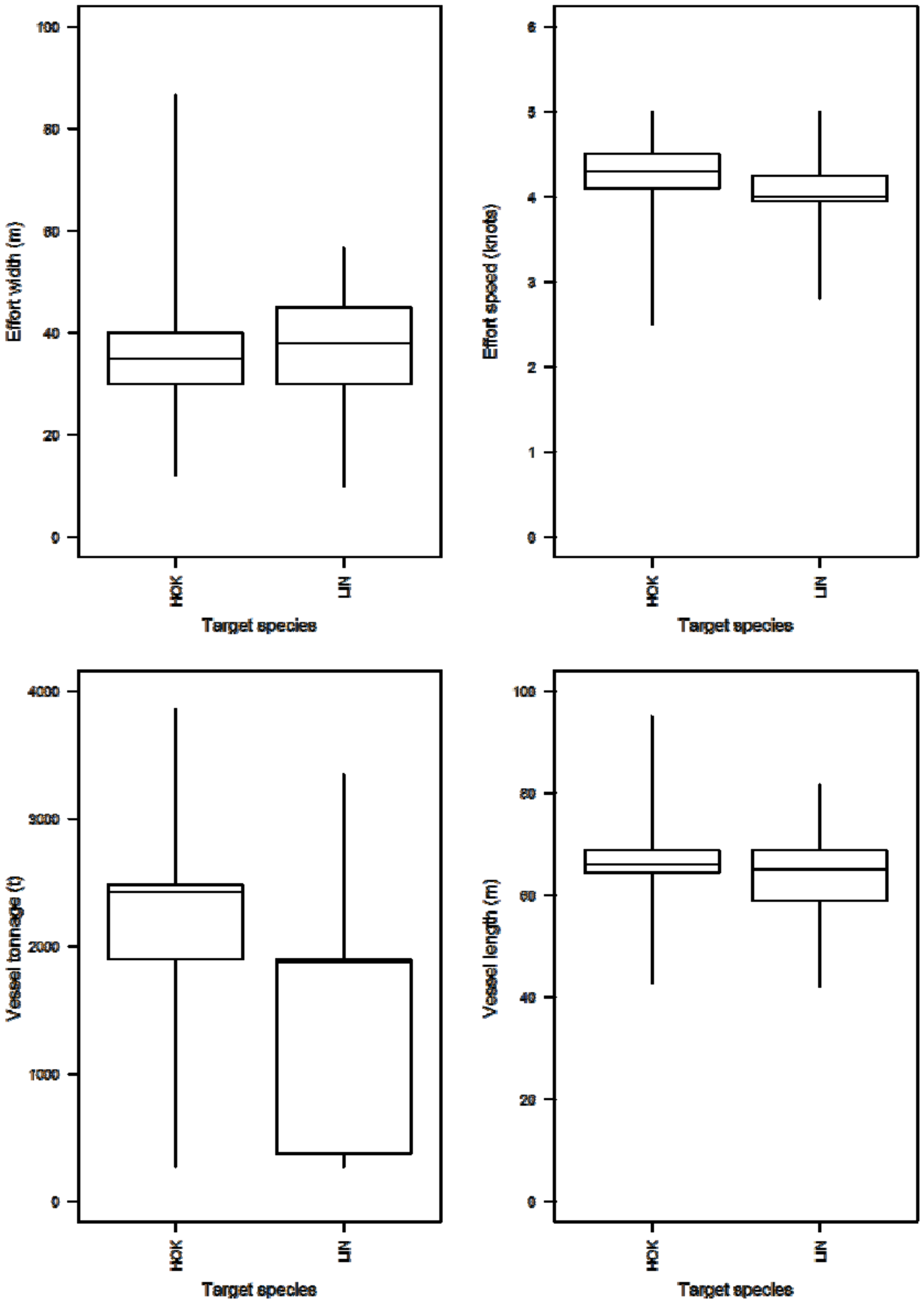



**Figure C23: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for hoki and ling targeted tows capturing pale ghost shark in the Southland/SUBA region using bottom trawl gear.**

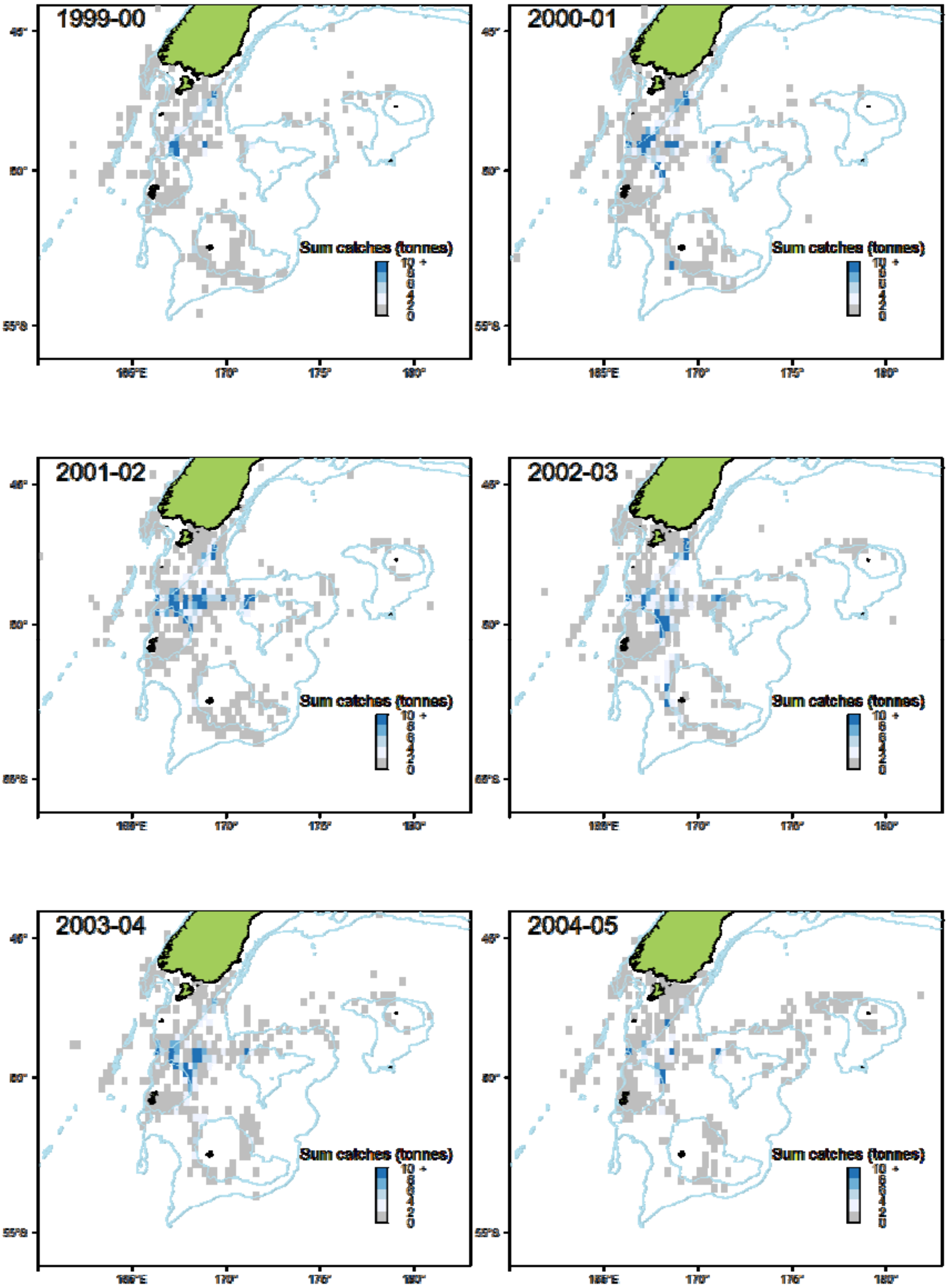



**Figure C24: Distribution of pale ghost shark catch taken by bottom trawl gear within the Southland/SUBA region aggregated into 0.2 degree spatial blocks for fishing years 2000–2005 from the TCEPR form.**

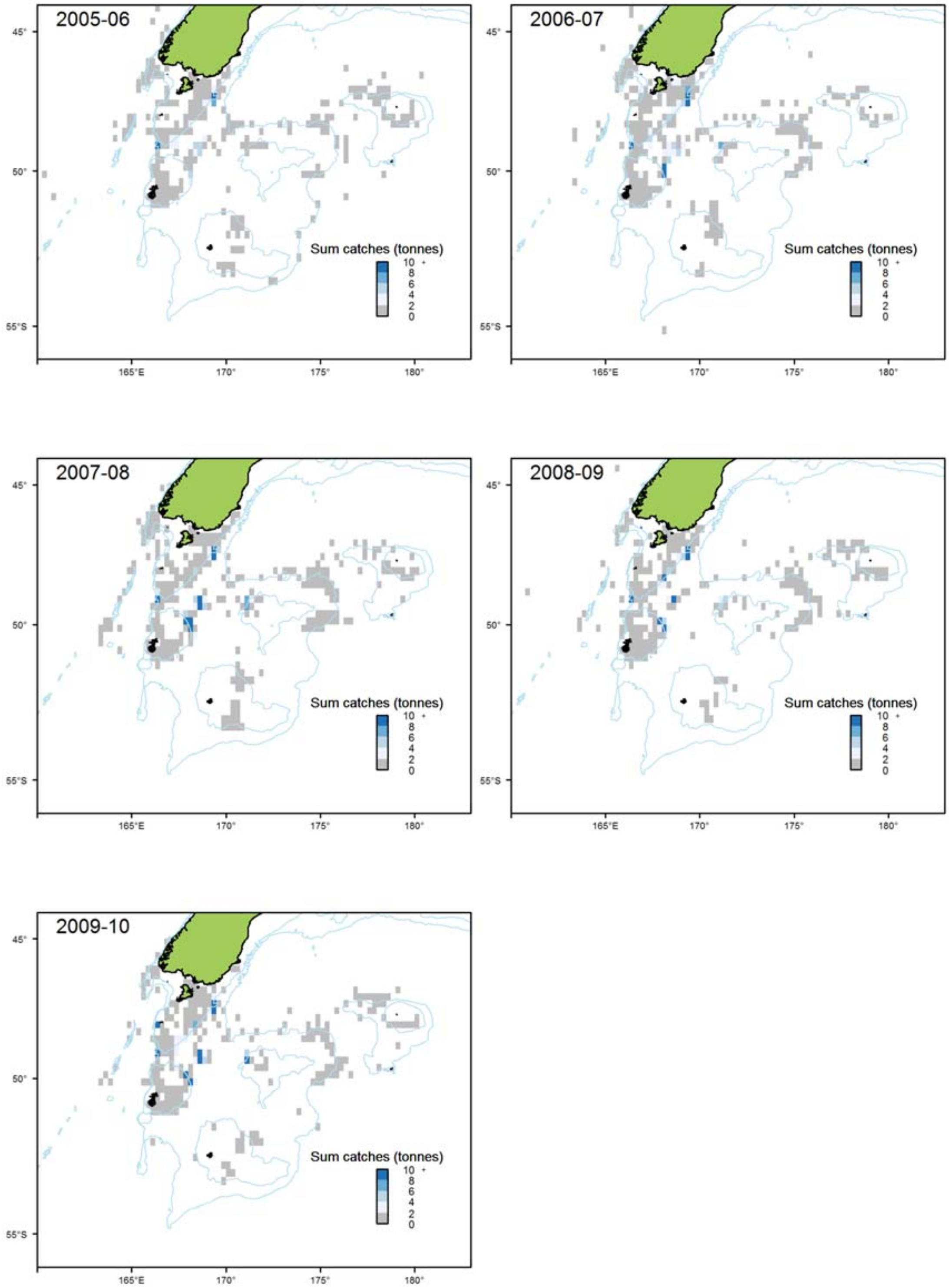



**Figure C24 continued: Distribution of pale ghost shark catch taken by bottom trawl gear within the Southland/SUBA region aggregated into 0.2 degree spatial blocks for fishing years 2006–2010 from the TCEPR form.**

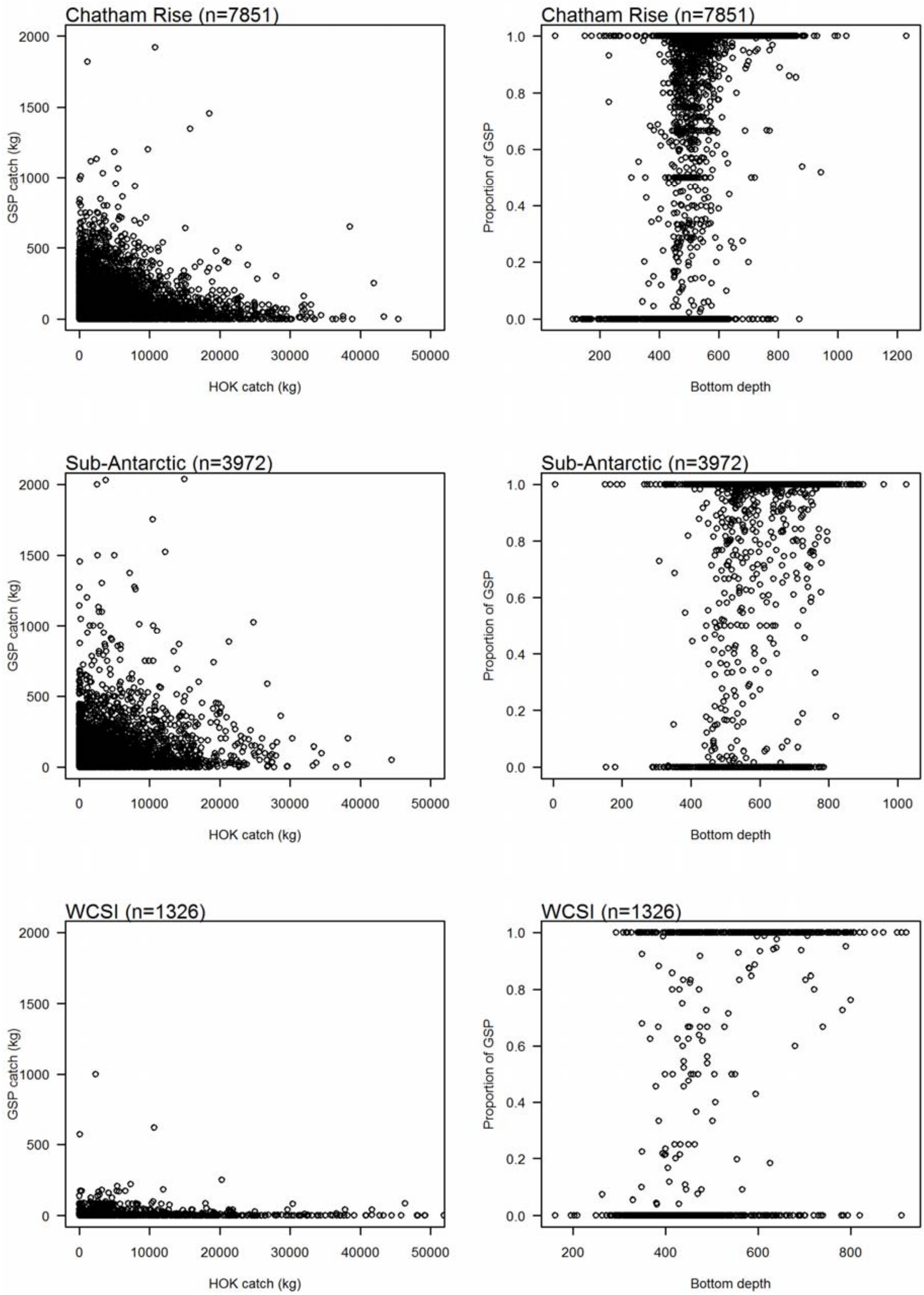



**Figure C25: The relationship between pale ghost shark catch and hoki catch from Observer Programme tows for various regions (left hand plots) and the proportion of tows containing pale ghost shark and bottom depth for the Chatham Rise, Sub-Antarctic and West Coast South Island (WCSI). n= no. of tows.**

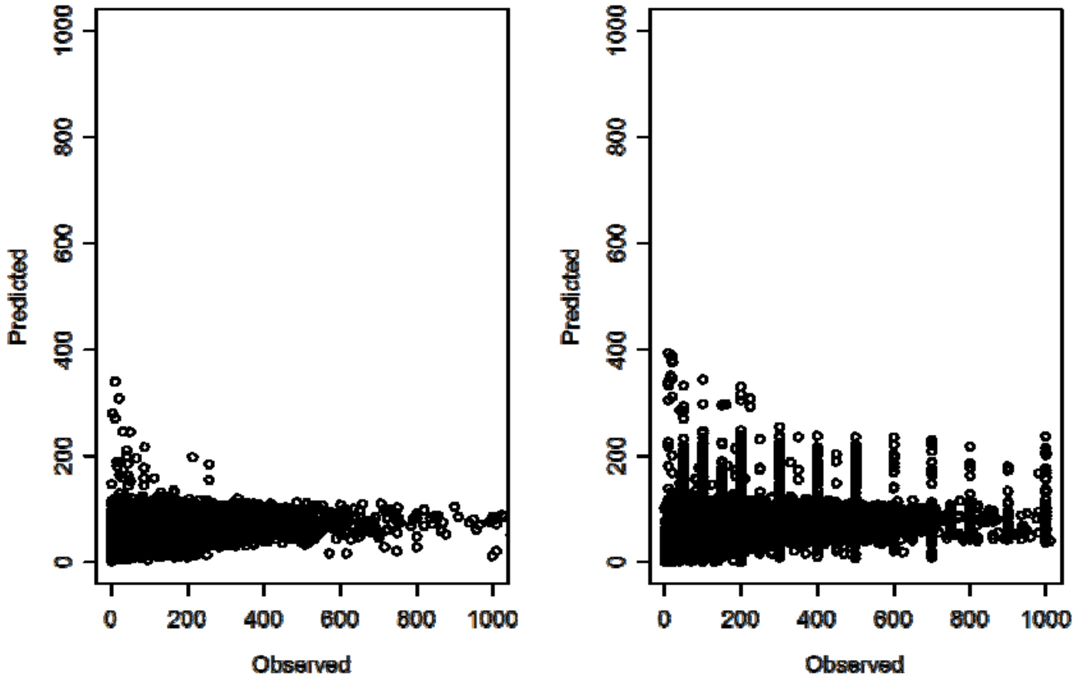



Figure C26: Predicted versus observed pale ghost shark catch for Model 1 (see Section 7.3.1) for observer data (left plot) and for commercial catch-effort data (right plot).

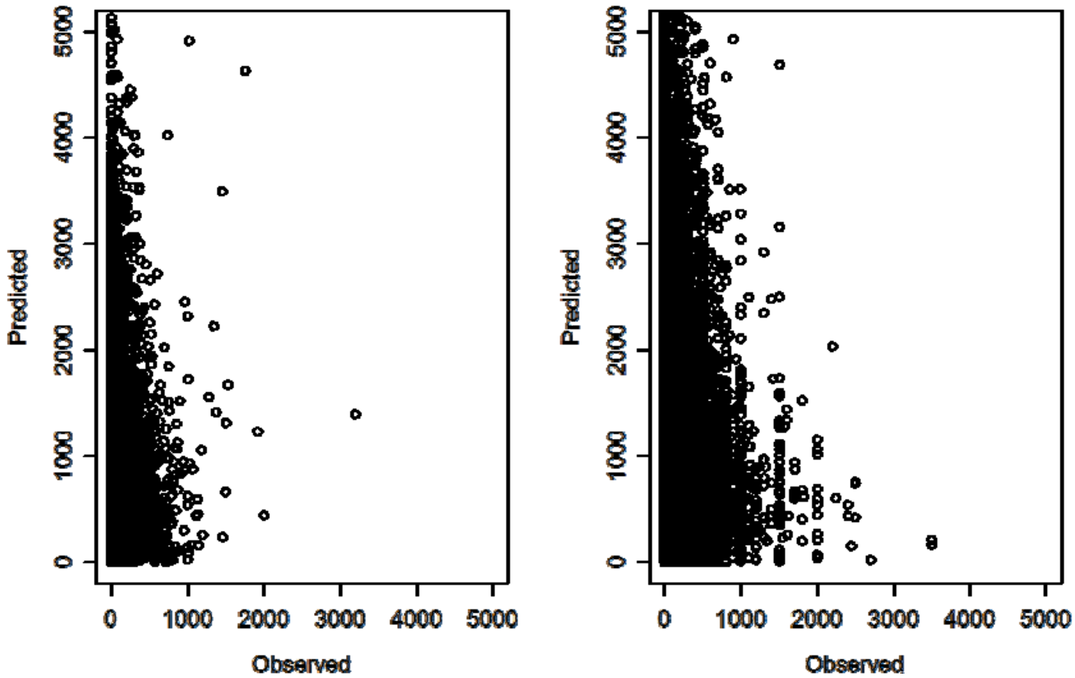



Figure C27: Predicted versus observed pale ghost shark catch for Model 2 (see Section 7.3.2) for observer data (left plot) and for commercial catch-effort data (right plot).

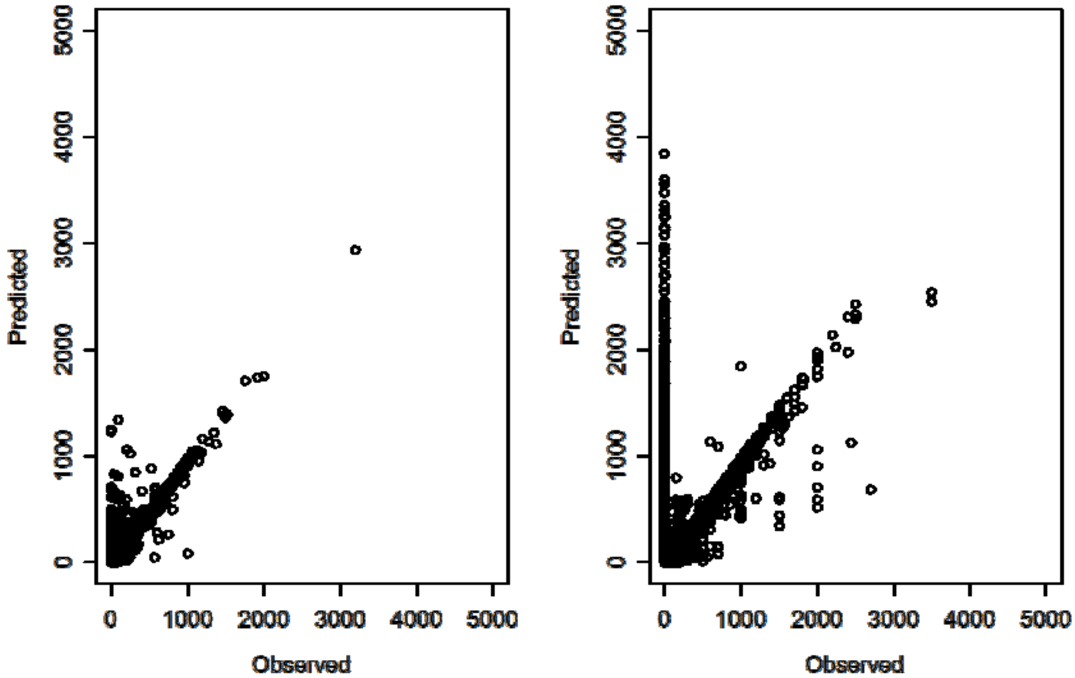



**Figure C28: Predicted versus observed pale ghost shark catch for Model 3 (see Section 7.3.3) for observer data (left plot) and for commercial catch-effort data (right plot).**

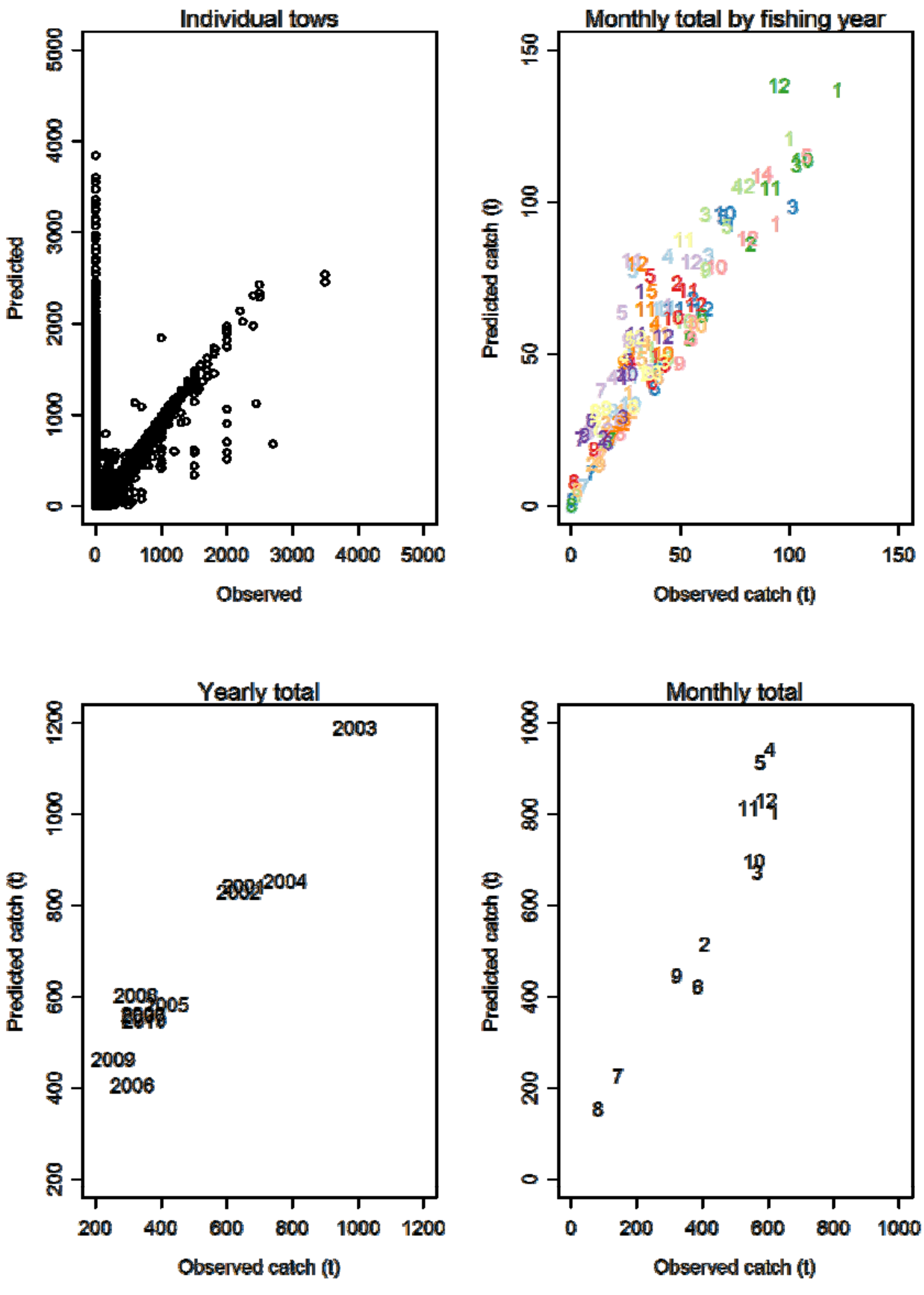



**Figure C29: Predicted versus observed pale ghost shark catch for Model 3 (see Section 7.3.3) for individual tows, months by year, by year, and monthly totals.**

## APPENDIX D: CATCH-PER-UNIT-EFFORT ANALYSES

**Table D1: CPUE datasets for all vessels and for core vessels for each year (2000–2010) for ECSI and Chatham Rise CPUE. CPUE is unstandardised catch per non-zero processing day. 'Zeros' are days where there was no reported processed pale ghost shark.**

| | All vessels | | | | Core vessels | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Zeros | Catch | No. days | CPUE | Zeros | Catch | No. days | CPUE |
| 2000 | 0.09 | 204.8 | 1 363 | 0.15 | 0.07 | 169.3 | 1 185 | 0.14 |
| 2001 | 0.10 | 673.9 | 1 459 | 0.46 | 0.05 | 600.6 | 1 288 | 0.47 |
| 2002 | 0.05 | 578.9 | 1 095 | 0.53 | 0.04 | 551.7 | 1 045 | 0.53 |
| 2003 | 0.06 | 565.5 | 1 244 | 0.45 | 0.04 | 510.7 | 1 100 | 0.46 |
| 2004 | 0.07 | 298.8 | 704 | 0.42 | 0.05 | 280.7 | 630 | 0.45 |
| 2005 | 0.11 | 114.4 | 371 | 0.31 | 0.05 | 99.4 | 278 | 0.36 |
| 2006 | 0.08 | 158.8 | 485 | 0.33 | 0.03 | 133.4 | 376 | 0.35 |
| 2007 | 0.26 | 73.90 | 279 | 0.26 | 0.15 | 49.0 | 152 | 0.32 |
| 2008 | 0.12 | 272.7 | 752 | 0.36 | 0.06 | 243.2 | 594 | 0.41 |
| 2009 | 0.09 | 283.2 | 739 | 0.38 | 0.07 | 232.6 | 566 | 0.41 |
| 2010 | 0.09 | 348.2 | 867 | 0.40 | 0.07 | 308.8 | 743 | 0.42 |
| Total | | 3 573.1 | 9 358 | | | 3 179.4 | 7 957 | |

**Table D2: Variables retained in order of decreasing explanatory value for the ECSI and Chatham Rise model and the corresponding total $R^2$ value.**

| Variable | $R^2$ |
|---|---|
| Fishing year | 16.25 |
| Vessel | 21.77 |
| Distance | 24.51 |

**Table D3: ECSI and Chatham Rise CPUE estimated values, upper and lower confidence intervals and c.v.s by year.**

| Year | CPUE | Lower CI | Upper CI | c.v. |
|---|---|---|---|---|
| 2000 | 0.29 | 0.27 | 0.31 | 0.03 |
| 2001 | 1.04 | 0.98 | 1.11 | 0.03 |
| 2002 | 1.39 | 1.3 | 1.49 | 0.03 |
| 2003 | 1.27 | 1.19 | 1.36 | 0.03 |
| 2004 | 1.26 | 1.16 | 1.37 | 0.04 |
| 2005 | 0.99 | 0.88 | 1.11 | 0.06 |
| 2006 | 1.05 | 0.95 | 1.16 | 0.05 |
| 2007 | 1.06 | 0.91 | 1.24 | 0.08 |
| 2008 | 1.06 | 0.97 | 1.16 | 0.04 |
| 2009 | 1.12 | 1.02 | 1.23 | 0.04 |
| 2010 | 1.12 | 1.04 | 1.21 | 0.04 |

**Table D4: CPUE datasets for all vessels and for core vessels for each year (2000–2010) for Sub-Antarctic CPUE. CPUE is unstandardised catch per non-zero processing day. CPUE is unstandardised catch per non-zero processing day. 'Zeros' are days where there was no reported processed pale ghost shark.**

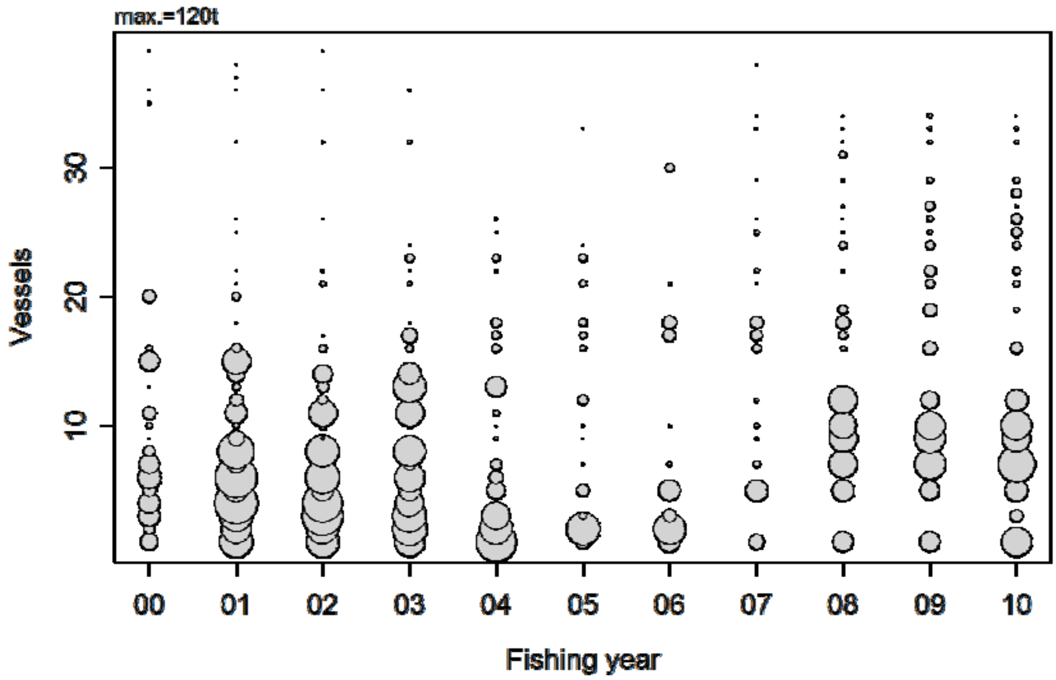
| | All vessels | | | | Core vessels | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Zeros | Catch | No. days | CPUE | Zeros | Catch | No.days | CPUE |
| 2000 | 0.18 | 87.1 | 669 | 0.13 | 0.15 | 82.6 | 634 | 0.13 |
| 2001 | 0.19 | 289.6 | 681 | 0.43 | 0.16 | 263.0 | 612 | 0.43 |
| 2002 | 0.16 | 275.1 | 712 | 0.39 | 0.09 | 243.3 | 627 | 0.39 |
| 2003 | 0.16 | 193.6 | 424 | 0.46 | 0.10 | 168.5 | 344 | 0.49 |
| 2004 | 0.20 | 54.5 | 133 | 0.41 | 0.21 | 37.7 | 81 | 0.47 |
| 2005 | 0.21 | 32.8 | 83 | 0.40 | 0.17 | 20.8 | 35 | 0.59 |
| 2006 | 0.13 | 18.7 | 53 | 0.35 | 0.07 | 13.4 | 38 | 0.35 |
| 2007 | 0.31 | 27.6 | 97 | 0.28 | 0.20 | 12.6 | 47 | 0.27 |
| 2008 | 0.22 | 114 | 176 | 0.65 | 0.18 | 112.0 | 165 | 0.68 |
| 2009 | 0.07 | 94.8 | 186 | 0.51 | 0.06 | 94.6 | 185 | 0.51 |
| 2010 | 0.11 | 114.8 | 234 | 0.49 | 0.09 | 111.4 | 229 | 0.49 |
| Total | | 1 302 | 3 448 | | | 1 160 | 2 997 | |

**Table D5: Variables retained in order of decreasing explanatory value for the Sub-Antarctic CPUE model and the corresponding total $R^2$ value.**

| Variable | $R^2$ |
|---|---|
| Fishing year | 17.58 |
| Vessel | 22.72 |
| Duration | 26.06 |
| Month | 29.08 |

**Table D6: Sub-Antarctic CPUE estimated values, upper and lower confidence intervals and c.v.s by year.**

| Year | CPUE | Lower CI | Upper CI | c.v. |
|---|---|---|---|---|
| 2000 | 0.30 | 0.27 | 0.34 | 0.06 |
| 2001 | 0.86 | 0.77 | 0.97 | 0.06 |
| 2002 | 0.88 | 0.79 | 0.98 | 0.06 |
| 2003 | 1.08 | 0.94 | 1.23 | 0.07 |
| 2004 | 0.92 | 0.74 | 1.15 | 0.11 |
| 2005 | 2.13 | 1.54 | 2.96 | 0.16 |
| 2006 | 0.76 | 0.56 | 1.03 | 0.15 |
| 2007 | 0.73 | 0.54 | 0.98 | 0.15 |
| 2008 | 1.82 | 1.52 | 2.17 | 0.09 |
| 2009 | 1.41 | 1.19 | 1.66 | 0.08 |
| 2010 | 1.45 | 1.24 | 1.69 | 0.08 |



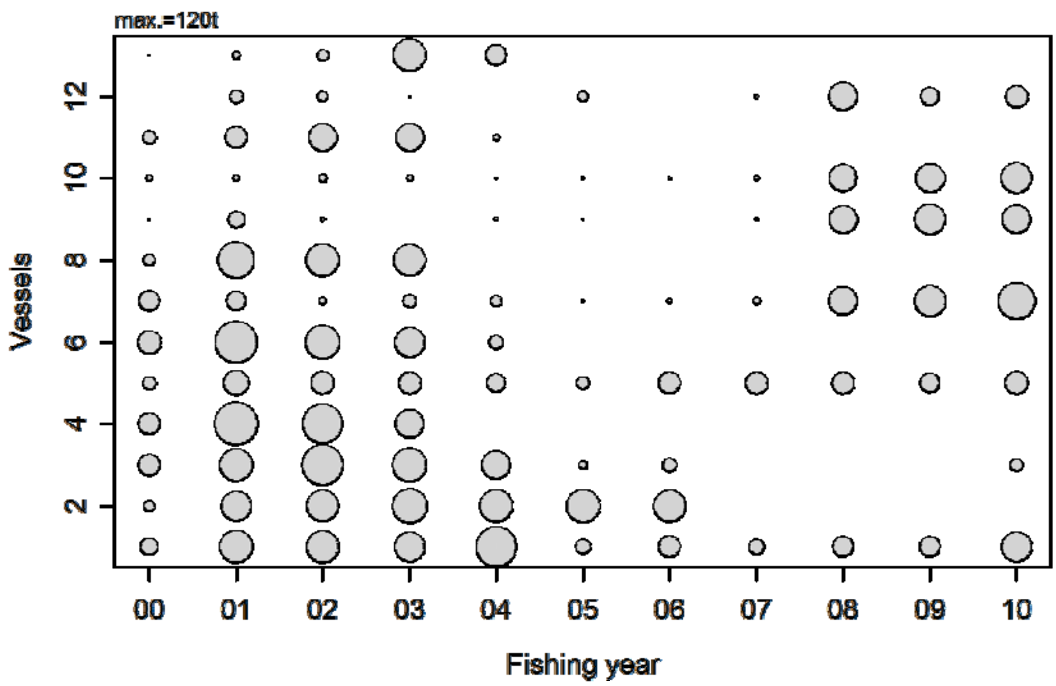




**Figure D1: ECSI and Chatham Rise scaled annual catch for all vessels (top plot) and for core vessel (bottom plot).**

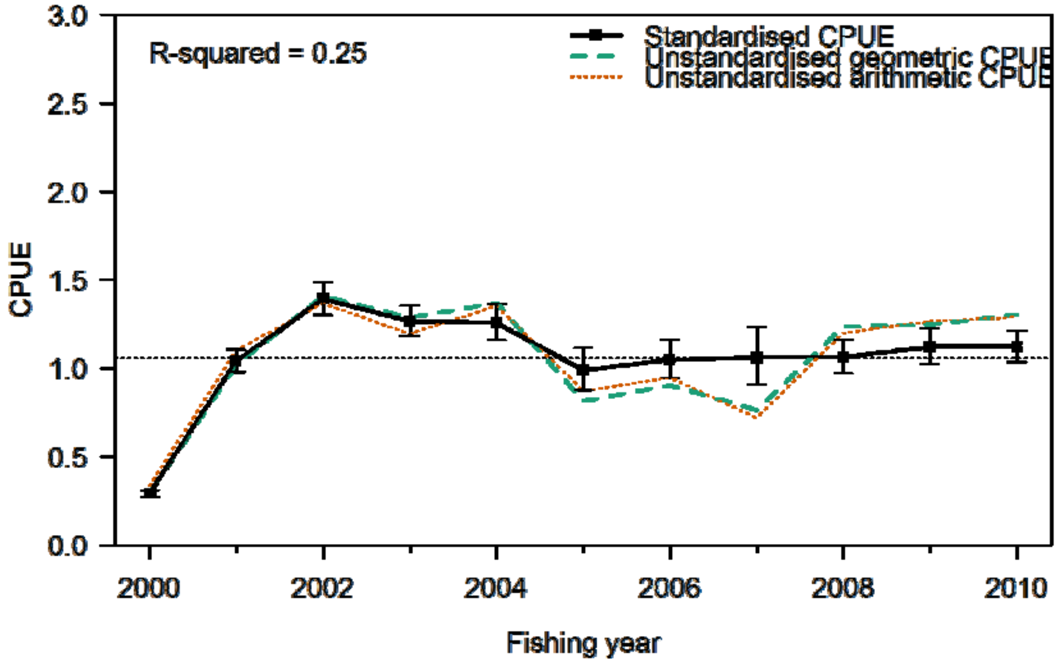



**Figure D2: ECSI and Chatham Rise standardised, geometric, and arithmetic CPUE for fishing years 2000–2010.**

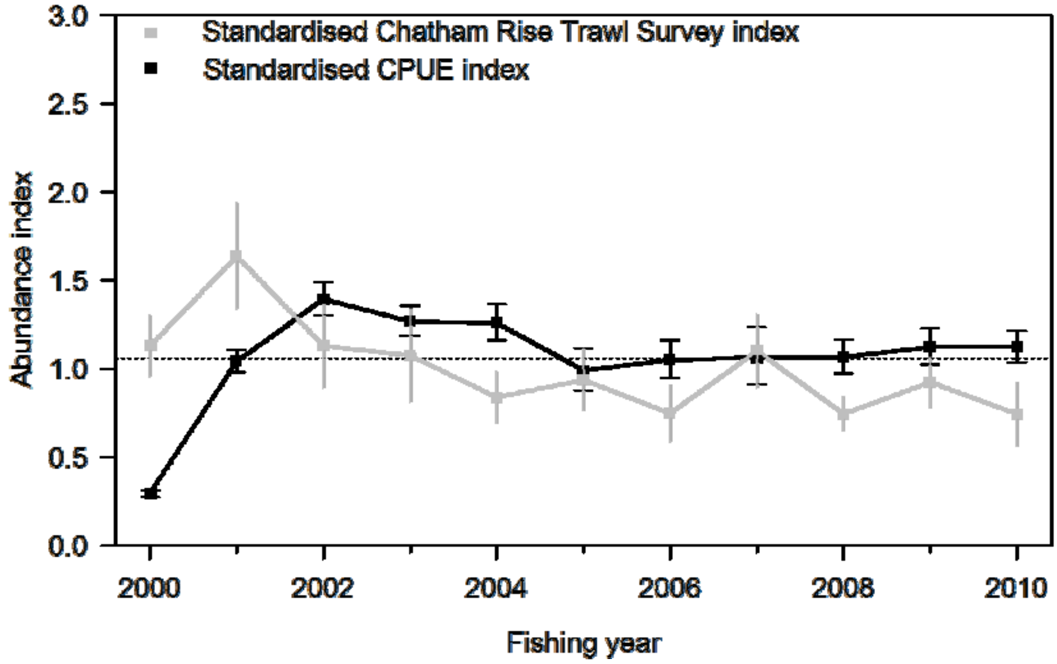



**Figure D3: Comparison of ECSI and Chatham Rise standardised CPUE and standardised Chatham Rise trawl survey abundance indices for fishing years 2000–2010.**

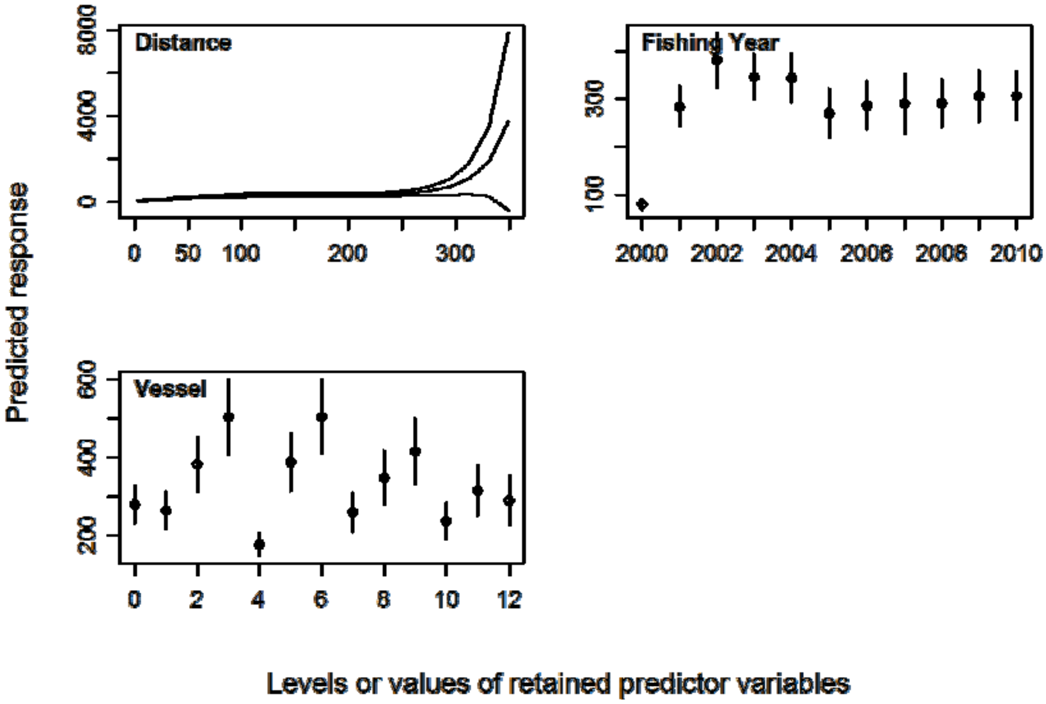



**Figure D4: ECSI and Chatham Rise CPUE predictor variables retained in the GLM analysis and their distributions by factor levels.**

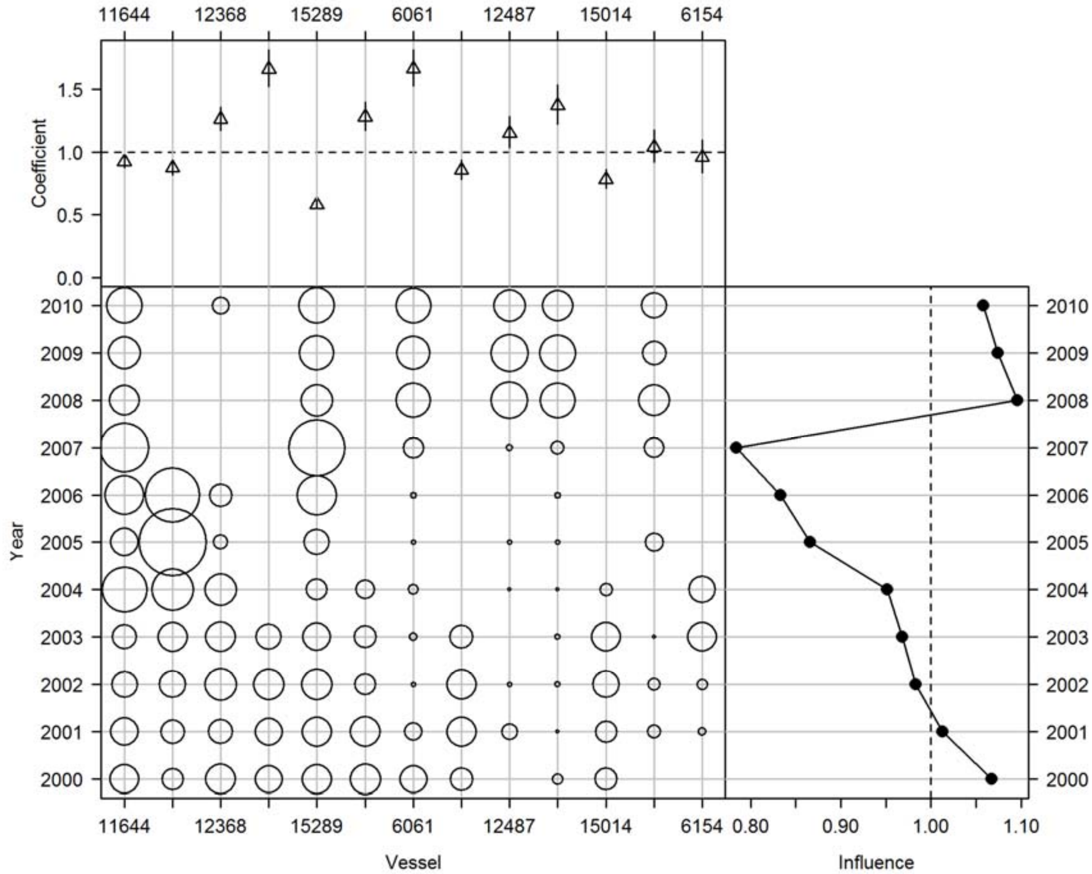



**Figure D5: Effect and influence of vessel for the ECSI and Chatham Rise CPUE model. Top: relative effect by level of variable. Bottom left: relative distribution of variable (vessel) by fishing year. Bottom right: influence of variable (vessel) on unstandardised CPUE by fishing year. Vessel numbers are vessel identification numbers.**

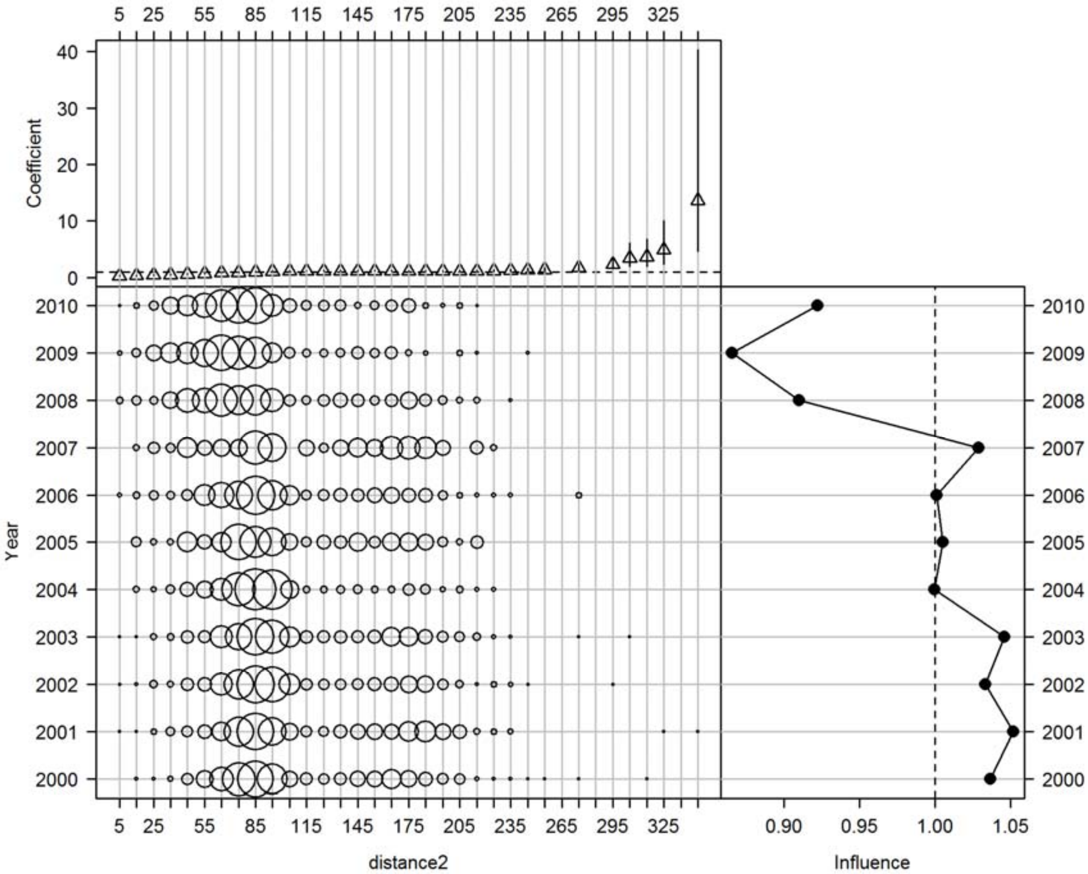



**Figure D6: Effect and influence of start time of distance towed for the ECSI and Chatham Rise CPUE model. See caption on Figure D5 for details.**

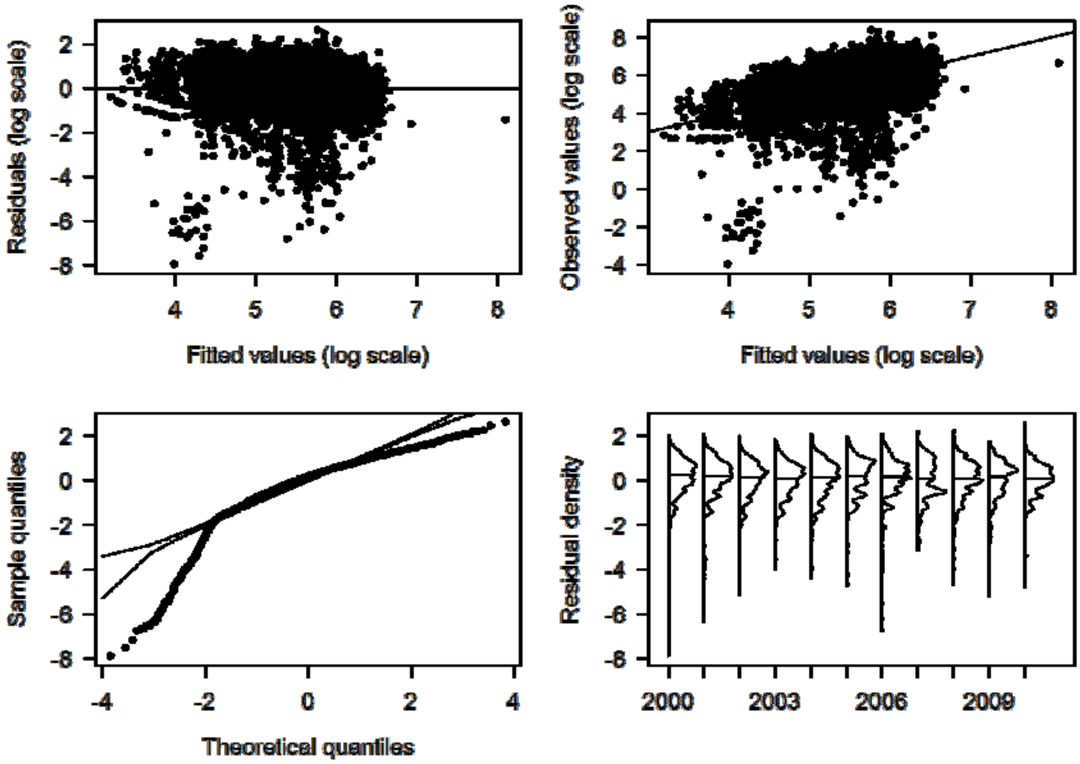
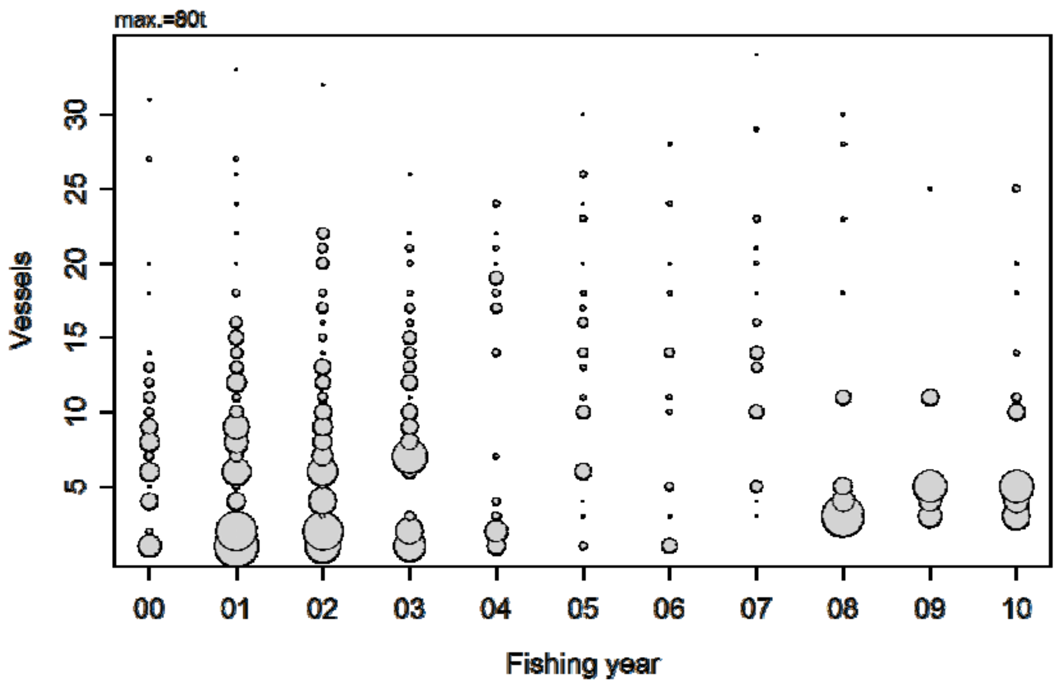



**Figure D7: ECSI and Chatham Rise CPUE residual diagnostic plots describing the fit of the GLM CPUE model.**



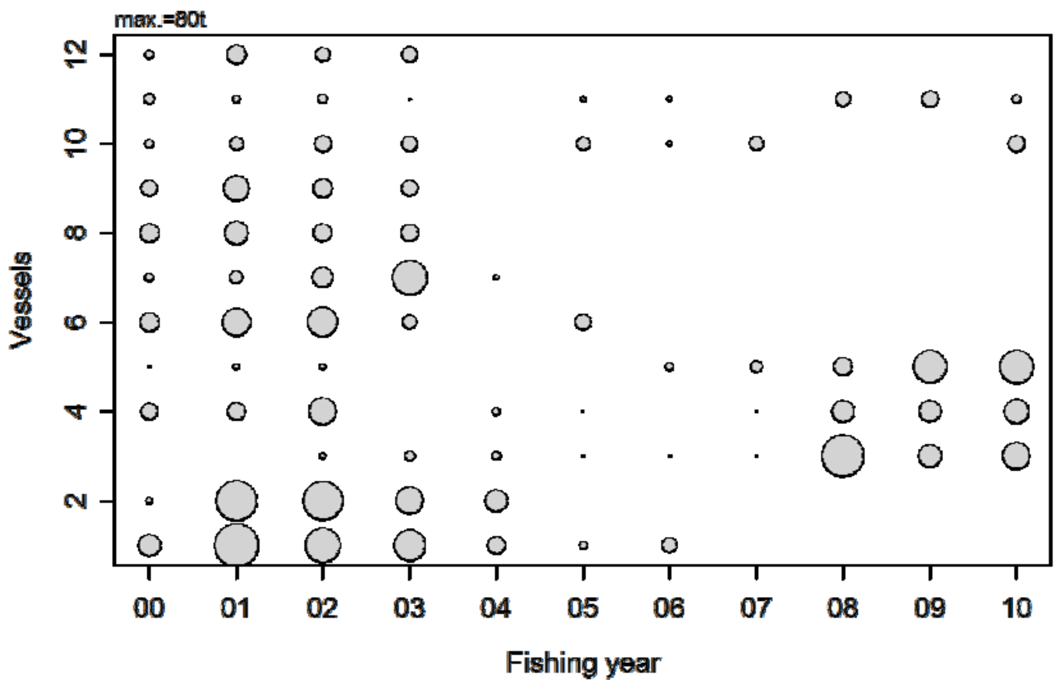




**Figure D8: Sub-Antarctic scaled annual catch for all vessels (top plot) and for core vessels (bottom plot).**

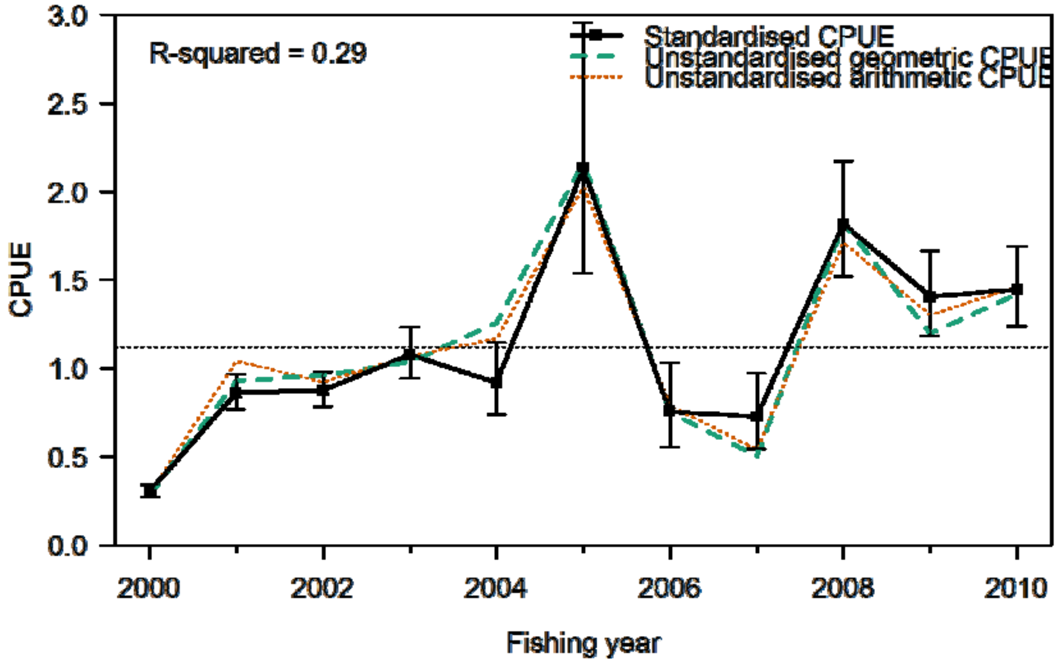



**Figure D9: Sub-Antarctic CPUE Standardised, geometric, and arithmetic CPUE for fishing years 2000–2010.**

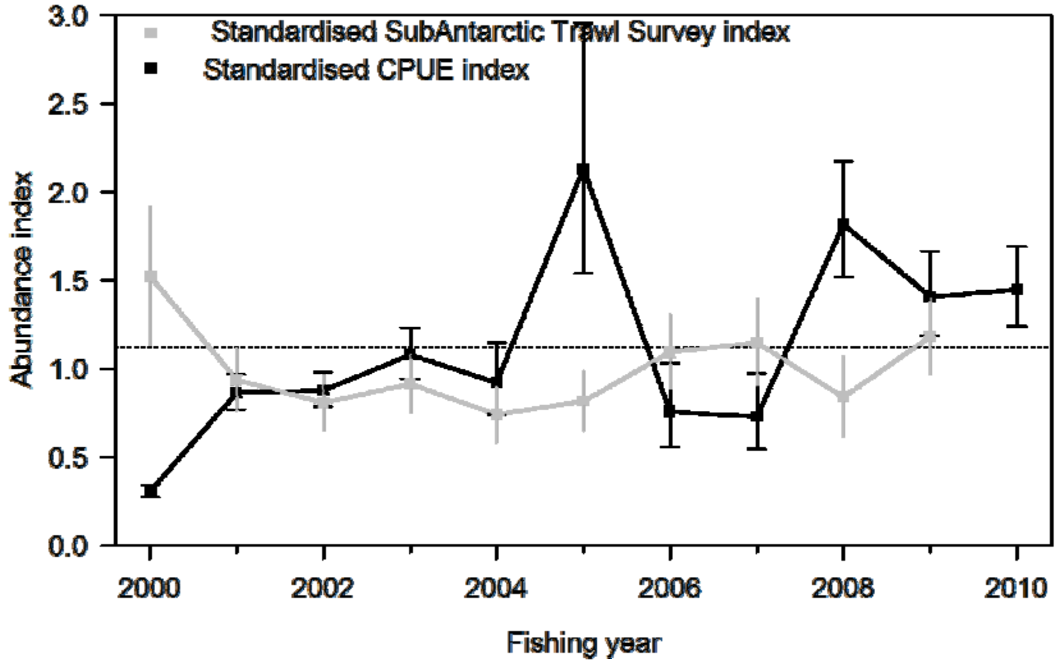



**Figure D10: Comparison of Sub-Antarctic standardised CPUE and standardised Sub-Antarctic trawl survey abundance indices for fishing years 2000–2010. NB: There was no Sub-Antarctic trawl survey in 2010.**

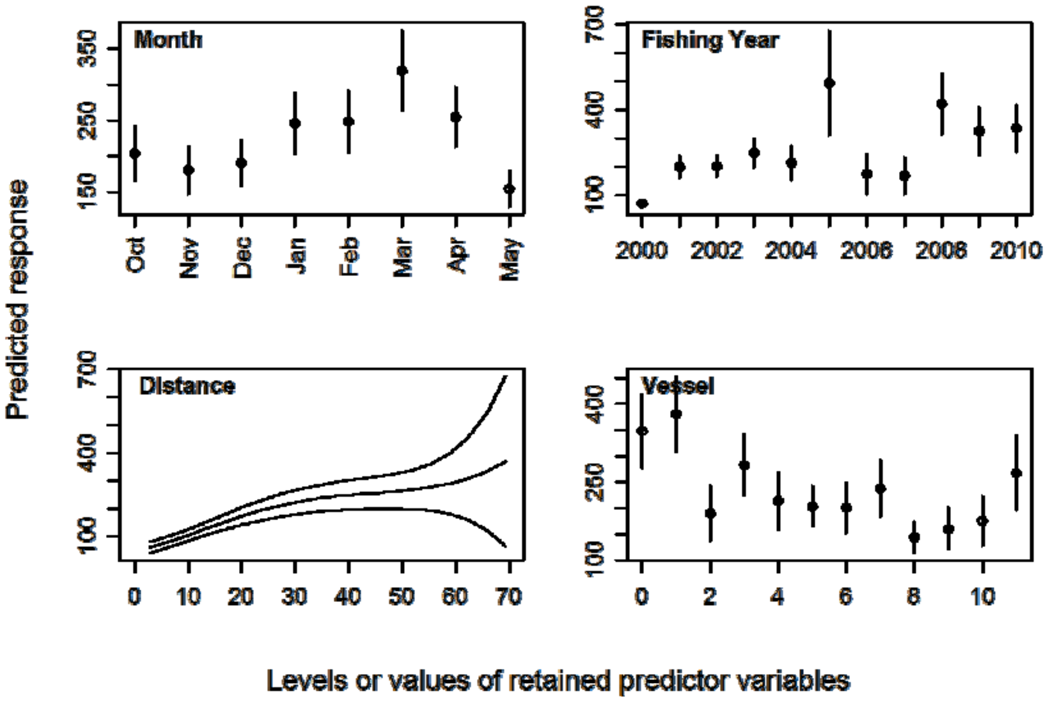



**Figure D11: Sub-Antarctic CPUE predictor variables retained in the GLM analysis and their distributions by factor levels.**

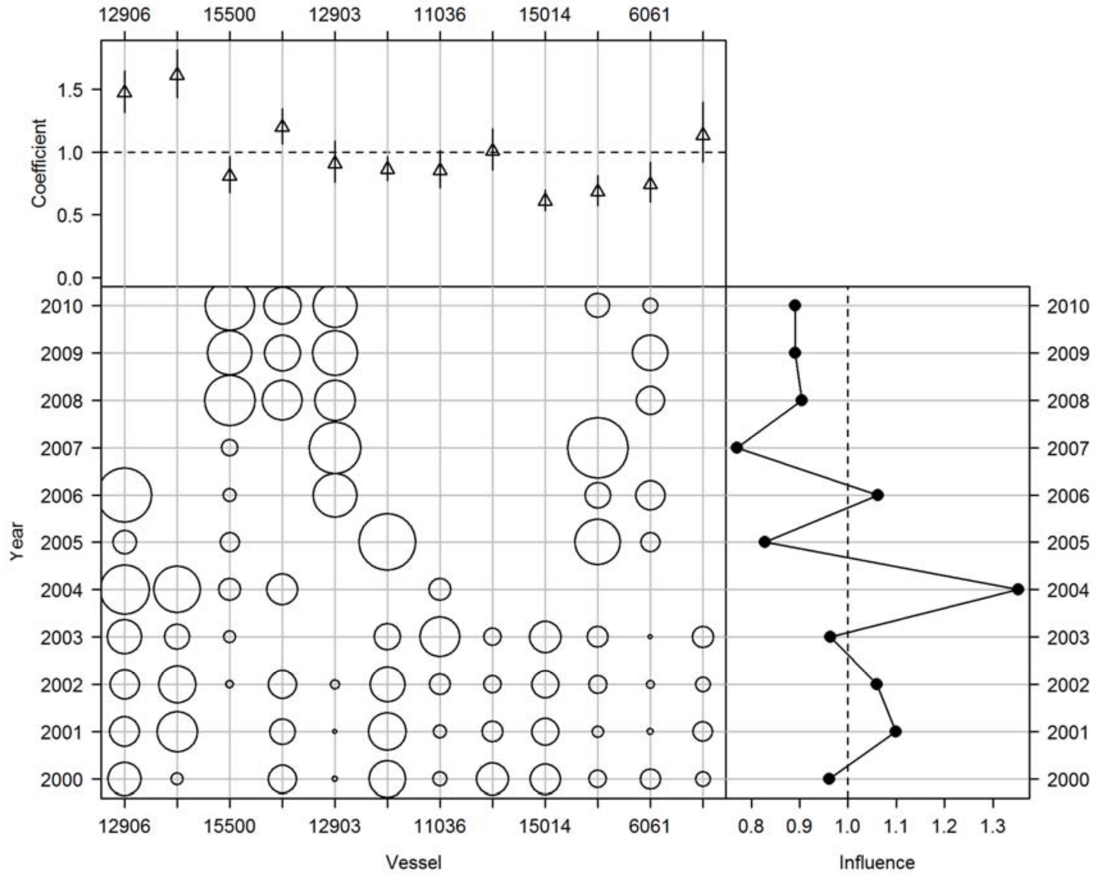



**Figure D12: Effect and influence of vessel for the Sub-Antarctic CPUE model. Top: relative effect by level of variable. Bottom left: relative distribution of variable (vessel) by fishing year. Bottom right: influence of variable (vessel) on unstandardised CPUE by fishing year. Vessel numbers are vessel identification numbers.**

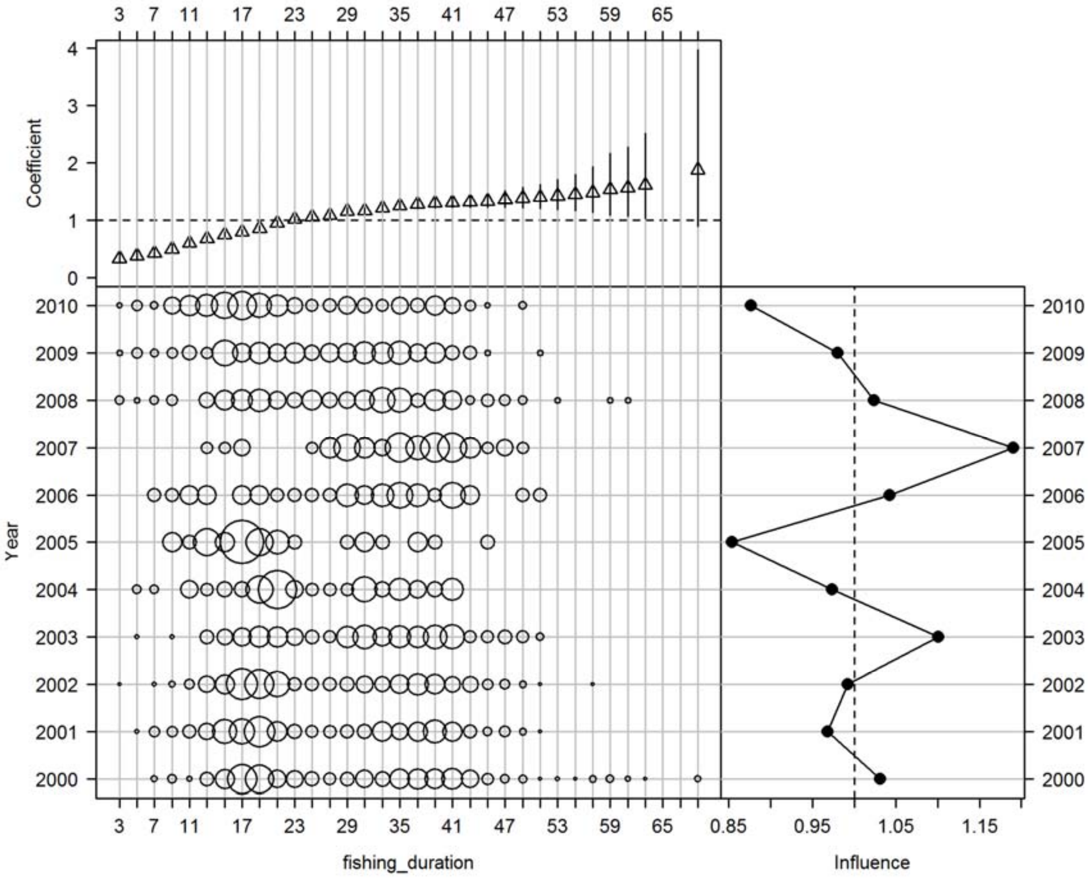



**Figure D13: Effect and influence of distance towed for the Sub-Antarctic CPUE model. See caption on Figure D12 for details.**

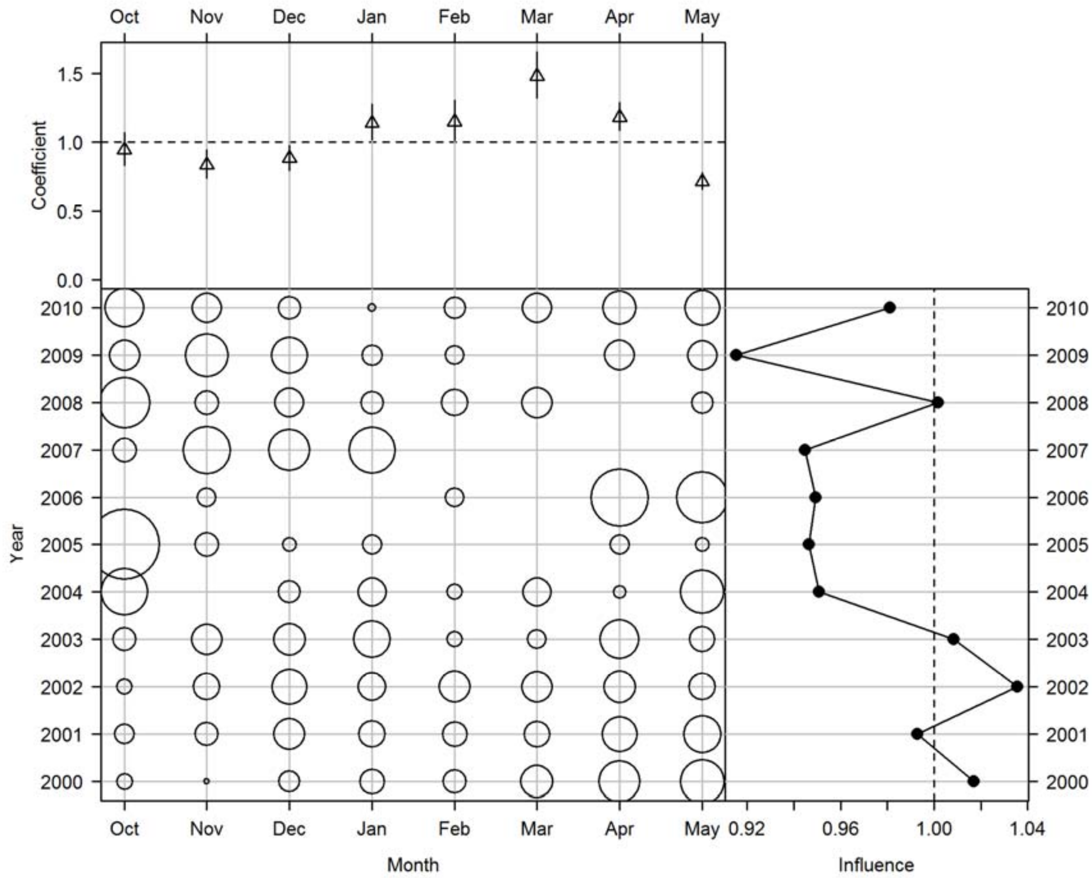



**Figure D14: Effect and influence of month for the Sub-Antarctic CPUE model. See caption on Figure D12 for details.**

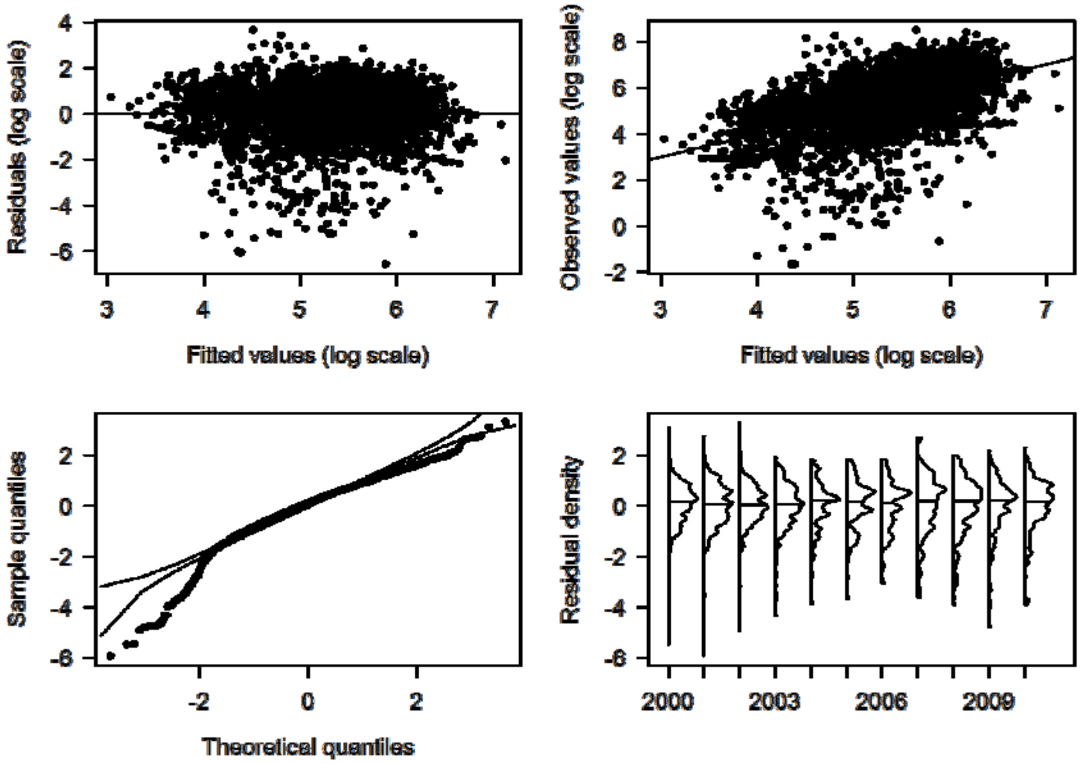



**Figure D15: Sub-Antarctic CPUE residual diagnostic plots describing the fit of the GLM CPUE model.**