

**Fishery characterisation and standardised CPUE analyses for  
silver warehou (*Seriolella punctata*) in SWA 3 and 4,  
1989–90 to 2007–08**

S. Parker<sup>1</sup>  
D. Fu<sup>2</sup>

<sup>1</sup>NIWA  
P O Box 893  
Nelson 7040

<sup>2</sup>NIWA  
Private Bag 14901  
Wellington 6241

**Published by Ministry of Fisheries  
Wellington  
2011**

**ISSN 1175-1584 (print)  
ISSN 1179-5352 (online)**

©  
**Ministry of Fisheries  
2011**

Parker, S.; Fu, D. (2011).  
Fishery characterisation and standardised CPUE analyses for silver warehou  
(*Seriolella punctata*) in SWA 3 and 4, 1989–90 to 2007–08.  
*New Zealand Fisheries Assessment Report 2011/1.*

This series continues the informal  
New Zealand Fisheries Assessment Research Document series  
which ceased at the end of 1999.

## EXECUTIVE SUMMARY

**Parker, S.; Fu, D. (2011). Fishery characterisation and standardised CPUE analyses for silver warehou (*Seriolella punctata*) in SWA 3 and 4, 1989–90 to 2007–08.**

*New Zealand Fisheries Assessment Report 2011/1.*

The Ministry of Fisheries has developed an assessment strategy to assemble and evaluate fishery and biological information to characterise and assess the status of fish stocks for which there is no robust stock assessment. This strategy will be used for selected fish stocks on a routine basis. The process is intended to provide a standardised reporting format to aid in the preparation of stock assessment plenary documents and to ensure a complete characterisation has been conducted. Silver warehou in QMAs 3 and 4 were identified for this process in 2008.

Silver warehou has been exploited since the mid 1960s, with significant development in the 1970s. Since the QMS was introduced, silver warehou has been mainly a bycatch component of bottom trawl fisheries both on the shelf and in middle depths to 500 m. However, in some areas and seasons a directed silver warehou fishery exists. Commercial harvest has typically exceeded the TACC during the past decade despite several TACC increases. SWA 1 has been managed under an Adaptive Management Programme and therefore has been reviewed by the New Zealand Seafood Industry Council. This report focuses on the status of SWA 3 and 4.

The distribution of silver warehou catch roughly conforms to the 100–400 m slope area, with the catch of smaller fish in shallower waters and larger fish in deeper waters. Although they occur around both North and South islands of New Zealand, their distribution is predominantly around the South Island. There are four main areas of catch: the west coast of the South Island (mainly associated with the winter hoki fishery); Southland, which encompasses the Stewart-Snares shelf, Puysegur region, and the Campbell Plateau (and is mainly driven by target silver warehou fishing or bycatch in the squid fishery); the east coast of the South Island focusing on the area surrounding Banks Peninsula to Mernoo Bank; and the eastern Chatham Rise, centred around the Chatham Islands. Catch in these areas is seasonal depending on the target fishery, and targeting of SWA occurs by some vessels throughout the year, especially in Southland. Most catch is by bottom trawl, though some catch using midwater gear occurs in each region. In addition to the hoki and squid fisheries, silver warehou is also taken as bycatch at low levels in shelf trawl fisheries around New Zealand.

Length frequency distributions are available from research bottom trawl surveys and from observer samples from larger offshore vessels in SWA 1, 3, and 4. Although variable, length modes are visible that typically track from year to year as the fish grow. The typical 50 cm length mode observed in the Chatham Islands and the ECSI has diminished since 2004 and was mostly absent in 2008 in both surveys and in observer data. Although strong size modes near 40 cm were present in 2008, these distributions should be monitored in the near future for evidence of a weak year class.

The catch of SWA in 2007–08 was dramatically lower than in previous years. The main decrease in catch was off the east coast of the South Island and Southland. The most likely explanation for the decrease in catch is an increase in deemed values and differential deemed value rates imposed for the 2007–08 fishing year.

Within areas SWA 3 and SWA 4, three main bottom trawl fisheries occur that interact with silver warehou. A standardised catch per unit effort (CPUE) analysis of fisheries in these areas was conducted using bottom trawl data stratified by statistical area, target species and trip (merged data), or tow-level data from vessels reporting using TCEPRs (unmerged data) from 1990 to 2008. Standardised CPUE indices for each area fit the data poorly, explaining 18 to 52% of the null deviance of the various models depending on configuration. All three areas showed variable, but relatively flat CPUE indices overall, but with some similar multi-year trends and peaks within the 18 year time series.

The CPUE indices are not likely to reflect relative trends in abundance in each area. The factors that were selected often only marginally improved the fit and observed annual CPUE variations would be infeasible as changes in actual biomass. CPUE trends are influenced by large variations in target fishery mortality, movement and mixing, deemed values, and life history factors such as recruitment and schooling. The combination of unrealistically large annual changes in biomass, lack of any consistent trend within or among regions, presence as bycatch in large fisheries that have had large fluctuations in catch themselves, and the strong effect of deemed value increases on catch rates show that CPUE is not indicative of relative abundance of silver warehou.

## 1. INTRODUCTION

Most of New Zealand's middle depth fisheries, other than hoki, hake, ling, and southern blue whiting, are not routinely monitored or assessed despite their moderate size and value. This project was designed to ensure that data available for monitoring important middle depth species are routinely summarised and assessed on a five-year rotating schedule as described in the Ministry of Fisheries medium-term research plan for middle depth species (Ministry of Fisheries 2008a). Silver warehou (*Seriolella punctata*) was chosen for full characterisation in 2008.

A second broad objective for the project was to develop a standard reporting format for all species to be characterised. The report includes sections of text and tables that can be transferred to the Plenary document as appropriate. A consistent format for analyses and reporting will provide economies of scale as many computer scripts and methods developed under this project will be largely transferable to future descriptive analyses of the other middle depth species. Some topics present in Plenary documents were excluded from this report.

The report summarises the analyses carried out for the Ministry of Fisheries under project MID200703. Due to the timing of the project, we have obtained permission from the Ministry of Fisheries to include data through the 2007–08 fishing year.

## 2. FISHERY SUMMARY

### 2.1 Commercial fisheries

Silver warehou (also recorded as *S. maculata* Forster) are caught in coastal waters mainly around the South Island of New Zealand, as well as on the Chatham Rise and Campbell Plateau at depths to about 500 m (Anderson et al. 1998). Most of the commercial catch is taken from the Chatham Rise, Canterbury Bight, southeast of Stewart Island, and the west coast of the South Island. Throughout the fishery history, most of the silver warehou catch has been taken as a bycatch of the hoki (*Macruronus novaezelandiae*), squid, barracouta, and jack mackerel (*Trachurus* spp.) trawl fisheries, though some target fishing occurs (Knuckey et al. 1998, Phillips 2001).

The fishery is currently managed as three separate fish stocks based on Quota Management Areas (QMAs, Figure 1): North Island and the west coast of the South Island (SWA 1), southeast coast of the South Island (SWA 3), and sub-Antarctic, Southland, and the eastern Chatham Rise (SWA 4). An administrative stock has been established for the Kermadec area (SWA 10), but no catch of silver warehou has been recorded from that area.

Commercial fishing for silver warehou developed in the late 1960s and early 1970s. Before the establishment of the Exclusive Economic Zone (EEZ), silver warehou, common or blue warehou, and white warehou were all lumped under the category of “warehou”. Estimated total annual catches of silver warehou based on area of capture were about 13 000 t in 1976, 1977, and 1978 (Paul 1980, Livingston 1988; Table 1). Concern about overfishing on the eastern Stewart–Snares shelf led to closure of this area to trawlers between October 1977 and January 1978. Initially, effort shifted to the Chatham Rise and total estimated catch did not change (Ministry of Fisheries 2008b). The catches did drop significantly after the establishment of the EEZ, and the reported landings fluctuated between 3000 t and 8000 t from 1978–79 to 1985–86 (Tables 1 and 2).

After the introduction of the EEZ, an initial TAC of 18000 t was set but subsequently halved in 1980–81 (Livingston 1988). The foreign licensed fleet was assigned area and species limits and their allocation of silver warehou was gradually reduced from 5500 t in 1978–79 to 2000 t in 1982–83 (T. Norris, unpublished data). At this time, 7000 t of the overall TAC of 9000 t was allocated to domestic and charter operations (*Catch '82*). On 1 April 1983, silver warehou was one of seven species included

under the Deepwater Policy that introduced individual quotas into the deepwater fishery, allocating quota to New Zealand owned or chartered “deepwater” vessel operators.

On 1 October 1986, Individual Transferable Quotas were introduced under the Quota Management System (QMS). The total allowable commercial catch (TACC) for silver warehou was initially set to be 8010 t, based on existing allocations and allowances under the deepwater policy. Reported landings history and actual TACC levels are shown in Table 2.

The TACC in SWA 1 was increased in 1991–92 under the "adaptive management" programme (AMP). After 5 years, a review concluded an appropriate monitoring programme was not in place and it was not known if the TACC was sustainable (Ministry of Fisheries 2008b). SWA 1 was removed from the AMP in October 1997 and the TACC was reduced to 2132 t. SWA 1 entered a new AMP in October 2002, with the TACC increasing to 3000 t. However, catches have not approached the new TACC level since inception. SWA 1 is currently monitored using biological information and total mortality (Z) estimates based on the age structure of the catch, as the CPUE was determined unlikely to track abundance. The AMP for SWA 1 was reviewed in 2007 (SeaFIC 2007), and suggested that fishing mortality was substantially lower than natural mortality and had not increased from 1992 to 2005 based on catch curve analysis. Much of the decrease in catch in SWA 1 is likely due to the decrease in west coast South Island (WCSI) hoki catch, as silver warehou is mainly a bycatch in the hoki fishery. If WCSI hoki catch is increased, silver warehou catch is likely to increase as well. SWA1 CPUE was also evaluated as part of the AMP by Cordue (SeaFIC, unpublished results), and found that although a large signal in CPUE existed in the middle of the time series, the overall CPUE model did not explain much of the variation in the data.

The TACC was last increased to 3280 t in SWA 3 and 4090 t in SWA 4 in the 1994–95 fishing year by the Quota Appeal Authority (following several adjustments in the late 1980s and early 1990s) and has remained unchanged since. However, landings in both stocks have increased to levels well above TACC in most recent years (Table 2). In SWA 3 landings in 2006–07 were nearly double the TACC. In SWA 4 annual landings have also exceeded the TACC from 1999–2000 to 2006–07. Catches in both SWA 3 and 4 dropped substantially in 2007–08, likely due to an increase in deemed values for SWA 3 and SWA 4. The main decrease in catch was as bycatch in the hoki fishery. Bycatch in the squid fishery, and target SWA catch actually rose in 2007–08. Overall, for more than the past 12 years, the total catch has typically exceeded the combined TACC (Figure 2).

The silver warehou fisheries in SWA 3 and SWA 4 up to 1998–99 were last reviewed by Phillips (2001). He examined trends in CPUE for two trawl fisheries in the sub-Antarctic and Chatham Rise areas, both target and bycatch of the hoki and middle depth target fisheries. He concluded that the CPUE indices for the east coast South Island (ECSI), WCSI, Southland (sub-Antarctic) and western Chatham Rise (excluding the eastern Chatham Rise) did reflect relative changes in abundance. The CPUE trends were similar among areas and did not show evidence of a long-term trend. SeaFIC’s (2007) analysis of SWA 1 concluded that fishing mortality was likely sustainable, being below natural mortality estimates. However, no analysis of the fisheries in SWA 3 or SWA 4 has been completed to determine the cause or effects of the catch exceeding the TACC in those management areas for the past decade. Because SWA 1 is monitored separately under an AMP, this report focuses on the characterisation and status of SWA 3 and SWA 4 fisheries.

## **2.2 Recreational fisheries**

There are no current recreational fisheries for silver warehou.

## **2.3 Maori customary fisheries**

Quantitative information of the current level of customary non-commercial catch is not available.

## 2.4 Illegal and misreported catch

Silver warehou have been misreported as white or blue warehou in the past. In addition, juvenile silver warehou are commonly caught in shallower coastal waters which could lead to non-retention of unmarketable fish. The extent of these practices is unknown and could lead to under-reporting of silver warehou catches.

## 2.5 Other sources of mortality

Other sources of mortality are unknown.

# 3. BIOLOGY

## 3.1 Distribution

Globally, *Seriolella punctata* can be found throughout the southern hemisphere (33–47° S) in waters less than about 600 m deep (Paulin et al. 1989, Pequeño 1989). The distribution of adult silver warehou in New Zealand waters is fairly well mapped by fishing effort and trawl survey efforts throughout the past 30 years (Figure 3). The adults are found in deeper waters than the juveniles and are often targeted around Mernoo Bank and at the 200 m depth contour, sometimes known as “silver street” off Southland. However, their distribution is much more dispersed with respect to depth than that term implies, with catches occurring across Chatham Rise (especially between Banks Peninsula and Mernoo Bank), the Stewart-Snares shelf, and the northern west coast of the South Island with a depth distribution centred on 200 m (Figure 4). Minor catches occur around the North Island also, but targeting only occurs in the shallow waters in the northern half of the North Island and comparatively little catch results.

Quantitative bottom trawl surveys show similar distributions to commercial catch distributions in their respective areas (Figure 4). The surveys occur only seasonally and could be unrepresentative of changes in distribution during the year. However, scientific observer data do not show large differences in spatial distribution of adult fish by season, with the caveat that little sampling has occurred in winter months outside the WCSI and the ECSI (Figure 5).

Juvenile and 0+ silver warehou are found in shallower waters and are concentrated on the west, north and east sides of the South Island in waters shallower than 200 m (Figures 4 and 6), (Hurst et al. 2000, Horn et al. 2001, O’Driscoll et al. 2003). Zero-plus juveniles have been observed in shallow waters around the North Island also, especially the south east coast, Bay of Plenty, and Taranaki Bight in research trawls. Their distribution tends to shift south as 1+ fish, and as 2–4 year olds they become much more prevalent around the northern end of the South Island (O’Driscoll et al. 2003). Observer samples have also reported juvenile fish (under 44 cm) around Taranaki Bight, and adult size fish all around the North Island (Figures 4 and 6). Their distribution is consistent with a behaviour of seeking shallow water, as juveniles are found in areas such as Tasman Bay or Taranaki Bight where spawning does not appear to occur. Occurrence of juveniles in the sub-Antarctic, on the Challenger Plateau and around the North Island (except the Wairarapa coast) is sporadic.

## 3.2 Stocks and spatial distribution

Gavrilov (1979) gave the first description of the biology and distribution of silver warehou off New Zealand. He proposed a single Chatham Rise stock based on life history characteristics and developmental timing. Nearly 10 years later, Livingston (1988) summarised fishery and biological data and suggested that up to four spawning areas existed (WCSI, Chatham Islands, Mernoo Bank, and Stewart-Snares shelf). Spawning migrations were not indicated because catches of adult fish were made year round in all four

locations (Livingston 1988). She suggested that these spawning areas could represent separate spawning stocks and recommended separate TACS to manage harvest. However, the administrative boundaries were already set and remain today (Ministry of Fisheries 2008b).

With a validated ageing methodology, Horn et al. (2001) investigated growth rates, gonad staging information, and age structure with regard to stock structure, but found no evidence from these characteristics for separate reproductive units. The only study to examine silver warehou genetic structure has been off southeast Australia, and no differentiation was observed (Bruce et al. 2001). The current consensus is that despite the knowledge of several spawning areas (some with different timing from others), and that largely distinct adult distributions exist, the overall distribution of silver warehou is continuous within their preferred depth range.

### **3.3 Spawning**

#### **3.3.1 Timing**

Observations of mature silver warehou indicate that they are winter/spring spawners, with ripe fish present by July, and spent fish appearing by October (Figure 7). Gavrilov (1974) conducted a histological analysis of silver warehou oogenesis on the Chatham Rise and classified the species as batch spawners, producing three batches of eggs (October, November, and December) with decreasing numbers of eggs released in each batch. We assume the same process occurs in other regions. The peak timing for spawning is earliest on the WCSI, and otherwise a south to north progression appears to take place, with a peak occurring later to the north and in shallower water (see Figure 5). This compares well with a previous summary of research survey and observer information (O'Driscoll 2003). Later spawning in shallower water is likely an artefact of younger fish in shallower water maturing later in the season (Berkeley et al. 2004). There is some evidence that they spawn on the east coast of the North Island (Annala et al. 1999, Hurst et al. 2000). In fact, a relatively tight distribution of adult fish can be noted in the Bay of Plenty and off the southeast coast of the North Island. A corresponding presence of 0+ fish is also observed in these locations, but fish 1–4 years old appear to be absent from these areas. Eggs have been recorded off Kaikoura in autumn (Robertson 1975). Eggs hatch after about 6 days (146 hours at 10–13 °C) and emergent yolk-sac larvae are about 3 mm long (Grimes & Robertson 1981).

#### **3.3.2 Maturation**

Gavrilov (1974) indicated an age of maturity of 3–4 years based on histological analysis, corresponding to a length of 46–48 cm. Observations of developmental stage have been collected on survey and commercial vessels for many years. The staging system has five levels for females (1: immature or resting, 2: maturing, 3: ripe, 4: running ripe, 5: spent). Because immature and resting fish both score 1 (and are difficult to separate especially during non-reproductive seasons), it is not possible to estimate maturity ogives with these data. However, very few females smaller than 25 cm have been staged as “maturing”. Numbers of maturing fish rise sharply both in absolute number of observations and as a percentage of the total number of observations, indicating significant reproductive development when fish are 30–40 cm. It is likely that 47 cm is close to the size at 100% maturity, with the size at 50% maturity closer to 44 cm. Currently, 47 cm is widely cited as the length at 50% maturity. It is interesting to note that the size distributions (1968–76) of the fish characterised by Gavrilov were larger than those reported later, with many fish over 60 cm and average lengths of about 53–54 cm.

Distributions of spawning fish in the winter/spring periods indicate spawning areas on the WCSI near Westport, Mernoo Bank, Eastern Chatham Rise, and Stewart-Snares shelf. There is some evidence for maturing fish off the east coast of the North Island (ECNI, O'Driscoll et al. 2003), but these fish are not very far from Mernoo Bank and given the protracted spawning season could easily participate on

the Chatham Rise. However, the presence of adult fish in the Bay of Plenty during spawning season is not as easily explained, especially when 0+ juveniles are present there. It appears that small populations of silver warehou exist off the North Island, but become rare towards the northern end.

### **3.4 Climate and recruitment**

No analyses have examined any link between climate characteristics and recruitment.

### **3.5 Ageing**

Age determination using otoliths was validated by Horn & Sutton (1996). Earlier ageing work by Gavrilov used scales and was not considered reliable for fish over about 8 or 9 years of age. Ages have been determined for several thousand samples collected during bottom trawl surveys (mostly from Southland and the WCSI). Additional samples, collected from the WCSI hoki fishery by scientific observers have been aged by SeaFIC and analysed as part of the AMP monitoring programme for SWA 1 (SeaFIC 2007).

### **3.6 Growth curves**

Von Bertalanffy growth curve parameter estimates for each sex were derived for three regions around the South Island of New Zealand by Horn and Sutton (1996) (Table 3).

### **3.7 Natural mortality**

Horn & Sutton (1996) estimated instantaneous natural mortality ( $M$ ) using catch-curve analysis to be approximately 0.25.

### **3.8 Length-weight relationships**

The length–weight relationship was reported for samples from the Chatham Rise and from Southland by Horn & Sutton (1996). They observed no difference between sexes and reported a single relationship (Table 4).

### **3.9 Feeding and trophic status**

Gavrilov & Markina (1970) described the progression of juveniles into deeper water with increasing size and in relation to the distribution of their prey. Very young fish of 12–14 cm length feed on plankton, juveniles 14–15.5 cm feed on Amphipoda and Chaetognatha in coastal waters. At 24–31 cm they move into the deeper part of the shelf, feeding on zooplankton – especially salps. Fish more than 30 cm long feed on macroplanktonic organisms of the upper slope region. A summary of feeding information before to 2000 from the Chatham Rise and Southland research surveys (D. Stevens, NIWA, unpublished manuscript) found that over 95% of stomachs with food contained salps and that this was consistent across all size classes (20–60 cm); the remaining items were crustacean (euphausiid, amphipod, isopod, natant decapod), teleost (unidentified), and squid.

## **4. FISHERY INDEPENDENT OBSERVATIONS**

### **4.1 Research surveys**

#### **4.1.1 Biomass indices**

Bottom trawl surveys have been conducted since the early 1990s using either *Tangaroa* (Chatham Rise survey or sub-Antarctic Survey) or *Kaharoa* (ECSI or WCSI). These surveys all encounter silver warehou, but are not optimised to estimate biomass for this species. A discontinued survey of Southland (1993-96) did attempt to optimise for silver warehou (Hurst & Bagley 1997). Note, that the Southland surveys were not included here as a time series because it included only 4 years and does not provide information on current status as it ended 14 years ago. We use the term Southland to refer to all fishery activity, survey activity, and biological characteristics south of the Otago Peninsula. In addition, the inshore *Kaharoa* surveys occur in areas and depths where juveniles are present, and so may not represent adult biomass trends. The catch distribution is often very patchy and c.v.s for the biomass estimates are typically higher than optimal (average Chatham Rise: 42%; Southland: 68%; Sub-Antarctic: 59%; ECSI: 35%; and WCSI: 27%), but are sometimes between 20% and 30%. The biomass trends for the four surveys are variable and appear flat overall, but the Chatham Rise index suggests a slowly increasing biomass for the past decade (Figure 8). Because the survey is not optimised for silver warehou and average c.v.s are high, it was not considered a good monitoring tool (Ministry of Fisheries 2008b). It may none the less be useful in interpreting CPUE analysis results for the Chatham Rise fishery as the biomass trend shows some contrast in signal (an increasing trend). The ECSI survey was first conducted as a winter survey (1991–96) then as a summer survey (1996–2000, Beentjes et al. (2004). It was then discontinued, but restarted as a winter survey in 2007. There is no indication that silver warehou change their distribution between summer and winter, especially as juveniles. Therefore, we have presented the entire series noting that 1996–2000 occurred at a different time of year.

#### **4.1.2 Length and age sampling**

The South Island bottom trawl surveys also collect length, sex, and subsamples of gonad stage information for silver warehou which are useful in evaluating stock structure, monitoring progression of year classes through time, and identifying spawning periods and areas. Each survey measures several hundred to several thousand individuals depending on catch; but because silver warehou are a schooling species and occur in a patchy manner, these samples may not describe the size distribution of the overall population (see below). Age structures have been collected from silver warehou during surveys and were used by Horn & Sutton (1996) and Horn et al. (2001) to estimate growth rates and examine evidence for stock structure. Those samples were collected from Southland and WCSI surveys only in the early 1990s and are not useful for long term monitoring of age structure (Table 5). Since 1995, no silver warehou otoliths have been collected during bottom trawl surveys. Otoliths have been collected through the scientific observer programme for SWA 1 and were aged and analysed by SeaFIC (2007), but collections do not exist for other regions. Therefore, although length distributions exist, annual age-length keys from trawl surveys for the different regions are not available.

#### **4.1.3 Length and age frequencies**

The Chatham Rise survey length distributions typically show an adult mode near 50 cm, with sporadic modes usually just below 40 cm (Figure 9). However, the larger mode near 50 cm apparent in the 1990s becomes sporadic in the 2000s and is not present after 2005. Three times during the time series, a distinct smaller mode near 25 cm is present and this can usually be observed as larger fish in the subsequent year (e.g. 2000–01, 2005–06). The Chatham Rise series does show several examples of modal progression, notably 2000–05, and a second from 2005–07. However, the modes don't always track all the way through, e.g., the expected 50 cm size mode is missing from 2008.

Modes are more apparent in the ECSI survey as it samples both juvenile and adult depth ranges (Figure 10). Length modes of near 20 or 30 cm are common, but larger adult modes are infrequent, appearing only in 1997 and to some degree in 2000. Length modes in the survey datasets track between years much better than modes from the observer datasets, despite higher sample sizes from observers (see below). However, the survey length distributions often completely lack modes that were strong in observer data or were strong in the survey in the previous year. Because of this, strong year classes are difficult to detect. The Southland time series typically shows an adult size mode only, with the exception of an additional smaller mode in 2007 (Figure 11), in contrast to the observer data which show a consistent strong representation of smaller fish. Although a strong mode was also observed in the ECSI series in 2007, fish length was about 25 cm, compared with 35 cm in the Southland series. The WCSI series is dominated by a single juvenile mode of about 20 cm and these fish are typically from Tasman Bay/Golden Bay samples (Figure 11).

An additional feature of these time series, especially with the Chatham Rise and ECSI series, is that the size distributions are extremely variable among years. The Chatham Rise survey sometimes completely lack the typical 50 cm size class, and often lacks the 25 or 35 cm modes even though the appropriate mode is present in the subsequent year. The variability is highest in the ECSI survey, which shows up to four distinct size modes, but usually only one or two simultaneously (See Figure 10). Variability in adult size classes captured in this survey is a common feature and is thought to be a result of either environmental influences on fish distribution, fish schooling by size, or the result of problems with gear performance (Beentjes et al. 2004).

Strong year classes are not consistently coincident between the four survey areas, suggesting these populations are not strongly linked. However, these time series are fraught with missing modes, making progression difficult to see when a strong year class does appear in one series. The length distributions from the observer programme were sometimes similar to the distributions obtained from the survey sampling in the appropriate area (Figures 9 and 12), but they did not always match; the ECSI was typically very different between survey and observer distributions (Figures 10 and 13). It was noted by Horn et al. (2001) that the surveys did not adequately sample the populations due to low sample sizes and the schooling behaviour of silver warehou. However, observer samples should be more representative despite the sample size issues raised by SeaFIC (2007). It is likely that the patchy, schooling nature of silver warehou makes characterising the population size structure with a relatively small number of tows problematic. To address this, more tows would need to be allocated to depth strata where silver warehou occur (i.e., include SWA as a target when optimising the survey).

## 4.2 Other data

Other research concerning population dynamics and stock structure of *Seriolella punctata* includes genetic work by Robinson et al. (2008) which indicated no genetic differentiation among silver warehou sampled in eastern and western Victoria, Australia. Data from a study of larval distribution in southeastern Australia also suggested that larvae were widely distributed and that little spatial differentiation existed within the region studied (Bruce et al. 2001). Horn et al. (2001) examined age structure and spawning status but other than documenting four putative spawning regions, no evidence for separate stocks was found. No other studies of stock structure using genetic techniques, parasitology, tagging, or otolith microchemistry have been conducted with silver warehou in New Zealand.

## 5. FISHERY DEPENDENT OBSERVATIONS

### 5.1 Observer data

#### 5.1.1 Length and age sampling

The Ministry of Fisheries Observer Programme has collected silver warehou length, weight, female gonad stage, and otoliths from various fisheries since 1985 (Table 6). Otoliths from commercial catches have been collected only from the hoki fishery on the WCSI (see SeaFIC 2007), but additional otoliths were collected from 1993–96 on *Tangaroa* trawl surveys (See Table 5).

#### 5.1.2 Length and age frequencies

Scaled length frequency distributions from observer data (following the procedure of SeaFIC (2007)) typically show three modes in each of the areas sampled; a large mode of 50+ cm, a middle mode of 40+ cm, and a small mode in the 35 cm range (Figures 12–14). A fourth mode is present in some years near 20 cm, but it is very inconsistent and likely below any reliable selectivity level for the fisheries. These modes correspond to age modes of 2, 3, 4 and above following Horn & Sutton (1996). The tail of the large mode never exceeds 60 cm and shows no evidence of truncation since the mid-1980s. However, significant catches occurred before the 1980s (Livingston 1988) suggesting that size distributions from the late 1980s may not be pristine. Gavrilov's data (1979) from 1968 to 1976 showed much larger fish, with a mode in the mid-50s and many fish over 60 cm.

Strong smaller year classes are sporadically present in the three areas examined (Chatham Rise, ECSI, and Southland) and often are observed to progress into larger modes in subsequent years. However, these larger modes are often missing, as are smaller modes in the year before a strong larger mode. Still, strong year classes do appear in more than one area in the same year (e.g., 1999–2000), but not consistently (e.g., 2005–06). Overall, the size distributions from the Chatham Rise show a single mode of adult fish, typically centred near 50 cm. There is little evidence of a progression of year class modes within the Chatham Rise area (as compared with the survey data), although some progression can be seen from 2003–05. The ECSI, although spatially bordering the Chatham Rise area, shows smaller size modes more often and modal progression can be observed, especially since 2005–06. Southland shows a different pattern. Here, multiple size classes are often present, and typically two modes can be observed (at 43–45 cm and at 33–35 cm). Modal progression is apparent throughout the data series. The maximum fish size also appears to be a few centimetres less in Southland samples, especially when compared to the upper mode from the Chatham Rise samples.

Comparing Observer Programme and survey length frequency distributions sometimes shows different patterns, with one source sometimes showing a mode missing in the other source (e.g., 2002 Chatham Rise survey (See Figure 9) versus 2001–02 Observer Programme (See Figure 12) do not show the same pattern). The same is true for 2005 and 2006. The modal progression observed in the survey series (2001–05 and 2005–07 are not visible in the observer data, though the observer data do seem to reflect some progression from 2003 to 2005. Note that these series are often not strictly comparable and the Chatham Rise is the best one to examine. The largest difference is in gear type (mesh size), but even for the larger modes, areas fished can be different. For example, the ECSI survey, despite its reconfiguration in 1996, probably does not index a similar area to the observer data, which typically come from larger offshore vessels. And in Southland, silver warehou catches in the survey are fairly infrequent, whereas observer samples are huge. For example, the 2007 distributions are fairly similar between Figures 11 and 14, but sample size constraints prevent a robust comparison.

Overall, observer length frequencies do not suggest that strong year classes in one area translate into strong year classes for all three areas.

The representativeness of observer sampling in SWA 1, 3, and 4 was evaluated by plotting the proportion of landed catch for each year by statistical area and month as bubbles, and overlaying this with the proportion of the observed catch for those same cells as crosses (Figure 15). If the proportions are the same, the plots align. Oversampling is indicated if the crosses are larger than the bubbles, and under sampling if they are smaller. An examination of the plots in Figure 15 suggests that in each QMA, observer sampling of the main areas harvesting SWA has been very good, but if anything, tends to oversample the main areas and undersample small catches in the inshore statistical areas. The match has been steadily improving among the main statistical areas and is likely driven by low observer coverage rates on inshore vessels.

On a seasonal basis, the pattern is not as good, with mismatches within each year and variable representation among months in successive years. However, it is very difficult to predict the actual month in which a given percentage of the catch occurs, making it difficult to assign observer effort at the proper scale. The only way to improve this match is to have a very high constant percentage of observer coverage, so that variation in catch by particular vessels, or unpredictable effort by vessels, does not determine the percentage of catch observed.

## 5.2 Catch and effort data sources

Catch and effort data were requested from the Ministry of Fisheries catch-effort database “*warehouse*” as extract 7334. The data consist of all fishing and landing events associated with a set of fishing trips that reported a positive landing of silver warehou in SWA 1, 3, and 4 between 1 October 1989 and 30 September 2008. The fishing year extends from 1 October through 30 September of the next calendar year. In this report, fishing year is labelled as the most recent year (i.e., the 1998–99 fishing year is referred to as 1999). Catches from SWA 1 were requested because trips landing to multiple stocks occur at the boundaries of stock units and error correction is enhanced by having records from trips fishing in neighbouring QMAs. The fields from the database tables requested are listed in Table 7.

The estimated catch associated with the fishing events were reported on the general Catch Effort Landing Returns (CELR) and the more detailed Trawl Catch Effort and Processing Return (TCEPR). The greenweights associated with landing events were reported on the bottom part of the CELR forms, or where fishing was reported on the TCEPR, on the associated Catch Landing Return (CLR). TCEPR forms record tow-by-tow data and summarise the estimated catch for the top five species (by weight) for individual tows. CELR forms summarise daily catches, which are further stratified by statistical area, method of capture, and target species. Trawl vessels less than 28 m in length can use either CELR or TCEPR forms; trawl vessels over 28 m use TCEPR forms. From 1 October 2007, the Trawl Catch Effort Return (TCER) forms replaced the CELR forms, and summarise daily estimated catches up to the top eight species for all vessel sizes.

Information on total harvest levels are provided via the QMR/MHR system, but only at the resolution of Quota Management Area. The catch-effort and landing returns report catches at the level of individual fishing events, and the fishers are required to report only the top five species in their catch. This has led to concerns (e.g., Phillips 2001) that bycatch species, such as silver warehou, may not be well reported at the fishing event level. The AMP review on SWA 1 found that trips that landed to SWA 1 and reported no estimated catch on TCEPR/CELR forms tended to be those with small landings (less than 1 t), and that the estimated catch at the individual tow level showed strong correlation with observer reported catch (SeaFIC 2007).

The “daily processed” part of the TCEPR contains information regarding the catch (of all quota species) that was caught and processed that day, and these data are generally believed to provide a more accurate account of low and zero catch observations (Phillips 2001). However, it was suggested (SeaFIC 2007) that processed catch data for SWA 1 suffer from similar problems as the estimated catch data: trips that have no estimated catch also tend to have no processed catch recorded. In addition, daily processed catch data suffer from the inability to assign processed catch to a specific day

or amount of effort because catch is not always processed on the day it was caught and can be split among days. The daily processed catch is not examined in this study.

The extracted data were groomed and restratified to derive the datasets required for the characterisation and CPUE analyses using a variation of Starr's (2007) data processing method as implemented by Manning et al. (2004), with refinements by Blackwell et al. (2005) and Manning (2007), and further modified for this study. The method allows catch-effort and landings data collected using different form types that record data with different spatial and temporal resolutions to be combined. It also overcomes the main limitation of the CELR and TCEPR reporting systems (frequent non-reporting of species that make up only a minor component of the catch). The procedure has been developed for monitoring bycatch species in the AMP, and was comprehensively described by Manning et al. (2004) and Starr (2007). The major steps are as follows.

- Step 1: The fishing effort and landings data are first 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 within each valid trip is then restratified by statistical area, method, and target species.
- Step 3: The greenweight landings for each fish stock for each trip are then allocated to the effort strata. The greenweight landings are mapped to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fish stock.
- Step 4: The greenweight landings are then allocated to the effort strata using the total estimated catch in each effort stratum as a proportion of the total estimated catch for the trip. If estimated catches are not recorded for the trip although a landing was recorded for the trip, then the total fishing effort in each effort stratum as a proportion of the total fishing effort for the trip is used to allocate the greenweight landings.
- Step 5: The original intent of the merging process was to allow trip level landings data to be mapped to CELR effort strata. However, many species are captured in fisheries reporting using a combination of form types, and some may use TCEPR forms almost exclusively. The grooming and merging process also allows an evaluation of the amount of catch and effort that is not captured using TCEPR forms at the fishing event level. If significant, the best characterisation dataset is likely to be the merged trip-level data. But if the amount of lost catch and effort is predictable, minor, and stable over time and area, the estimated catch at the level of the fishing event provides a much more detailed dataset for characterisation and CPUE analysis.

## **6. DESCRIPTIVE ANALYSIS OF CATCH**

### **6.1 Summary of catches**

The reported QMR/MHR landings, the catch-effort landings (un-groomed), and TACC for SWA 1, 3, and 4 from 1983–84 to the 2007–08 fishing year are shown in Figure 16. The spatial distribution of total commercial catch is depicted in Figure 3. For all three stocks, the catch-effort landings in the raw dataset exceed the reported MHR landings throughout the time series, but generally conform in trend. The MHR landings have overrun the TACC in most recent years for SWA 3 and 4 (Table 2, Figure 16).

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, and interim landing events, where catch is transferred or retained, and may therefore appear subsequently as a final landing event (SeaFIC 2007). Starr’s procedure separates final and interim landings based on the landing destination code, and only landings with destination codes which indicate a final landing are retained (See table 2 in Starr (2007)).

Table 8 summarises the number of landing events for the major destination codes in the dataset. There are a significant number of landing events recorded under “T” (transferred to another vessel) and “R” (retained on board) destination codes (both are defined as interim landing events by Starr (2007)). For all three fish stocks, the “T” events appear in the early part of the series through to the late 1990s and were recorded by vessels using TCEPR forms. It was unknown how the catches from those trips are recorded, as the transferred catches could be landed by foreign vessels to ports outside New Zealand. Those transferred landing events accounted for more than half of the annual landings from 1989–90 to 1995–96 and excluding them from the dataset will lead to (1) retained landings falling short of the MHR by more than 50%, (2) a large number of trips with estimated catch, but no reported landings, and (3) annual estimated catch exceeding retained landings by up to 40% in the mid-1990s (Figures A1–3 in Appendix A). It is therefore prudent to retain the “T” landing events in the analysis and exclude other interim landing events as defined by Starr (2007). The weight, number of records, and disposition of catch for each potential landed state is given in Table 9.

The retained landings, interim landings, and total landings dropped during data grooming are shown in Figure 17. The grooming process excluded a small number of trips with invalid codes in fishing method, target species, statistical area, and trip date which cannot be fixed using the median imputation method. The estimated catch and landings removed from the dataset in this process were generally insignificant throughout the time series. For the three stocks, the retained landings were less than of the reported MHR in the early 1990s, but match closely for the later part of the time series.

The groomed and unmerged landings are summarised by process state in Figure 18. For all three stocks, the bulk of catches were processed to “DRE” state since 1990–91 (In this report, “Dressed”, “Headed, gutted, and tailed”, and “Trunked” are treated as “DRE”); a small but consistent proportion of catches were landed green in recent years. The conversion factors for some processed states of silver warehou have been changed over time since the full implementation of the QMS (Ministry of Fisheries 2008c). The conversion factor for the “DRE” state was increased from 1.60 to 1.65 from 1 October 1995, and to 1.70 from 1 October 2000, but decreased back to 1.65 with effect from 1 October 2006. The conversion factor for the “HGU” state increased from 1.50 to 1.55 from 1 October 1995. This means that different amounts of greenweight catch are associated with the same amount of processed catch for particular product forms throughout the database. Therefore the greenweights are 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 silver warehou, rather than real changes in processing methodology across the fleet. The adjustment has slightly increased the greenweight for the early part relative to the late part of the series (Figure 19).

The retained landings adjusted for the change of conversion factors 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 areas 018, 019, and 027), 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 the catches of the straddling statistical area had been taken from a single Fishstock 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. This approach was not practical in the case of SWA 3, where about 20% of trips had reported to other stocks but only a very small amount of catch was taken from straddling statistical areas 018 and 019. Excluding trips that had fished in statistical areas 018 and 019 and reported to multiple stocks would result in removal of landings by up to 40% in some years. Therefore statistical areas 018 and 019 were allocated to SWA 3 because most of the area is in SWA 3.

For SWA 4, over 50% of the trips had reported to other stocks. Statistical area 027 was allocated to SWA 4 as most of the area is in SWA 4 (See Figure 1).

The annual landings present in the raw dataset, retained landings in the groomed and unmerged dataset, and retained landings and estimated catches in the groomed and merged dataset are summarised in Table 10 and plotted in Figure 20. Manning (2004) calculated the recovery rate, defined as the groomed and merged landings as a proportion of the groomed and unmerged landings. The recovery rate was close to 100% in most years for SWA 3 and 4, indicating a consistent match between the recorded statistical areas on the CELR/TCEPR and the stocks reported on the CELR/CLR on a trip basis. There could be some bias in apportioning landings to statistical areas 018 and 019, but the bias was likely to be small as the two statistical areas accounted for less than 2% of the total estimated catch (Figure 20).

The reporting rate, defined to be the annual estimated catch as a proportion of the retained landings in the groomed and merged dataset, was also calculated. For SWA 1 and 3, the reporting rate was calculated for vessels using CELR, TCEPR, and TCER (since 1 October 2007) forms, respectively. For SWA 4, the overall reporting rate was given because very few CELR forms were used. For all three stocks, the annual estimated catches consistently fell short of the reported catches (Figure 20), and there has been no apparent change in the level of reporting through the time series (Figure 21). However, in SWA 1, the reporting rate under the CELR has been on average 20% lower than that under the TCEPR, indicating the reporting level was lower for vessels using the CELRs. In SWA 3, the annual estimated catches fluctuated at about 90% of reported landings for both CELRs and TCEPRs. In SWA 4, which was dominated by vessels using TCEPR forms, the reporting rate was slightly higher, fluctuating at about 95% and increasing in recent years.

The proportions of estimated catches and retained landings by form type for each fish stock are shown in Figure 22. For all three stocks the bulk of estimated catches are recorded on TCEPR (with the landings recorded on the corresponding CLR forms). For SWA 1 and 3, there has also been a small but consistent proportion of catch recorded on CELR forms, presumably by smaller vessels fishing in inshore areas. In the 2008 fishing year all vessels previously on CELR forms appeared to have switched to TCER forms. In SWA 4, there has been little catch recorded on CELR forms, except for a few years in the early 2000s.

The 2007 AMP review of SWA 1 examined trips that had landed silver warehou but reported no estimated catch, and suggested that this relates to trips with small catches and vessels using CELR forms (SeaFIC 2007). There appears to have been a similar trend in SWA 3 and 4, where on average over 50% of trips by vessels using CELR reported no estimated SWA catch (yet had positive landings) annually, but the level of under-reporting was much lower for vessels using TCEPR (usually less than 30%) and has been decreasing over recent years (Table 11). Similar to SWA 1, most trips that recorded no estimated catch had reported a small amount of landings (usually less than 1 t, though there were exceptions), for both CELR and TCEPR forms (Figure 23).

Though estimated catches tend not to be recorded when catches are small (as vessels only reported the top five (now eight) species caught, overall, the estimated catches capture about 80% of the harvest reported via the MHR/QMR system for SWA 1, 3, and 4. There also appears to be a reasonably close match between estimated catch and reported landings at trip level (Figures 24–26).

## 6.2 Fishery summary

The silver warehou fisheries in QMAs 3 and 4 are clearly visible in the distribution of commercial tows targeting and catching silver warehou (Figure 27). Unfortunately, the distribution of silver warehou nominal stocks does not match the administrative boundaries used for management as noted by Livingston (1988). The objectives here are to characterise the fisheries and conduct CPUE analyses, requiring the distribution of fishing effort and catch to dictate the regions defined for analysis. Total estimated catch for each region around New Zealand from the groomed and merged dataset is shown in

Table 12. Three main regions were defined using discontinuities in the spatial distribution of catch. The characterisation was therefore split into Chatham Rise, East Coast South Island, and Southland regions, with SWA 3 contributing to two fisheries, and SWA 4 contributing to all three (Figure 27). The silver warehou fishery on the western Chatham Rise is continuous with the ECSI and focused on the region between Banks Peninsula and Mernoo Bank. Given the bathymetry, Reserve Bank also likely holds silver warehou, but much of the substrate is not amenable to bottom trawling. South of Banks Peninsula, silver warehou catch declines and reaches a natural break point at statistical area 024 (Otago Peninsula) with almost no catch recorded in statistical area 302. Beginning with statistical area 026, catch and effort is continuous and grows to the south and continues to the south of Campbell Island. The eastern region of Chatham Rise appears to be distinct from the western part, with a strong decrease in catch near 179° E. This discontinuity has been described previously, leading Philips (2001) to separate his CPUE analyses for East and West Chatham Rise fisheries. Although his recommendations were to aggregate the two regions, it was due to a perceived lack of data. Therefore, with an additional 10 years of catch information, separating the two regions for characterisation was justifiable for initial analysis.

Fishing vessels catching silver warehou are of several nationalities, primarily Korean, but also New Zealand and Japanese (Figure 28a). Many vessels in the early 1990s have an unknown nationality. Most of these vessels were 50–100 m in length, ranged from less than 300 to almost 6000 kilowatts, and were mostly less than 500 t, with some up to 5000 t (Figure 28b–d).

In 2007–08, the Ministry of Fisheries introduced the TCER form, which provides tow-level location information for a class of vessels that was previously only required to report statistical area of the catch. Therefore, the last year of data used in this analysis provides an opportunity to see where, in relation to the overall SWA catch, these new vessels fish. Figure 29 shows the distribution of fishing effort reported on the TCER form overlaid on the total fishery distribution of effort. The distribution is shallower and more coastal than the TCEPR data available previously and used in the main analysis. The catch locations show a similar distribution to the larger vessels on the South Island, but the North Island shows effort concentrated near the East Cape region and light effort around the North Island that is not apparent in the TCEPR data. Also different is the distribution of west coast South Island tows, which are south and inshore compared to the main catch from the hoki fishery. The difference in the distribution of observer sampling effort is apparent by comparing locations of sampling data in Figure 4. It will be important in future years to include TCER data with the TCEPR analysis because of this difference in distribution and therefore difference in size structure of the silver warehou catch.

### 6.2.1 Chatham Rise region

Silver warehou is caught throughout the year on the eastern Chatham Rise, but historically, more catch was taken in November to January, and sporadically in April to June (Figure 30a). The major statistical area of the catch varied annually but catch was rare in areas 403 and 412 (Figure 30b). Catch on the Chatham Rise was almost exclusively by bottom trawl, though from 1996 to 2004 a modest amount was captured using midwater trawl gear (Figure 30c). In some years a moderate amount of silver warehou was captured during targeted tows, but most catch was taken as bycatch in the hoki, hake, and barracouta fisheries (Figure 30d). Midwater trawl catch also occurred mainly while targeting barracouta or jack mackerel in areas close to the Chatham Islands. Within a statistical area and target species, there is no strong trend in the amount of silver warehou catch through time (Figure 31).

No strong pattern in the proportion of catch from tows targeting SWA is apparent through time, indicating that an emerging target fishery for SWA is not occurring. The lack of pattern also makes it difficult to characterise SWA catch as either a bycatch or a target fishery (Figure 32). However, statistical area 410 does show a large proportion of catch from tows targeting SWA in some years, especially in May and June.

Although SWA catch in tows targeting other species is common, the occurrence of SWA in the catch varies depending on the target species and also varies to a lesser degree through time. The proportion of

hoki target tows not capturing SWA has been stable at about 50% for the past 10 years, but the proportion of hake target tows not catching SWA has steadily increased since 1990 from none to about 50% (Figure 33). Less than 20% of the tows targeting SWA reported zero SWA catch. The time trend in number of tows and catch per tow is different for different target species, but shows definite patterns (Figure 34). The patterns are very similar using different metrics of effort such as catch per tow or per kilometre. The pattern in catch between SWA target and hoki target tows is very similar; however, hake target tows simply show a baseline amount throughout the series. Despite the increasing proportion of ling target tows reporting zero SWA catch, the catch per tow shows an increasing trend since the late 1990s.

The different SWA bycatch rates among the various target species are not surprising given the differences in the fishing duration and depth for the various target species (Figures 35 and 36). SWA are usually targeted in the 200–300 m depth range, which is much shallower than the almost 600 m depth targeted for hoki, and similar to the depths targeted for barracouta and squid.

The distribution of bottom trawl tow effort variables (e.g., tow speed, net size) are very similar among target species (Figure 37). Vessels targeting hoki tend to be large vessels, while those targeting other species are much smaller. All target SWA to some degree. For midwater trawl effort variables, much more variability exists (Figure 38). Obviously, the trawl sizes are larger than for bottom trawl, and the vessels are larger too, but no strong trends defining target species effort is apparent.

There is no apparent change in the location of SWA catch within the Chatham Rise area over recent years (Figure 39). Figure 40 shows the combined distribution of tows or the major target species encountering SWA within the Chatham Rise region. Spatially, the depth distribution for the squid fishery overlaps very well with SWA target tows but few target squid tows exist to make any comparison. Target tows for several species are spatially segregated, indicating that silver warehou are widespread among those areas (Figure 40).

## 6.2.2 East Coast South Island

Silver warehou on the ECSI are mainly taken with bottom trawl and midwater trawl, as on the Chatham Rise. They are encountered year round, with a predominance in recent years of April and May (Figure 41a). This occurs mainly in statistical areas 020, 021, and 022 (Figure 41c,d). Statistical areas 016 and 017 are included in the characterisation as part of the ECSI fishery, but excluded in later CPUE analyses. Silver warehou are taken as bycatch mainly in the hoki fishery, with some catch in squid and occasionally barracouta and red cod target tows. Almost all the SWA catch is taken in the inshore statistical areas (Figure 42). The majority taken as hoki bycatch is in area 020, but SWA is common as hoki bycatch in all ECSI statistical areas. It is present in squid, red cod, and barracouta target fisheries mostly in area 022. Annual catches in each area are somewhat variable and no trend in SWA catch is evident within a given statistical area.

In contrast to the Chatham Rise fisheries, the proportion of SWA tows is fairly constant in all the major statistical regions throughout the time series (Figure 43). Silver warehou targeting is also common in every month and area, especially in the past few years. In each statistical area, and throughout the fishery history, the proportion of SWA from targeted catch has been stable at 25–50%.

The proportion of tows reporting zero SWA catch on the ECSI is lower than on the Chatham Rise. Hoki and squid target tows report SWA catch in about 70% of tows, and the rate has been stable since 1990 (Figure 44). Strangely, although target SWA tows not reporting SWA are more infrequent, they are fairly variable, ranging between 10 and 30% of all target SWA tows. Over the past 10 years, the catch rates (kg SWA per hour towed) have been mostly stable in non-target tows (Figure 45). However, SWA catch rates in target SWA tows more than doubles and halves throughout the time series. SWA as bycatch in the squid fishery is fairly constant early in the series and began to increase in 2003. However, the amount of effort then declined dramatically by 2008. This increase is not clearly visible in the bycatch rates of other target species in the same areas but somewhat matches the BAR pattern (Figure 45). Targeted SWA effort

drops to minimal levels in the middle 1990s through to 2005. In the same period, hoki effort increased dramatically. This suggests that SWA targeting is influenced by the amount of hoki effort.

Fishing duration in the various target fisheries on the ECSI was somewhat more variable throughout the time series than on the Chatham Rise, especially for SWA target tows, but this may be due to sample size differences between the two areas (Figure 46). The depth fished for each non-SWA target species is also more variable, though the median depths are similar to the Chatham Rise fisheries (Figure 47). In contrast, SWA target tows are deeper than observed on the Chatham Rise, usually about 400 m in recent years.

Bottom trawl effort variables (vessel size, speed, and net size) on the ECSI are similar to those on the Chatham Rise (Figure 48). Barracouta and red cod target tows were typically from smaller vessels, likely the inshore vessels. Midwater trawl effort variables are also similar to those on the Chatham Rise, although it is interesting that large midwater trawlers sometimes target barracouta (Figure 49).

Location of fishery catches has been stable through time, shown since 2003 (Figure 50). Silver warehou catch mainly occurs around the slope areas of the western Chatham Rise, Mernoo and Reserve Banks, and southwest towards Canterbury Bight centred at 200 m.

### **6.2.3 Southland**

The Southland fishery has a more definitive structure to it than either of the other two regions. Silver warehou is captured mainly between November and June and in three main statistical areas: 026, 027, and 028 (Figure 51a,b). Catch has been reported from area 030, but this effort and catch appears to have shifted to area 504 in recent years (a shift to the southeast). Again, catch is dominated by bottom trawl, but with a higher percentage of midwater tows since the mid1990s. Bycatch in the hoki fishery does not dominate the catch in Southland, although it is significant. Bycatch is dominated by the squid fishery, and total catch is dominated by target SWA fishing (Figure 51c,d). Interestingly, bycatch in the squid fishery was not significant before the mid1990s.

The target SWA fishery is much more stable throughout the time series and contributes at least 50% of the catch each year for most statistical areas (Figure 52). In statistical areas 027 and 028, some catch occurs by midwater vessels targeting JMA. No SWA targeting occurred using midwater trawl. Targeting SWA is not a quota cleanup fishery because targeting accounts for a large proportion of the catch in any given month and this behaviour has been stable over time (Figure 53).

Bycatch levels in the hoki fishery have been stable over time, with about 40–50% of the tows not reporting SWA catch (Figure 54). The proportion of positive tows in the squid fishery has been declining throughout the history of the fishery. However, the total SWA catch in SQU target tows has not declined monotonically (Figure 51d). The bycatch rate in SQU target tows (in kg per tow) did increase from 1994 though 2000, but has declined since then (Figure 55). The bycatch rate for other target species varied. There was a large increase in the bycatch rate for hoki target since 2002, dropping significantly in 2008. The SWA target fishery has remained stable with about 10% of the tows not reporting SWA (See Figure 54) catch and a fairly constant catch rate with the exception of a peak in 2004.

Fishing duration for SWA and for other fisheries in Southland has been variable (Figure 56). Duration for BAR target tows has increased throughout the time series. A tendency for longer duration tows is visible in the plots for SQU, HOK, and SWA. The depth fished for non-SWA target fisheries is similar to depths fished in the other regions. However, SWA target tows are deeper at 350–400 m (Figure 57) compared to the 200–300 m depths on Chatham Rise. There has been no time trend in the depths of tows for any of the main target species. Vessel tow effort variables for bottom trawl and midwater trawl are similar to those observed on the ECSI (Figures 58, 59).

Areas fished in Southland have also been stable through time, with an obvious concentration along the 300 m depth contour; i.e. along the silver line (Figure 60). A discrete area of bycatch occurs around Puysegur Point and presence was variable in the bycatch of tows nearby Campbell Island.

## 7. CPUE ANALYSES

The previous standardised CPUE analyses for silver warehou have included tow by tow estimated catch from TCEPR forms (Knuckey et al. 1998, Phillips 2001), with some differences in area stratification, measure of fishing effort, and target species mix. 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). However, it is noted that under-reporting of estimated catch was common among the fisheries, where trips that landed SWA had reported no estimated catch, though the landed catch from such trips is in general not substantial (see Section 6.3). This aspect of TCEPR data omission therefore significantly affects effort and recorded number of tows but not catch, therefore changing CPUE (Figure 61). This is one major difference between the merged (stratified) and unmerged (tow-level) data, and to examine the impact of pooling data versus excluding small unreported catches these two datasets were modelled separately.

Only TCEPR catch effort was considered. CELR data were dropped from the CPUE analysis because they were minor (Figure 22). As almost all the catch was taken by bottom trawl and just a minor component was midwater trawl, which occurs only part way through the time series, only bottom trawl catch and effort were included for the CPUE analysis. For each area, each CPUE dataset was further defined to encompass a mixed-species fishery which includes both SWA target and major bycatch species in statistical areas where most of the SWA catches were taken ( See Figures 30, 41, 51). To examine the effect of various target species on CPUE, major target species indices were modelled separately and combined. It is possible silver warehou were not targeted as frequently as the data suggest and that the recorded target species was simply the main species actually caught (whether it was targeted or not) rather than any pre-determined fishing behaviour (Paul & Bradford 2000). In the latter case, excluding non-target effort could result in a CPUE series which is not a fair representation of the trend in the underlying fish stock.

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 (2000). A forward stepwise multiple-regression fitting algorithm (Chambers & Hastie 1991) implemented in the R statistical programming language (R Development Core Team 2008) 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. Alternative stopping rules or error structures were not investigated.

For trip-level data, the variables offered to the model were *fish\_year*, *vessel\_key*, *start\_stats\_area\_code*, *target\_species*, *month*, and *fishing\_duration* (as a 3<sup>rd</sup> order polynomial). For tow-level data, additional variables of *effort\_depth*, *effort\_width*, *effort\_height* (as a 3<sup>rd</sup> order polynomials) were added. Although additional variables were available, they were not offered as explanatory variables because they were correlated with variables that were offered (e.g., latitude and statistical area, or vessel key and vessel power). Of course, it is possible that factors that drive SWA CPUE are not available. 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. Vessels not involved in the fishery for consecutive years, or that had only participated for 1–3 years, were excluded because they provided little information for the standardisations (Knuckey et al. 1998), which could result in model over-fitting (Francis 2001). Thus, CPUE analyses were undertaken for “core” vessels. Core vessels are those vessels that were involved in the defined fishery for at least four consecutive years, and reported about 80% of the catch. In some cases, such as limiting the dataset to a particular target species, the number of vessels was limited. To increase the number of vessels qualifying, those reporting 90% of the catch were used (Philips 2001).

The dependent variable was the log-transformed landed catch per effort stratum when data were fitted on a trip-level resolution and the log-transformed estimated catch per tow when data were fitted on a tow-level resolution. Only the positive catches were retained, with zeros excluded. A zero refers to an effort stratum with no allocated landings for the merged dataset, or a tow with no estimated catch for the unmerged data. The percentage of tows with zero silver warehou catch was examined for time trends and the effect of excluding those tows was examined by fitting a logistic model to the number of zeros and combining that time series with the log-normal time series following Vignaux (1994). 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).

Hurst (2009) analysed the use of twin trawls (two trawls towed simultaneously by a single vessel). Twin bottom trawls have been used by seven vessels since the mid 1990s, but methods to record their use and the characteristics of the gear (e.g., ground gear length of each trawl or combined trawls) were ambiguous. Hurst (2009) identified several vessels that had the capability to use twin trawls and assigned a probability level of being a twin trawl to each tow. Tows with a code of 4 or 5 were very likely to have been twin trawls and these tows were identified in the SWA effort database. The vast majority of twin trawls are bottom trawls targeting hoki (26 842 of 28 082 (95%) coded 4 or 5). Because twin trawling may dramatically change the CPUE for those vessels, and because those vessels could contribute a large proportion of the SWA catch in a given region (SWA catch is mainly from targeting hoki), these tows, and tows that could not be identified as either twin or single (code 3) were excluded from the CPUE analysis for each area (Table 13). As all the tows encountering SWA for these vessels were twin trawls, these vessels were excluded from the analysis. The effect of removing these vessels was examined with a separate model (see below).

With three areas, two datasets (trip stratified and tow level), and several target species, and optional model approaches, a factorial approach to model development is not feasible. Therefore, we specified a number of model configurations to allow specific comparisons and ultimately to justify the choice of the most appropriate model for each area.

We developed 9 models (Table 14). Models 1 and 2 both include the major target species for each region. These were Chatham Rise (SWA, HOK, HAK, BAR), ECSI (SWA, HOK, SQU, BAR, RCO), and Southland (SWA, HOK, SQU). Model 1 used the stratified dataset, Model 2 used the tow-level dataset. Model 3 examined the effect of including data from the six twin trawl vessels. This was conducted only for the ECSI because twin trawls were not used in Southland tows, and although used in the Chatham Rise hoki fishery, the Chatham Rise dataset was relatively small, leaving the ECSI as the best dataset for the evaluation of any effect. Models 4, 5, and 6 isolate the main target fisheries within each area and conduct a CPUE standardisation for hoki, silver warehou, and squid, respectively. Model 7 was configured to address the effect of separating Chatham Rise from the ECSI area, resulting in a relatively small dataset with multiple target species near the Chatham Islands. By combining these two areas (as recommended by Philips 2001), the effects of the small target fisheries near the Chatham Islands will be de-emphasised, and the main target CPUE will be included. Model 8 was configured to examine the effect of allowing the model to use target species to explain CPUE variation when in fact the target species is an assignment made by the skipper after the catch from the

tow is known. By removing this “false” signal, model deviance is available to be explained by other variables. This was conducted on the tow-level dataset to allow other variables affecting catch to be included, such as bottom depth. Model 9 used Southland data only to investigate the effect of a trend in the proportion of zero catches when fitting the lognormal models (see below).

## 7.1 Chatham Rise

A subset of vessels was identified as a core set for CPUE analysis to exclude vessels that contributed a minor amount of catch (and effort) to the time series (Figure 62a, b; Table 15). Because several vessels had switched to twin trawl gear, their omission reduces the amount of catch included in the model. To maintain a high percentage of catch in the retained vessels, we extracted vessels reporting 90% of the catch, which could be attributed to about 25% of the vessels.

The nominal arithmetic and geometric CPUE along with the standardised CPUE series of Model 1 show very little change over the time series with the exception of a large increase in 2005–2006, followed by a drop in 2007 (Figure 62c). The reason for the spike in 2006 is likely due to a large proportion of the catch resulting from SWA targeted tows in those two years (Figure 30a). There is no large change in size distribution of the catch during the high CPUE year, either from the observer programme or Chatham Rise survey, though a strong recruiting class of about 25 cm was seen in the survey and somewhat in the observer data (See Figures 9 and 12). The model retained all explanatory variables offered, though the variability in the factor coefficients was large, and explained 41% of the null deviance (Figure 63, Table 16). The standardised index tracked the geometric mean closely, with the largest residuals for low CPUE values, tending to predict higher values than observed when CPUE was low (Figure 64).

Increasing sample size and the number of explanatory variables with the tow-level dataset in Model 2 resulted in a similar core vessel history, though many of the vessels had long series of very small catches (Figure 65a). Large catches occurred intermittently among vessels, likely indicating the patchy distribution of a schooling species. The CPUE trend was flatter than for Model 1 and although the peaks were in the same years, the degree of deviation from the long-term trend was less (Figure 65c). The model retained only effort, depth, month, stat area, and vessel key as explanatory variables, rejecting target species (Figure 66). Depth likely explains most of the signal available in target species. Model 2 explained 33% of the null deviance, fitted lower CPUE values better, but tended to predict lower values at high CPUEs (Figure 67).

## 7.2 East Coast South Island

More vessels reported SWA catch in this region, so the effect of twin trawling on the total catch included was not as large as for the Chatham Rise dataset. Still, there are many vessels with small intermittent catches throughout the fishery history (Figure 68a). Overall, annual catches were more stable throughout the time series and the vessels tend to contribute to the catch for many successive years. About 35% of the vessels accounted for 90% of the catch (Figure 68b). For Model 1, the standardised CPUE index does not follow the geometric mean for the last two years of the series (Figure 68c). Two prominent peaks occur in the standardised series, though the 1997 peak is only a single point. 1997 represents a reduction in SWA targeting as vessels began targeting hoki (See Figure 45). Since 2004 there is a modest downward trend, though the unstandardised indices tend to increase. Model 1 used all five explanatory variables available (Figure 69), but the model tended to overestimate low CPUE values, and the standardised residuals were unbalanced, especially for larger fitted values (Figure 70).

Model 2 produced a similar core vessel dataset, but a very different CPUE time series. Although flat overall, the peaks were not present and a long multi-year trend of increasing CPUE from 1999 to 2007 is present (Figure 71). The  $R^2$  for model 2 is poor (18%), but the large sample sizes for the ECSI result

in small confidence intervals for the index. However, only three explanatory variables were selected (target species, month, and vessel). The signal in target species is due to a higher SWA target CPUE (as expected). CPUE also trends higher over the winter months and towards the end of the fishing year, though the large catches in September are bycatch, not target catch (Figure 72). The diagnostic residual plots all indicate a good model fit, with some hint of predicting lower values than observed at the low end of the range (Figure 73).

### 7.3 Southland

Very little catch was attributed to twin trawl tows in the Southland area, and they were low in the ranking of total catch, so had little impact on the core vessel pool (Figure 74a,b). Only a few dominant vessels (15%) captured 80% of the SWA catch. However, one vessel was the dominant vessel from 1994 to 2003, with a second vessel becoming dominant since 2004. The unstandardised series are roughly similar, showing a steep decline from 1990 to 1995, at which point it flattened somewhat but continued an overall declining trend until 2005 (Figure 74c). The standardised CPUE index is flat over the entire series with a large peak centred on 2000, and another in 2007. Model 1 (stratified data) retained all five variables (Figure 75) and showed a strong effect of both fishing duration and statistical area. Strong effects for winter months, statistical area 602, and targeting SWA were apparent. Model 1 explained 31% of the null deviance and fitted the data poorly, showing unbalanced residuals throughout most of the range, and predicting higher values at both the lower and upper range of CPUE values (Figure 76).

Model 2 (tow-level data) included essentially the same core vessels and showed similar trends for the unstandardised data series. The standardised series was similar in timing of peaks to Model 1, but the magnitude of the peaks was diminished (Figure 77). The overall trends were still present and better defined in Model 2, with a steady increase in CPUE evident from 1995 to 2000. Otherwise, the index was remarkably flat. It explained 36% of the null deviance, and retained only statistical area, target species, and vessel as explanatory variables (Figures 78). Again, the strong target species effect was with SWA, with a similar pattern in statistical area as in Model 1. The diagnostic residual plots fit well overall with little evidence of asymmetry (Figure 79).

### 7.4 Comparing models

A biomass time series is available for the Southland area (the sub-Antarctic survey), and the Chatham Rise area (Chatham Rise survey) (See Figure 8). Although there is a survey for the ECSI, it does not overlap well in areas fished as it tends to fish shallower water and encounter juvenile silver warehou, in addition to the issues surrounding changing survey seasons and depth ranges. However, the Chatham Rise survey covers much of the area of the fishery (western Chatham Rise and Mernoo Bank). Therefore the ECSI CPUE is compared with the Chatham Rise biomass time series.

The CPUE trends resulting from Models 1 and 2 were overlaid for each area and compared with a mean-standardised bottom trawl biomass index (Figure 80). The stratified and tow-level indices for the Chatham Rise were very similar to each other and, in a general sense, track the survey biomass index with the exception of a decrease in the CPUEs in 2007 and 2008. The ECSI models show very different degrees of variation among years, though overall both are flat, as is the ECSI biomass trend. As a sensitivity analysis, the trip-stratified dataset was used to estimate CPUE while including the data from vessels using twin trawls for the latter half of the time series. This is configured as Model 3. The grey CPUE line shows that the effect of the twin trawl vessels was minor, but because sample sizes were typically sufficient, it is more conservative to omit those twin trawl vessels from the analysis. The indices from Southland Models 1 and 2 are very similar, varying only in magnitude of fluctuation, but the biomass trend from the sub-Antarctic survey is not useful in interpreting the CPUE indices because of the extremely large survey c.v.s in some years.

The potential effect of allowing target species to explain variation in the SWA CPUE (when targeting may not be occurring) was investigated by using the tow-level datasets for each area and comparing those CPUE trends with the same models excluding target species as an explanatory variable. Figure 81 (upper panel) shows an overlay plot of the three area CPUE indices from tow-level datasets. Figure 81 (lower panel) shows the same model output, but excluding target species as a possible explanatory variable (Model 8). Note that Model 1 for the Chatham Rise did not select target species and so the Model 8 index for Chatham Rise is identical. The other two trends were very similar, showing the same overall patterns but with slightly different fluctuations relative to each other. This indicates that target species itself is not inappropriately explaining variation and preventing subsequent meaningful explanatory variables from entering the model.

Models 4, 5, and 6 investigated the effects of individual target fisheries on the overall CPUE trend. This was conducted in only two areas as sample sizes for individual target species in the Chatham Rise area were too small for a robust analysis. Data for tows targeting HOK, SQU, and SWA were extracted separately from ECSI and Southland tow-level datasets. For each target species, core vessels were re-selected using the same criteria as in Model 2. CPUE models were fitted to each and the standardised indices for each species were overlaid in Figure 82.

For ECSI, the indices for HOK and SQU track each other well, while the SWA target index fluctuated widely during the middle of the series (1990–2003). The proportion of catch from SWA target tows is very low (Table A10), resulting in large c.v.s for the CPUE series (not shown, Table A15). The other significant deviation was the 1997 single point peak in the SQU target fishery. No obvious explanation appears in the fishery characterisation as 1997 was a typical year for both overall catch and overall effort and for the SQU fishery itself (See Figures 41 and 45). The overall indices are flat with some hint of an increasing trend since 2003.

In Southland, sample sizes are better for each target species, although the inter-annual trends are variable (Figure 82). Curiously, the pattern in fluctuation for each target species seems shifted, especially since 1997. If the hoki trend was shifted one year to the right, the overall patterns would be much more congruous. Again, no explanation is apparent in the characterisation, and the fisheries are not occurring in different seasons/fishing years to cause a shift as observed.

In previous working group discussions, and also concluded by Phillips (2001), separating the eastern Chatham Rise from the ECSI fishery was not acceptable. This was mainly due to the paucity of data from the eastern Chatham Rise, resulting in poorly fitted models. In this study, the two areas were modelled separately because an additional 10 years of eastern Chatham Rise fishery data were available. CPUE models did not fit Chatham Rise data any worse than they fitted the other two areas, and overall, the three areas showed a similar flat trend. However, the Chatham Rise does show a large increase for 2004–2006 that is not present in the other two series (See Figure 81). Catch was higher in those years (especially 2005–2006) and a strong year class is present in the survey data (See Figure 9), but not in the observer data (See Figure 12).

A CPUE model was configured combining the eastern Chatham Rise and the ECSI fisheries to be comparable with the output from Model 1. The results are not surprising because the sample sizes from the eastern Chatham Rise are still small compared to the ECSI, so the resulting CPUE trend is almost identical to the ECSI Model 1 (See Figure 68). The fit for Model 7 is also almost identical to Model 1 from the ECSI (Table 16).

One final model configuration tested was to examine the effect of a trend in the proportion of zero catches through the time series. For most target species, the trend in proportion of zero catches was relatively flat (or variable) though the series. However, a pronounced trend in zero catch is present in the SQU fishery in Southland (See Figure 54). Therefore, the annual proportion of zero catches was modelled for the Southland SQU fishery as Model 9. The binomial fitted the trend well, but when combined with the lognormal, little change is evident (Figure 83). Because this fishery had the

strongest trend in proportion of zero catches, it is unlikely that the proportion of zero catches in the other modelled fisheries would have any impact on the lognormal CPUE trends observed.

## **7.5 CPUE summary**

Although fishing year was forced into every CPUE model, it rarely explained more than a few percent of the null model deviance. Exceptions to this explained 12–15% of model deviance for Chatham Rise (Models 1 and 8) and Model 5 for ECSI (Table 16). The variable with the most explanatory value was typically fishing duration for the merged dataset, as expected. Explanatory variables were inconsistent for tow-level data. The one consistent result in all areas and in all models is that the trend in standardised CPUE is either flat, or too variable to be distinguished from flat. There is some indication that since 2004 CPUE and catch has increased somewhat, especially on the Chatham Rise. Even the large increases in CPUE occur in different years in the three areas. The increase, somewhat matching the biomass index, first increases off the ECSI and the Chatham Rise in 2004, but any increase in Southland does not occur until 2007 and all the indices drop in 2008.

There is also no evidence that the fisheries in the three areas are operating on different stocks, but the data are too variable to distinguish differences in length composition trends or CPUE. The results from evaluations of standardised CPUE in three areas for SWA 3 and SWA 4 are very similar to the results of the trends in age structure observed in SWA 1 (SeaFIC 2007). There, a flat signal in age structure shows no definitive response of silver warehou to the variations in fishing mortality or environmental conditions since the early 1990s. However, a recent CPUE analysis by SeaFIC (2009), suggested that the mid-1990s was a period of strong recruitment and silver warehou population growth. This trend is not visible in the other QMAs. Given a lifespan of about 20 years, the potential for large changes in stock biomass has been present, especially if small biological stocks exist. It appears that juvenile mixing, wide ranging movements of adults, large variations in fishing mortality, and the presence as bycatch in large fisheries that have had large fluctuations in TACC and catch themselves, all combine to make a clear CPUE signal for silver warehou difficult to identify.

The amplitude of annual deviations in CPUE is also large, meaning that even if CPUE did track abundance, a very large change in biomass would be needed to observe a trend in the CPUE. The catch has been increasing slowly since 1990, and the TACC was last increased in 2003 for SWA 1 and 1994 for SWA 3 and 4 (See Figure 16). However, catch has also been fluctuating over 30% for the past decade, which creates added variation in any CPUE trend and also biologically influences the stocks themselves. The inter-annual variability observed in the CPUE trends is too large to be biologically driven, with single year changes that double and halve. The combination of unrealistically large annual changes in biomass, lack of any consistent trend within or among regions, or in target and bycatch fisheries, and the strong effect of deemed value increases on catch rates show that CPUE is not indicative of relative abundance of silver warehou.

## **8. SUMMARY AND RECOMMENDATIONS**

### **8.1 Biology**

Although silver warehou have been harvested commercially at significant levels for more than 40 years, many aspects of their biology, important to stock assessment, remain uncertain. Foremost is their size and age at maturity. The most complete information on maturity is based on a single histological study of a few dozen fish in the 1970s. Although well done, ages were based on unvalidated scale reading methods, concerned females only, and maturity may have changed in the interim given the exploitation since the fishery started. It would be useful to update the size and age at maturity through a directed study that is spatially targeted at the multiple spawning areas at the appropriate time of year, uses a validated ageing methodology, and includes the male reproductive cycle. Because silver warehou are selected in the fishery long before they become sexually mature

(based on current information), this information will be required for any form of spawning biomass-based stock assessment.

A second biological aspect in need of directed study is the stock structure. No genetic stock discrimination work has been done for silver warehou, yet multiple, isolated spawning sites with similar timing exist. Because the administrative stock units do not coincide with the spawning area boundaries or fishery distributions, knowledge of the degree of any stock isolation is important.

Although catch is dominated by areas around the South Island, significant silver warehou catch does occur all around the North Island as well. Observations of 0+ and juveniles on the west coast of the North Island, and maturing adults on the east coast of the North Island, suggest there may be more spawning sites (and possible fish stocks) further to the north. *Seriolella punctata* occur at latitudes less than 35° S in Australia, suggesting that spawning could occur in more northern waters. Observer samples from the autumn and winter periods off the east coast of the north island may inform this aspect of silver warehou biology.

## 8.2 Status of the stocks

No estimates of current absolute biomass are available for any silver warehou fish stock. Biomass indices from *Tangaroa* and *Kaharoa* trawl surveys in QMAs 3 and 4 since 1991 are variable between years and have high c.v.s. Working groups have concluded they are unsuitable for stock assessment in isolation, although their usefulness may improve as the time series grow in duration. Maximum Constant Yield (MCY) cannot be determined. Problems with historical misreporting of warehou catches and the lack of stable catch histories make MCY estimates based on catch data alone unreliable, and because an estimate of current biomass is not available, Current Annual Yield cannot be estimated. The sustainability of current TACCs and recent catch levels for these fish stocks is therefore not known, and it is not known if they will allow the stocks to move towards a size that will support the maximum sustainable yield.

Length frequency distributions are variable among years, but a large size mode of about 50 cm is usually present in the Chatham Rise survey data, and the Chatham Rise and ECSI observer data series. The presence of these larger fish has diminished since 2004, being less prevalent in the Chatham Rise survey in 2005, and the Chatham Rise observer data and the ECSI observer data in 2006. They were almost absent in 2008. These larger fish should be monitored closely in the near future. Evidence of a stronger year class that was just over 40 cm in 2008 in both areas is present.

Although the catches in each QMA have been exceeding the TACC, targeting still occurs throughout the year and even in the last few months of the year in some areas. This may change as landings data only extend to 2007–08 and the deemed value increase was implemented beginning October 2007. As much of the catch is accumulated as bycatch in the hoki and squid fisheries, silver warehou bycatch could simply follow the catch of those target species. However, the bycatch in units of kg SWA per kg of target species (HOK and SQU) is variable year to year but with an overall increasing trend since 2000 (Figure 84). It is therefore not clear that if HOK or SQU TACCs change, that SWA catch will follow the same trend. The dramatic drop in catch in 2007–08 raises the issue of the ability to avoid silver warehou catch if desired. Obviously, CPUE trends are sensitive to such a change in catch rate. This behaviour may contribute substantially to the variation observed in the CPUE trends. Alternatively, the change could be a change in reporting. A comparison of the catch rates on observed tows versus the catch rates reported through landings should confirm that fishers are able to change catch rates through differences in fishing behaviour. If so, this behaviour needs to be included in any CPUE standardisation process.

The lack of robust conclusions from the CPUE analysis and the observation that the fishery can change SWA catch quickly in response to management pressure makes stock status evaluation difficult. The best approach would typically be to use an age or length-structured stock assessment.

Most of the basic information is available. However, a reliable index of abundance is not currently available for the stocks reviewed here.

Silver warehou catch should be well monitored in the future because most vessels have used TCEPR forms, and although some minor catches are not reported as one of the top five species on this form, the issue may be addressed by the new TCER form requesting the top eight species landed. In addition, the fisheries encountering silver warehou are fairly discrete spatially and have several dominant vessels that account for most of the catch. Silver warehou are not long lived and length modes can be seen in the data for at least the first 3–4 years of life. Observer sampling in each area provides consistent length frequency distributions and could provide otoliths in the future. Biology is reasonably well understood, but a few directed studies of reproductive development will enable robust maturity ogives to be determined. And lastly, although c.v.s are usually high, a fishery independent biomass estimate exists for each fishery area. Adding survey effort to optimise silver warehou biomass c.v.s could make them more useable with time. The major limiting factor is the apparent variability in the size (and presumably age) distributions that are encountered in the fishery independent surveys and in the various fisheries. The degree to which increased sampling effort would improve the characterisation of the population size and age structure would need to be addressed as a first step.

An alternative approach may be to determine the age structure of the main fisheries in these stocks and roughly monitor the level of fishing mortality relative to natural mortality.

### **8.3 Observer Programme sampling**

Sampling by the Observer Programme is very good, matching well on a spatial and inter-annual basis. Any under sampling is due to the extremely low levels of observer sampling on small vessels in inshore statistical areas.

### **8.4 Future data needs and research requirements**

Recognising that CPUE will not provide a relative abundance indicator for silver warehou, and with the goal of developing a quantitative stock assessment in the future, the data collection needs for silver warehou are as follows.

- 1) Length and age at maturity for each fish stock.
- 2) Definitive stock unit identification.
- 3) Investigation of potential North Island spawning sites through observer and survey information.
- 4) Otolith sampling from SWA 3 and SWA 4 to develop representative catch at age distributions.
- 5) Improve ability to link small amounts of SWA bycatch to individual tows (hopefully this will be an outcome of introducing TCER forms).

## **9. ACKNOWLEDGMENTS**

We thank D. Fisher for observer data extracts, D. Middleton for observer data interpretation and coding assistance, R. Hurst for twin trawl analysis, a thorough review, and valuable discussions of fishery history, and P. Horn for discussions on silver warehou life history. M. Vignaux and K. Sullivan provided excellent reviews of the document, and we especially thank them for their efforts. We also thank the New Zealand Ministry of Fisheries for funding this project through MID2007-03.

## 10. REFERENCES

- Anderson, O.F.; Bagley, N.W.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998). Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report 42*. 303 p.
- Annala, J.H.; Sullivan, K.J.; O'Brien, C.J. (Comp.) (1999) Report from the Fishery Assessment Plenary, April 1999: stock assessments and yield estimates. 430 p. (Unpublished report held in NIWA Greta Point library, Wellington.)
- Beentjes, M.P.; Smith, M.; Philips, N.L. (2004). Analysis of catchability for east coast South Island trawl surveys and recommendations on future survey design. *New Zealand Fisheries Assessment Report 2004/5*. 68 p.
- Berkeley, S., Hixon, M., Larson, R., Love, M. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. *Fisheries 29*(8): 23–32.
- Blackwell, R.G.; Manning, M.J.; Gilbert, D.J. (2005). Standardised CPUE analysis of the target rig (*Mustelus lenticulatus*) set net fishery in northern New Zealand (SPO 1 and SPO 8). Final Research Report for Ministry of Fisheries Project SPO2004-01, Objective 1. 37 p. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Bruce, B.D.; Neira, F.J.; Bradford, R.W. (2001). Larval distribution and abundance of blue and spotted warehou (*Serirolella brama* and *S. punctata*: Centrolophidae) in south-eastern Australia. *Marine and Freshwater Research 52*: 631–636.
- Catch '82* (1982). Finfish allocations announced. *Catch '82, 9*(4): 7–9.
- Chambers, J.M.; Hastie, T.J. (1991). Statistical models in S. Wadsworth & Brooks-Cole, Pacific Grove, CA. 608 p.
- Dunn, A.; Harley, S.J.; Doonan, I.J.; Bull, B. (2000): Calculation and interpretation of catch-per-unit-effort (CPUE) indices. *New Zealand Fisheries Assessment Report 2000/1*. 44 p.
- Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington.)
- Francis, R.I.C.C. (2001). Orange roughy CPUE on the South and East Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.
- Gavrilov, G.M. 1974: The age and rate of growth in the silver warehou (*Serirolella maculata* Forster). *Issledovanya po Biologii Ryb i Promyslovoi Okeanografii [Studies in Fish Biology and Fisheries Oceanography], TINRO, No. 5*: 50–59. [In Russian; English translation (FRC Translation No. 29) held in NIWA library, Wellington.]
- Gavrilov, G.M. (1979). *Serirolella* of the NZ plateau: fishery biology. TINRO, Vladivostok. 59 p. [In Russian; English translation (translation No 204) held in NIWA Library, Wellington.]
- Gavrilov, G.M.; Markina, N.P. (1970). The feeding ecology of fishes of the *Serirolella* (fam. Nomeidae) on the New Zealand plateau. *Journal of Ichthyology 19*(6): 128–135.
- Grimes, P.J.; Robertson, D.A. (1981). Egg and larval development of the silver warehou, *Serirolella punctata* (Pisces: Centrolophidae). *New Zealand Journal of Marine and Freshwater Research 15*: 261–266.

- Horn, P.L.; Sutton, C.P. (1996). Validated ages, growth, and productivity parameters for silver warehou (*Seriolella punctata*) off the south and east coasts of South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30: 301–312.
- Horn, P.L.; Bagley, N.W.; Sutton, C.P. (2001). Stock structure of silver warehou (*Seriolella punctata*) in New Zealand waters, based on growth and reproductive data. *New Zealand Fisheries Assessment Report 2001/13*. 29 p.
- Hurst, R.J. (2009). Determination of commercial fishing gear and changes in commercial fishing gear in all middle depths fisheries. Final Research Report for Ministry of Fisheries research project MID2006/04. (Unpublished report held by Mfish Wellington).
- Hurst, R.J.; Bagley, N.W. (1997). Trends in Southland trawl surveys of inshore and middle depth species, 1993-96. *New Zealand Fisheries Technical Report 50*. 67 p.
- Hurst, R.J.; Stevenson M.L.; Bagley N.W.; Griggs L.H.; Morrison M.A.; Francis M.P.; Duffy C.A. (2000). Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand coastal fish. Final Research Report for Ministry of Fisheries research project 1999/03, Objective 1. (Unpublished report held by Mfish Wellington).
- Knuckey, I.A.; Bridge, N.F.; Brown, L.P.; Gason, A.S.; Taylor, B.L. (1998). Stock assessment of silver warehou (*Seriolella punctata*): fishery description and analysis of CPUE data. (Unpublished report held by Ministry of Fisheries, Wellington.)
- Livingston, M.E. (1988). Silver warehou. New Zealand Fisheries Assessment research Document 88/36. Unpublished report held by NIWA library, Wellington. 14 p.
- Manning, M.J. (2007). Relative abundance of giant stargazer (*Kathetostoma giganteum*) in STA 5 based on commercial catch-per-unit-effort data. *New Zealand Fisheries Assessment Report 2007/14*. 42 p.
- Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. *New Zealand Fisheries Assessment Report 2004/61*. 135 p.
- Ministry of Fisheries (2007). Review of Sustainability Measures and Other Management Controls for 1 October 2007. Volume 4. Review of Deemed Values for Selected Fishstocks: Final Advice, Summary of Recommendations, Initial Position Paper, Summary of Submissions, Submissions. 5 September 2007. Ministry of Fisheries, Wellington.
- Ministry of Fisheries (2008a). Medium term research plan for middle depth fisheries, May 2008. Ministry of Fisheries, Wellington, New Zealand.
- Ministry of Fisheries (2008b). Report from the Fisheries Assessment Plenary, May 2008: stock assessments and yield estimates. Ministry of Fisheries, Wellington, New Zealand. 990 p.
- Ministry of Fisheries (2008c). The Fisheries (Conversion Factors) Amendment Notice 2008. Ministry of Fisheries, Wellington, New Zealand.
- O'Driscoll, R.L.; Booth, J.D.; Bagley, N.W.; Anderson, O.F.; Griggs, L.H.; Stevenson, M.L.; Francis, M.P. (2003). Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. *NIWA Technical Report 119*. 377 p.
- Paul, L.J. (1980). Warehouse – facts and figures. *Catch '80* 7(7): 5–6.

- Paul, L.J.; Bradford, E. (2000). Stock assessment of school shark; documentation of the results of a questionnaire sent to selected commercial fishers. Final Research Report for Ministry of Fisheries Research Project SCH199901. 29 p. (Unpublished report held by MFish, Wellington.)
- Paulin, C.; Stewart, A.; Roberts, C.; McMillan, P. (1989). New Zealand fish: a complete guide. *National Museum of New Zealand Miscellaneous Series No. 19*. xiv+279 p.
- Pequeño, G. (1989). Peces de Chile. Lista sistematica revisada y comentada. *Revista de Biología Marina, Valparaiso 24(2)*:1–132.
- Phillips, N.L. (2001). Analysis of silver warehou (*Seriolella punctata*) catch-per-unit-effort (CPUE) data. *New Zealand Fisheries Assessment Report 2001/73*. 48 p.
- R Development Core Team (2003). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. <http://www.R-project.org>.
- Robertson, D.A. (1975). A key to the planktonic eggs of some New Zealand marine teleosts. *Fisheries Research Division Occasional Publication No. 9*. 19 p.
- Robinson, N.; Skinner, A.; Sethuraman, L.; McPartlan, H.; Murray, N.; Knuckey, I.; Smith, D.C.; Hindell, J.; Talman, S. (2008). Genetic stock structure of blue-eye trevalla (*Hyperoglyphe antarctica*) and warehou (*Seriolella brama* and *Seriolella punctata*) in south-eastern Australian waters. *Marine and Freshwater Research 59*: 502–514.
- Seafood Industry Council (SeaFIC) (2007). Silver warehou: SWA 1 Adaptive Management Programme Full-term Review Report. AMPWG-2007/22. Unpublished report held by the Ministry of Fisheries, Wellington.
- Seafood Industry Council (SeaFIC) (2009). SWA 1: CPUE. Adaptive Management Programme Working Group presentation 08 April 2009. Unpublished presentation held by Ministry of Fisheries, Wellington.
- Starr, P.J. (2007). Procedure for merging Mfish landing and effort data, V2.0. Document AMPWG/07/04. (Unpublished report held by Ministry of Fisheries, Wellington).
- Vignaux, M. (1994). Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987-93. *New Zealand Fisheries Assessment Research Document 94/11*. Unpublished report held in NIWA library, Wellington. 29 p.

**Table 1: Estimated landings (t) of silver warehou by New Zealand, Japan, and USSR from calendar years 1974–1978 based on 70% of total warehou landings (Source: Livingston 1988). 1978–1983 from FSU and Livingston (1988).**

Year	Silver warehou landings
1974	7412
1975*	5869
1976	13142
1977	12966
1978	12581
1978–79**	4820
1979–80**	8082
1980–81**	9000
1981–82**	3917
1982–83**	4976

\* The value for 1975 is different from the 6869 t reported in the Ministry of Fisheries Plenary document (2008a).

\*\* From Livingston (1988) for calendar year 1 April to 31 March, and different from Ministry of Fisheries Plenary document (2008a).

**Table 2: Reported landings (t) of silver warehou by fishstock from 1983–84 to 2007–08 and TACCs (t) from 1986–87 to 2007–08.**

Fish stock	SWA 1		SWA 3		SWA 4		SWA 10		Total	
	1,2,7,8 & 9		3		4, 5, & 6		10		Total	
Fishing year	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983–84*	541	–	725	–	1829	–	0	–	3095	–
1984–85*	587	–	1557	–	4563	–	0	–	6707	–
1985–86*	806	–	2284	–	3966	–	0	–	7056	–
1986–87†	1337	1800	1931	2600	2779	3600	0	10	6047	8010
1987–88†	2947	1815	3810	2601	2600	3600	0	10	9357	8026
1988–89†	1605	1821	1476	2640	2789	3745	0	10	5870	8216
1989–90†	2316	2128	2713	3140	3596	3855	0	10	8625	9133
1990–91†	2121	2128	1889	3144	3176	3855	0	10	7186	9137
1991–92†	1388	2500	2661	3144	3018	3855	0	10	7066	9509
1992–93†	1231	2504	2432	3145	3137	3855	0	10	6800	9514
1993–94†	2960	2504	2724	3145	2993	3855	0	10	8677	9514
1994–95†	2281	2504	2336	3280	2638	4090	0	10	7255	9884
1995–96†	2884	2504	2939	3280	3581	4090	0	10	9404	9884
1996–97†	3636	2504	4063	3280	5336	4090	0	10	13035	9884
1997–98†	3380	2132	3721	3280	3944	4090	0	10	11045	9512
1998–99†	1980	2132	2796	3280	4021	4090	0	10	8797	9512
1999–00†	2525	2132	4129	3280	4606	4090	0	10	11260	9512
2000–01†	3025	2132	3664	3280	4650	4090	0	10	11339	9512
2001–02†	1004	2132	2899	3280	4648	4090	0	10	8551	9512
2002–03†	1029	3000	3772	3280	4746	4090	0	10	9547	10380
2003–04†	1595	3000	3606	3280	5529	4090	0	10	10730	10380
2004–05†	1467	3000	3797	3280	4279	4090	0	10	9543	10380
2005–06†	1023	3000	4524	3280	5591	4090	0	10	11138	10380
2006–07†	2093	3000	6059	3280	6022	4090	0	10	14174	10380
2007–08†	1679	3000	2918	3280	3510	4090	0	10	8107	10380

\*FSU data.

†QMS data.

**Table 3: Four-parameter von Bertalanffy growth curve parameters\* for silver warehou for three regions from Horn and Sutton (2001). 95% Confidence intervals in parentheses.**

Region	Sex	$L_{\infty}$ (CI)	k (CI)	$t_0$ (CI)	P (CI)
Southern Plateau	Male	53.0 (52.4–53.6)	0.275 (0.237–0.314)	-0.06 (-0.29–0.16)	0.508 (0.407–0.610)
	Female	56.1 (55.4–56.8)	0.217 (0.189–0.245)	-0.01 (-0.21–0.18)	0.462 (0.390–0.533)
Chatham Rise	Male	53.7 (52.1–55.3)	0.178 (0.119–0.237)	0.02 (-0.39–0.43)	0.359 (0.246–0.473)
	Female	58.4 (56.9–59.9)	0.115 (0.101–0.129)	0.33 (-0.02–0.64)	0.271 (0.244–0.299)
West Coast South Island	Male	53.8 (53.1–54.4)	0.195 (0.166–0.225)	0.30 (0.16–0.43)	0.338 (0.290–0.387)
	Female	56.8 (56.1–57.6)	0.157 (0.132–0.182)	0.28 (0.14–0.43)	0.318 (0.276–0.361)

\*4-parameter model:  $l = L_{\infty}(1 - e^{-k(t-t_0)})^P$

**Table 4: Length weight relationship parameter values for silver warehou from Horn & Sutton (1996).**

Parameter	a	b
Chatham Rise	0.00848	3.214
Southland	0.00473	3.380
Combined sexes (no difference in length-weight relationships noted)		

**Table 5: Number of otolith pairs collected by the Observer programme and during *RV Tangaroa* surveys by region from 1992–2003.**

Year	Scientific observer programme							<i>Tangaroa</i> surveys			
	CHA	SOU	SEC	SOE	CEE	SOI	CEW	STEW	SNAR	PUYS	Total
1992	435										435
1993	155	134	98	46	4	13		228	9	12	699
1994	712	120	4	21	40	6		72	33	41	1049
1995	430	188	9	107	24	1	9	81	45	27	921
1996	679	169	112	7	40	24					1031
1997	400										400
1998	399										399
1999	395										395
2000	396										396
2001	400										400
2002	451										451
2003	417										417
Total	5269	611	223	181	108	44	9	381	87	80	6993

\* Additional structures have been collected and aged, but as of March 2009 were not catalogued in the age database.

**Table 6: Number of fish sampled for length from each silver warehou fish stock by the observer programme, 1985–2008.**

Fishing year	SWA 1	SWA 3	SWA 4	Total
1985/1986		177		177
1986/1987	992	173	195	1360
1987/1988	921	360		1281
1988/1989	1031	79	105	1215
1989/1990	929	266	80	1275
1990/1991	4324	496	393	5213
1991/1992	3380	366	1288	5034
1992/1993	1283	1092	3020	5395
1993/1994	9220	782	2091	12093
1994/1995	2591	169	1748	4508
1995/1996	3831	1205	1709	6745
1996/1997	2502	1059	965	4526
1997/1998	2658	929	5305	8892
1998/1999	3306	1828	4950	10084
1999/2000	5026	2196	6369	13591
2000/2001	3987	3857	14798	22642
2001/2002	1572	825	6055	8452
2002/2003	1832	1505	5762	9099
2003/2004	2020	1486	8455	11961
2004/2005	2334	1473	7384	11191
2005/2006	970	1717	6173	8860
2006/2007	1726	2576	6201	10503
2007/2008	2514	1289	3589	7392
Total	58949	25905	86635	171489

**Table 7. List of tables and fields requested in the Ministry of Fisheries extract 7334.**

**Fishing\_events table**

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

**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 stocks)	Processed_weight	Resrch_yn
State_code	Processed_weight_type	
	Form_type	

**Estimated\_subcatch table**

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

**Vessel\_history table**

Vessel_key	Built_year	Gross_tonnes
Flag_nationality_code	Engine_kilowatts	Overall_length_metres

**Table 8: Number of landing events by major destination code and form type for SWA 1, 3, and 4 from 1989–90 to 2007–08. “L” refers to “landed to NZ”; “T” refers to “transferred to another vessel”; “R” refers to “retained on board”.**

SWA 1	CLR form			CELR form			Total
	L	T	R	L	T	R	
1990	166	99	148	162	0	0	627
1991	180	83	122	189	0	0	627
1992	183	76	89	263	0	0	639
1993	258	85	79	340	0	0	803
1994	354	90	107	334	0	2	972
1995	437	107	49	369	0	0	1030
1996	573	88	36	325	0	0	1076
1997	763	73	55	380	0	0	1338
1998	733	41	41	262	0	1	1157
1999	598	18	41	223	0	1	956
2000	589	5	58	250	0	0	974
2001	675	21	43	252	0	2	1085
2002	676	11	33	188	0	0	992
2003	602	0	33	210	0	0	919
2004	544	0	27	202	0	0	846
2005	460	0	27	257	0	0	810
2006	424	0	27	226	0	2	757
2007	500	0	27	309	0	1	948
2008	798	0	33	6	0	1	946

SWA 3	CLR form			CELR form			Total
	L	T	R	L	T	R	
1990	134	68	24	57	0	0	295
1991	206	50	18	242	0	0	530
1992	319	77	32	477	0	0	931
1993	336	97	32	559	0	0	1043
1994	318	63	56	554	0	0	1023
1995	310	99	32	666	0	0	1170
1996	407	86	45	794	0	0	1396
1997	463	38	43	541	0	0	1144
1998	532	15	34	640	0	0	1279
1999	476	1	27	639	0	0	1210
2000	504	0	55	384	0	0	1029
2001	621	0	42	648	0	0	1407
2002	549	0	41	305	0	0	961
2003	603	0	63	399	0	0	1131
2004	479	1	72	362	0	0	974
2005	436	0	40	373	0	0	910
2006	417	0	25	290	0	0	801
2007	428	0	40	179	0	1	891
2008	459	0	45	36	0	0	811

**Table 8: Continued.**

SWA 4	CLR form			CELR form			Total
	L	T	R	L	T	R	
1990	108	62	26	1	0	0	205
1991	155	74	40	3	0	0	292
1992	164	81	44	9	0	0	317
1993	176	97	56	36	0	4	376
1994	150	64	51	54	0	3	328
1995	219	79	41	78	0	13	435
1996	262	71	39	67	0	6	448
1997	329	39	44	80	0	3	499
1998	303	14	50	72	0	0	449
1999	356	0	52	106	0	2	519
2000	411	0	45	82	0	7	548
2001	510	0	46	127	0	17	729
2002	594	0	42	141	0	17	797
2003	508	0	52	108	0	10	680
2004	557	0	57	152	0	10	780
2005	520	0	46	173	0	19	759
2006	462	0	40	170	0	16	688
2007	443	0	38	157	0	10	648
2008	432	0	27	147	0	0	606

**Table 9: Destination codes, total landing weight, number of landings and if the records were kept or discarded for all SWA catch 1989–2008 for SWA 1, SWA 3, and SWA 4.**

Destination code	Greenweight (t)	No. records	Description	Action
<b>SWA 1</b>				
L	47159.930	16689	Landed in NZ to a Licensed Fish Receiver	Keep
O	2235.065	209	Conveyed outside New Zealand	Keep
C	419.125	43	Disposed to the Crown	Keep
E	177.781	1297	Eaten	Keep
A	44.310	79	Accidental loss	Keep
D	23.691	52	Discarded	Keep
S	21.467	5	Seized by the Crown	Keep
F	0.504	47	Recreational catch	Keep
W	0.136	25	Sold at wharf	Keep
H	0.005	1	Loss from holding pot	Keep
U	0.000	1	Used as bait	Keep
T	10376.770	1173	Transferred to another vessel	Drop
R	9800.075	1600	Retained on board	Drop
Null	104.988	15	Missing destination type code	Drop
Q	0.124	9	Holding receptacle on land	Drop
<b>SWA 3</b>				
L	101311.153	21321	Landed in NZ to a Licensed Fish Receiver	Keep
O	1985.947	149	Conveyed outside New Zealand	Keep
C	764.902	78	Disposed to the Crown	Keep
A	148.895	103	Accidental loss	Keep
E	97.519	1832	Eaten	Keep
D	44.712	50	Discarded	Keep
W	0.015	2	Sold at wharf	Keep
S	0.010	6	Seized by the Crown	Keep
T	19603.264	1264	Transferred to another vessel	Drop
R	10313.939	1534	Retained on board	Drop
Null	99.716	23	Missing destination type code	Drop
Q	0.021	1	Holding receptacle on land	Drop
<b>SWA 4</b>				
L	110384.500	11503	Landed in NZ to a Licensed Fish Receiver	Keep
O	1987.948	165	Conveyed outside New Zealand	Keep
C	834.045	73	Disposed to the Crown	Keep
E	274.075	2543	Eaten	Keep
A	197.800	139	Accidental loss	Keep
D	51.173	62	Discarded	Keep
S	0.016	6	Seized by the Crown	Keep
F	0.005	1	Recreational catch	Keep
T	20652.580	1232	Transferred to another vessel	Drop
R	11152.230	1780	Retained on board	Drop
Null	92.918	11	Missing destination type code	Drop

**Table 10: The reported MHR, 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 SWA 1, 3, and 4 from 1989–90 to 2007–08.**

Year	MHR	SWA 1			MHR	SWA 3			MHR	SWA 4		
		unmerged landings	merged landings	merged estimated catch		unmerged landings	merged landings	merged estimated catch		unmerged landings	merged landings	merged estimated catch
1990	2316	1115	1059	763	2713	860	593	590	3596	1489	1311	1220
1991	2121	1247	1077	835	1889	714	706	685	3176	861	859	879
1992	1388	710	630	532	2661	1517	1503	1366	3018	1336	1331	1265
1993	1231	674	574	488	2432	1026	993	1129	3137	1757	1750	1764
1994	2960	1827	1812	1939	2724	1392	1306	1452	2993	1517	1516	1984
1995	2281	1597	1530	1530	2336	1203	1066	1385	2638	1439	1325	1800
1996	2884	1913	1841	1729	2939	1653	1291	1683	3581	1745	1742	2226
1997	3636	2919	2723	2447	4063	3312	2749	2419	5336	4035	3993	3857
1998	3380	3150	3052	2623	3721	3545	3038	2664	3944	3690	3586	3396
1999	1980	1849	1803	1537	2796	2630	2355	1960	4021	3922	3846	3464
2000	2525	2252	2183	1814	4129	3688	2894	2285	4606	4468	4292	4099
2001	3025	2883	2710	2372	3664	3660	2865	2633	4650	4219	4130	3763
2002	1004	1082	1055	764	2899	2759	2067	1805	4648	4855	4696	4259
2003	1029	1058	1023	808	3772	3329	2212	2114	4746	4504	4310	4316
2004	1595	1412	1245	1104	3606	3606	2793	2553	5529	5545	4928	4601
2005	1467	1422	1381	1215	3797	3965	3351	2737	4279	4128	3513	3676
2006	1023	1034	911	757	4524	4259	3889	3313	5591	5213	4928	5105
2007	2093	2076	2039	1834	6059	5914	5575	4807	6022	5931	5759	5666
2008	1679	1768	1686	1508	2918	3018	2734	2235	3510	3402	3140	3164

**Table 11: Total number of trips, number of trips with zero estimated catch and percent of trips with zero estimated catch, by form type for SWA 1, 3, and 4 from 1989–90 to 2007–08.**

SWA 1	CELR			TCEPR		
	Total	Zero	Percent	Total	Zero	Percent
1990	164	99	0.60	155	51	0.33
1991	182	110	0.60	163	42	0.26
1992	262	181	0.69	160	56	0.35
1993	330	199	0.60	211	88	0.42
1994	319	203	0.64	319	137	0.43
1995	333	217	0.65	367	129	0.35
1996	293	176	0.60	479	192	0.40
1997	362	224	0.62	620	228	0.37
1998	244	141	0.58	585	191	0.33
1999	220	137	0.62	455	137	0.30
2000	240	139	0.58	427	127	0.30
2001	246	117	0.48	481	180	0.37
2002	188	124	0.66	507	221	0.44
2003	206	134	0.65	468	210	0.45
2004	200	128	0.64	414	187	0.45
2005	254	154	0.61	355	162	0.46
2006	229	158	0.69	338	167	0.49
2007	303	202	0.67	363	151	0.42
2008	7	6	0.86	295	100	0.34

SWA 3	CELR			TCEPR		
	Total	Zero	Percent	Total	Zero	Percent
1990	55	42	0.76	88	26	0.30
1991	233	140	0.60	184	79	0.43
1992	471	312	0.66	269	87	0.32
1993	551	278	0.50	320	108	0.34
1994	547	228	0.42	311	78	0.25
1995	656	296	0.45	300	72	0.24
1996	761	353	0.46	364	87	0.24
1997	526	303	0.58	387	55	0.14
1998	630	380	0.60	450	85	0.19
1999	633	388	0.61	379	69	0.18
2000	373	243	0.65	381	64	0.17
2001	644	360	0.56	393	38	0.10
2002	302	175	0.58	348	70	0.20
2003	391	212	0.54	367	42	0.11
2004	360	202	0.56	296	26	0.09
2005	368	231	0.63	257	31	0.12
2006	290	206	0.71	253	34	0.13
2007	176	117	0.66	254	32	0.13
2008	36	30	0.83	150	5	0.03

**Table 11: Continued.**

SWA 4	CELR			TCEPR		
	Total	Zero	Percent	Total	Zero	Percent
1990	1	0	0.00	78	10	0.13
1991				140	30	0.21
1992				149	36	0.24
1993	4	3	0.75	151	33	0.22
1994	3	2	0.67	153	28	0.18
1995	12	4	0.33	202	27	0.13
1996	6	1	0.17	201	31	0.15
1997	3	2	0.67	238	27	0.11
1998				237	18	0.08
1999	2	1	0.50	246	21	0.09
2000	7	4	0.57	248	23	0.09
2001	17	13	0.76	283	27	0.1
2002	17	6	0.35	291	32	0.11
2003	11	6	0.55	297	33	0.11
2004	10	3	0.30	305	29	0.1
2005	18	7	0.39	317	46	0.15
2006	16	5	0.31	284	36	0.13
2007	10	6	0.60	259	35	0.14
2008				238	41	0.17

**Table 12: Total catch (t) for each region from groomed and merged data for fishing years 1990 – 2008.**

Fishing year	Chatham Rise	ECNI	ECSI	Southland	WCNI	WCSI	Total
1990	35	27	1215	3663	37	1646	6623
1991	308	40	1571	2491	67	1631	6108
1992	102	114	2343	3073	2	1038	6673
1993	253	131	2635	2783	11	920	6734
1994	292	196	2328	3055	14	2279	8164
1995	275	234	2284	2111	60	1925	6890
1996	633	374	2425	2991	85	2086	8595
1997	486	221	3532	4810	57	3017	12124
1998	219	193	3343	3855	38	2986	10634
1999	124	180	2028	4440	44	1669	8484
2000	302	209	2473	5405	6	1989	10384
2001	385	124	3031	4454	13	2741	10748
2002	389	121	2244	4989	44	931	8719
2003	496	86	2830	4210	49	887	8557
2004	359	68	3287	5566	11	1242	10533
2005	898	115	3413	3848	13	1181	9468
2006	546	41	3595	5348	30	837	10398
2007	391	98	5465	6073	26	1861	13915
2008	539	105	2689	3222	9	1530	8093
Total	7032	2678	52732	76389	615	32397	171843

**Table 13: Number of tows in each QMA and probability of being a twin trawl as scored by Hurst (2009). Tows scoring 50% or greater were excluded from the CPUE analysis.**

Excluded from CPUE	Twin trawl probability	SWA1	SWA3	SWA4	Total
	5%	6643	10952	6066	23661
	20%	203	248	105	556
exclude	50%	108	100	33	241
exclude	80%	877	3592	2631	7100
exclude	95%	4267	12938	2293	19498
	NA	2	1		3
	Total tows	12100	27831	11128	51059

**Table 14: Description of CPUE model datasets used for CPUE analyses.**

Model	Area	Bottom trawl only	TCEPR form only	Target species	Logistic	Merged (trip-level dataset)	Unmerged (tow-level dataset)	Twin trawl tows
1	C,E,S	Y	Y	Major		Y		
2	C,E,S	Y	Y	Major			Y	
3	E	Y	Y	Major		Y		Y
4	E,S	Y	Y	HOK		Y		
5	E,S	Y	Y	SWA		Y		
6	E,S	Y	Y	SQU		Y		
7	C+E	Y	Y	Major		Y		
8	C,E,S	Y	Y	No target			Y	
9	S	Y	Y	SQU	Y	Y		

**Table 15: CPUE datasets for all vessels and for core vessels for each year (1990–2008) for Model 1 (stratified dataset) and Model 2 (tow-level dataset) for each CPUE area (Chatham Rise, ECSI, and Sotuhland).**

**ECSI Model 1**

Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	317	0.31	1169	220	5.31	131	0.3	640	92	6.95
1991	501	0.27	1384	364	3.8	260	0.33	864	175	4.94
1992	745	0.26	2107	548	3.84	394	0.3	1451	274	5.3
1993	842	0.31	2165	578	3.75	513	0.35	1520	331	4.59
1994	580	0.26	1986	430	4.62	343	0.29	1711	244	7.01
1995	735	0.34	1831	485	3.78	516	0.33	1642	348	4.72
1996	865	0.33	1759	580	3.03	579	0.34	1454	384	3.79
1997	878	0.27	2688	641	4.19	543	0.27	2056	399	5.15
1998	962	0.29	2496	686	3.64	703	0.29	1893	502	3.77
1999	852	0.32	1561	582	2.68	645	0.32	1347	441	3.05
2000	839	0.3	1966	590	3.33	690	0.3	1622	485	3.34
2001	994	0.27	2611	724	3.61	811	0.27	2195	591	3.71
2002	798	0.31	1916	547	3.5	633	0.31	1263	435	2.9
2003	916	0.35	2212	598	3.7	674	0.37	1494	426	3.51
2004	650	0.31	2751	449	6.13	515	0.31	1783	353	5.05
2005	592	0.3	2756	412	6.69	411	0.33	1750	277	6.32
2006	546	0.23	2838	419	6.77	392	0.24	1821	297	6.13
2007	535	0.25	4286	400	10.72	365	0.24	2662	277	9.61
2008	435	0.29	1984	310	6.4	232	0.29	1145	165	6.94

**ECSI Model 2**

Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	2836	0.67	1138	950	1.2	1294	0.63	579	478	1.21
1991	3361	0.73	1291	922	1.4	1745	0.69	840	545	1.54
1992	5368	0.73	1679	1468	1.14	3071	0.71	1055	892	1.18
1993	5402	0.73	1934	1475	1.31	2821	0.7	1466	851	1.72
1994	4065	0.69	1836	1253	1.47	2475	0.61	1671	971	1.72
1995	5344	0.76	1699	1309	1.3	3608	0.68	1596	1139	1.4
1996	8033	0.79	1722	1650	1.04	4133	0.72	1482	1146	1.29
1997	8059	0.72	2230	2259	0.99	4412	0.67	1801	1472	1.22
1998	9532	0.75	2273	2389	0.95	6024	0.72	1791	1696	1.06
1999	8696	0.81	1279	1627	0.79	6078	0.8	1110	1243	0.89
2000	8687	0.75	1599	2161	0.74	7136	0.75	1255	1786	0.7
2001	9583	0.72	2343	2645	0.89	7439	0.71	1980	2149	0.92
2002	6942	0.79	1837	1434	1.28	4942	0.8	1132	1011	1.12
2003	8346	0.79	2059	1765	1.17	5692	0.79	1416	1171	1.21
2004	5852	0.59	2501	2374	1.05	4223	0.62	1590	1617	0.98
2005	4545	0.61	2454	1761	1.39	2561	0.63	1539	943	1.63
2006	4724	0.57	2577	2042	1.26	3235	0.59	1647	1321	1.25
2007	4240	0.49	3887	2162	1.8	2321	0.51	2469	1138	2.17
2008	3590	0.58	1704	1496	1.14	1807	0.58	951	755	1.26

**Table 15: Continued.**  
**Southland**  
**Model 1**

Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	259	0.31	3149	180	17.49	103	0.33	2155	69	31.23
1991	330	0.32	1776	226	7.86	110	0.3	1037	77	13.47
1992	370	0.3	2720	258	10.54	173	0.36	2275	110	20.68
1993	426	0.36	2450	273	8.97	305	0.37	2237	193	11.59
1994	299	0.29	2575	213	12.09	206	0.22	2484	160	15.52
1995	357	0.41	1850	211	8.77	226	0.32	1665	153	10.88
1996	352	0.36	2064	227	9.09	225	0.37	1815	142	12.78
1997	516	0.34	2935	341	8.61	307	0.29	2444	219	11.16
1998	468	0.35	2388	303	7.88	256	0.34	2010	169	11.89
1999	464	0.41	3503	274	12.78	348	0.39	3472	211	16.45
2000	516	0.33	4453	347	12.83	375	0.29	4080	266	15.34
2001	605	0.36	3476	389	8.94	400	0.3	3144	282	11.15
2002	640	0.37	3548	403	8.8	462	0.33	3079	311	9.9
2003	582	0.34	2876	382	7.53	405	0.32	2633	274	9.61
2004	545	0.25	3691	409	9.02	390	0.21	2990	309	9.68
2005	569	0.24	3329	435	7.65	447	0.21	2867	354	8.1
2006	542	0.15	4404	458	9.62	414	0.13	3847	360	10.69
2007	537	0.16	4760	452	10.53	463	0.11	4489	410	10.95
2008	337	0.2	2897	271	10.69	262	0.11	2765	232	11.92

**Southland**  
**Model 2**

Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	3107	0.72	3305	873	3.79	1144	0.65	2311	400	5.78
1991	4391	0.86	1549	631	2.45	1012	0.79	981	211	4.65
1992	4692	0.83	2504	816	3.07	1491	0.66	2119	512	4.14
1993	4791	0.82	2285	873	2.62	2225	0.68	2103	702	3
1994	4137	0.78	2429	916	2.65	2085	0.63	2334	771	3.03
1995	4783	0.83	1651	815	2.03	2123	0.69	1495	648	2.31
1996	3996	0.81	2000	749	2.67	1952	0.71	1764	570	3.1
1997	6503	0.79	2949	1350	2.18	3545	0.71	2368	1032	2.29
1998	5806	0.82	2331	1039	2.24	2428	0.68	1992	766	2.6
1999	5396	0.77	3203	1262	2.54	3587	0.66	3173	1210	2.62
2000	6328	0.78	4091	1400	2.92	2890	0.62	3784	1085	3.49
2001	6290	0.76	3258	1485	2.19	2769	0.54	3014	1273	2.37
2002	6940	0.77	3381	1565	2.16	3867	0.65	2980	1353	2.2
2003	6155	0.8	3138	1251	2.51	3985	0.73	2904	1062	2.73
2004	5906	0.65	3669	2048	1.79	3854	0.62	2962	1461	2.03
2005	6324	0.68	3411	2023	1.69	4603	0.64	2993	1656	1.81
2006	5923	0.54	4468	2717	1.64	4410	0.52	3951	2118	1.87
2007	3703	0.43	4624	2118	2.18	2929	0.34	4333	1926	2.25
2008	2832	0.56	2814	1256	2.24	2108	0.44	2692	1175	2.29

**Table 15: Continued.**  
**Chatham Rise Model 1**

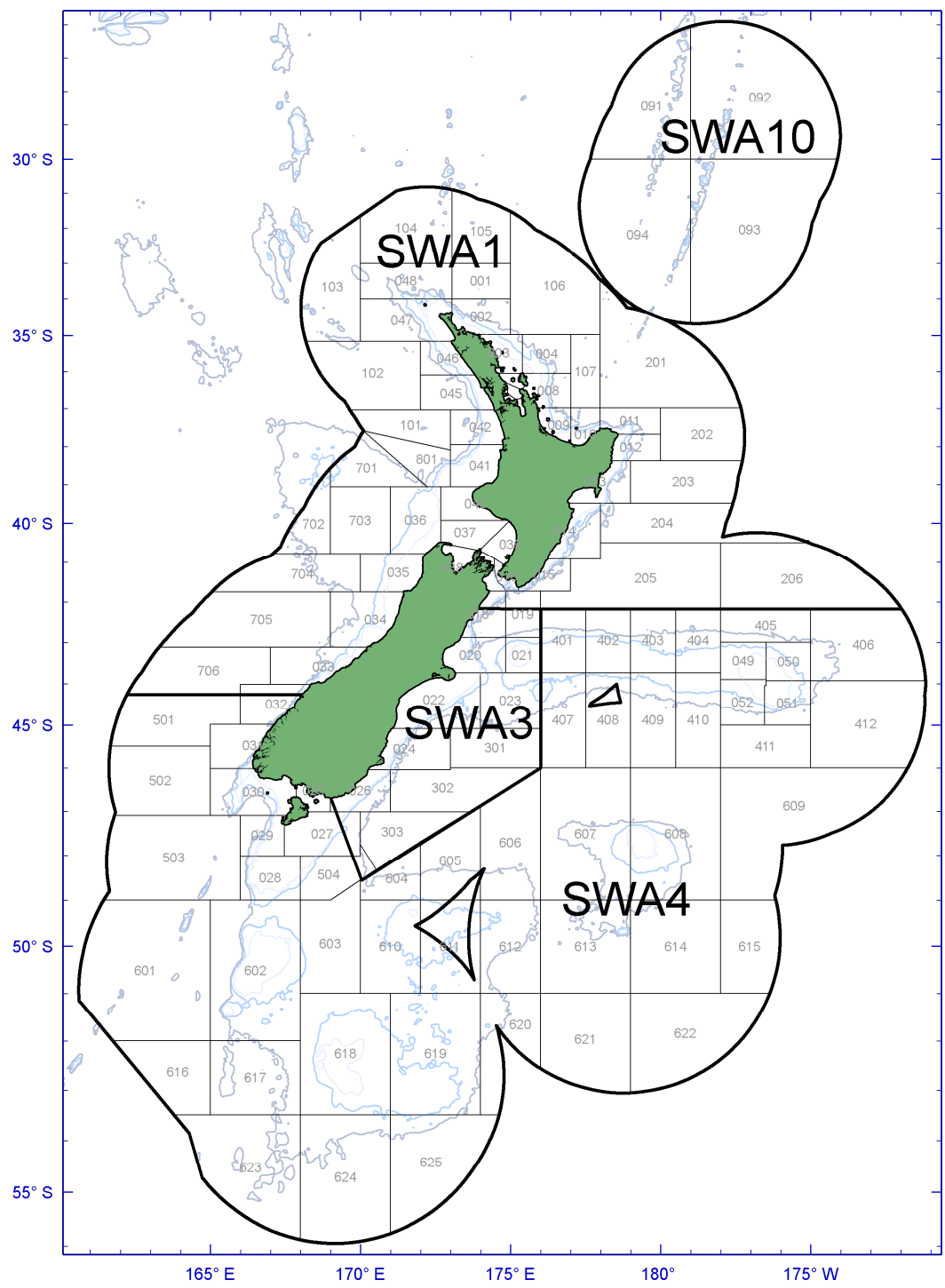
Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	49	0.61	32	19	1.7	11	0.36	22	7	3.09
1991	44	0.5	294	22	13.36	27	0.48	277	14	19.81
1992	73	0.29	83	52	1.6	30	0.3	67	21	3.21
1993	60	0.28	235	43	5.45	20	0.5	70	10	7.04
1994	69	0.33	282	46	6.13	33	0.3	249	23	10.81
1995	113	0.48	237	59	4.02	36	0.39	86	22	3.89
1996	111	0.37	395	70	5.65	65	0.43	244	37	6.6
1997	116	0.33	392	78	5.03	55	0.27	378	40	9.45
1998	153	0.38	186	95	1.96	67	0.45	119	37	3.23
1999	140	0.51	39	68	0.58	61	0.62	31	23	1.34
2000	115	0.56	54	51	1.05	37	0.59	43	15	2.86
2001	150	0.52	147	72	2.04	51	0.43	70	29	2.4
2002	146	0.41	215	86	2.49	57	0.46	75	31	2.42
2003	116	0.54	86	53	1.62	23	0.43	23	13	1.76
2004	116	0.42	191	67	2.85	27	0.37	61	17	3.62
2005	105	0.4	690	63	10.95	28	0.29	202	20	10.1
2006	64	0.34	313	42	7.46	17	0.29	234	12	19.53
2007	90	0.29	289	64	4.52	23	0.26	24	17	1.39
2008	109	0.5	282	55	5.12	54	0.54	186	25	7.45

**Chatham Rise Model 2**

Year	All vessels					Core vessels				
	No records	Zeros	Catch	Effort	CPUE	No records	Zeros	Catch	Effort	CPUE
1990	393	0.77	31	90	0.35	151	0.55	22	68	0.32
1991	332	0.76	283	80	3.54	166	0.72	268	47	5.7
1992	898	0.8	79	184	0.43	162	0.42	65	94	0.69
1993	802	0.8	189	163	1.16	317	0.74	27	84	0.32
1994	821	0.83	266	143	1.86	284	0.62	234	109	2.15
1995	1473	0.82	173	267	0.65	324	0.56	77	144	0.54
1996	991	0.71	449	290	1.55	542	0.58	286	225	1.27
1997	1130	0.73	429	308	1.39	483	0.45	410	268	1.53
1998	1451	0.91	197	125	1.58	356	0.79	133	76	1.75
1999	2468	0.97	26	71	0.37	562	0.89	26	62	0.41
2000	1207	0.96	47	51	0.93	203	0.83	41	35	1.18
2001	1346	0.88	126	158	0.8	374	0.71	67	107	0.62
2002	1508	0.86	231	211	1.09	653	0.77	115	149	0.77
2003	1339	0.93	65	96	0.68	196	0.8	16	39	0.41
2004	1624	0.88	147	201	0.73	560	0.93	53	40	1.32
2005	1328	0.72	623	367	1.7	667	0.76	185	162	1.14
2006	459	0.72	337	130	2.59	81	0.44	259	45	5.76
2007	885	0.68	226	284	0.8	265	0.76	31	64	0.48
2008	1109	0.83	243	193	1.26	466	0.8	170	93	1.83

**Table 16: Variables retained in order of decreasing explanatory value by each model for each area and the corresponding total R<sup>2</sup> value. Note that Model 7 is for Chatham Rise and ECSI combined and the results are reported under the ECSI column.**

Model	Chatham Rise		ECSI		Southland	
	Variable	R <sup>2</sup>	Variable	R <sup>2</sup>	Variable	R <sup>2</sup>
1	fishing year	0.14	fishing year	0.03	fishing year	0.02
	fishing duration	0.21	vessel	0.23	target species	0.11
	target species	0.30	fishing duration	0.30	fishing duration	0.19
	month	0.35	target species	0.33	stats area	0.25
	vessel	0.39	stats area	0.35	vessel	0.29
	stats area	0.41	month	0.36	month	0.31
2	fishing year	0.15	fishing year	0.03	fishing year	0.08
	effort depth	0.25	vessel	0.12	target species	0.24
	vessel	0.29	target species	0.15	start latitude	0.30
	target species	0.31	month	0.18	vessel	0.35
	month	0.33			start longitude	0.36
3			fishing year	0.03		
			vessel	0.22		
			fishing duration	0.30		
			target species	0.33		
			month	0.35		
4			fishing year	0.06	fishing year	0.07
			fishing duration	0.23	vessel	0.19
			month	0.35	fishing duration	0.29
			stats area	0.42	month	0.34
			vessel	0.46	stats area	0.38
5			fishing year	0.12	fishing year	0.04
			fishing duration	0.39	fishing duration	0.38
			vessel	0.44	month	0.46
			month	0.48	vessel	0.50
			stats area	0.50	stats area	0.52
6			fishing year	0.04	fishing year	0.03
			fishing duration	0.22	fishing duration	0.07
			vessel	0.31	stats area	0.16
			month	0.33	vessel	0.19
7					month	0.23
			fishing year	0.03		
			vessel	0.22		
			fishing duration	0.30		
			target species	0.34		
8			stats area	0.37		
			month	0.38		
	fishing year	0.15	fishing year	0.03	fishing year	0.08
	effort depth	0.25	vessel	0.12	vessel	0.19
	vessel	0.29	month	0.15	start longitude	0.30
month	0.31	effort depth	0.16	start latitude	0.32	
		start latitude	0.17	effort depth	0.33	



**Figure 1: Map showing the administrative fishstock boundaries for SWA 1, SWA 3, SWA 4, and SWA 10, including statistical areas, and the 200 m, 500 m, and 1000 m depth contours.**

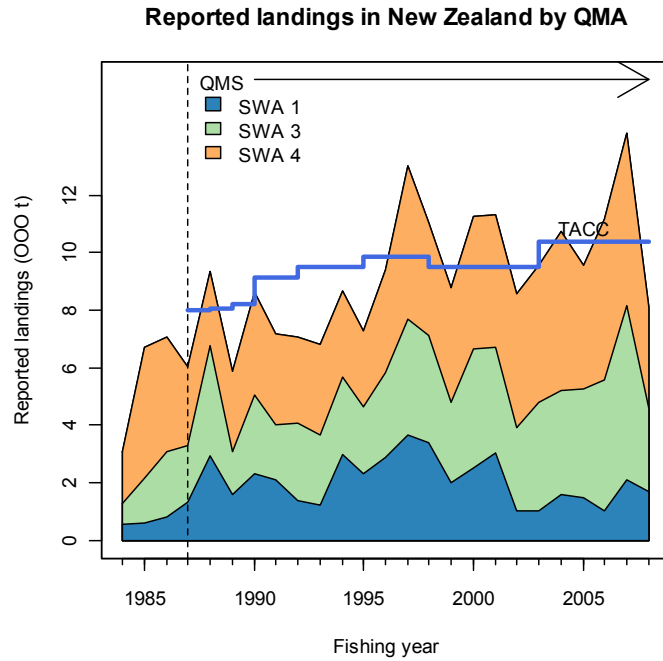


Figure 2: Total reported landings by QMA (shaded regions) and TACC from fishing years 1984 though 2008.

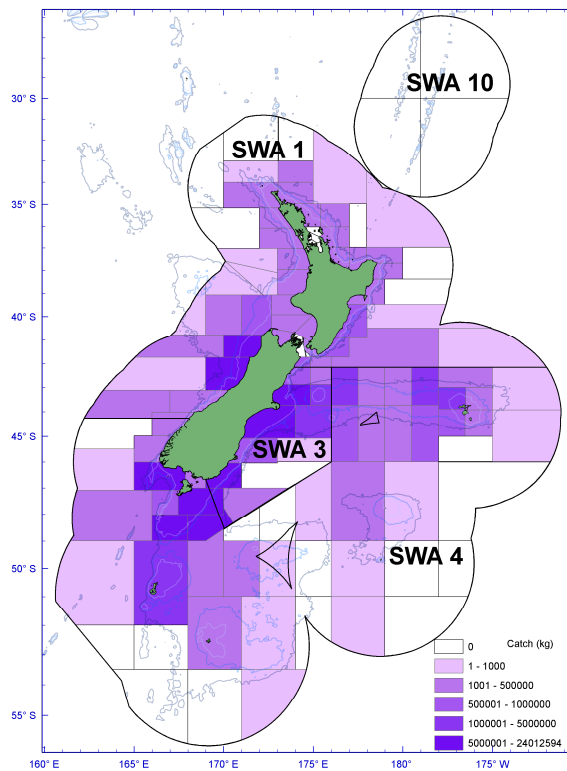
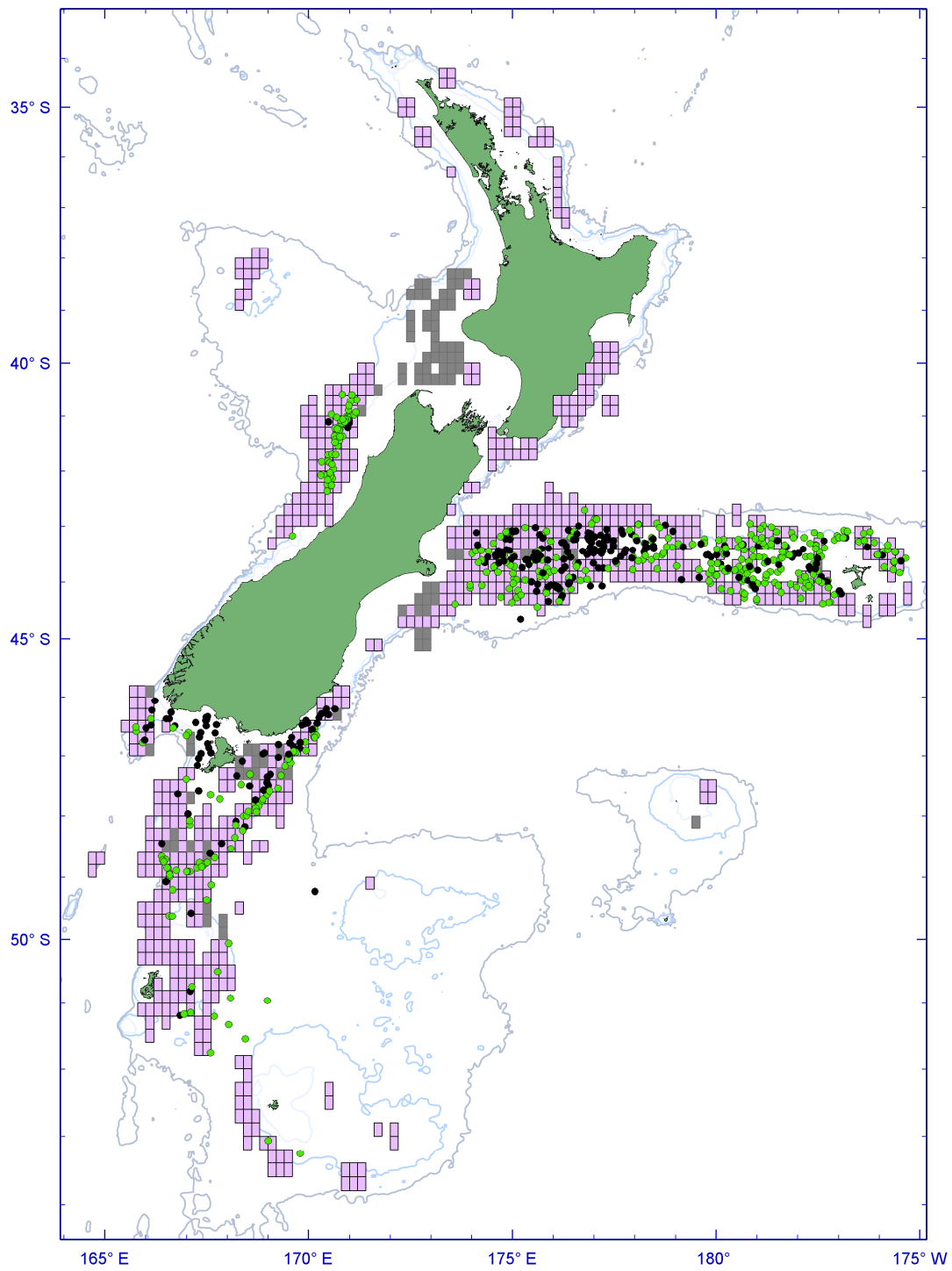
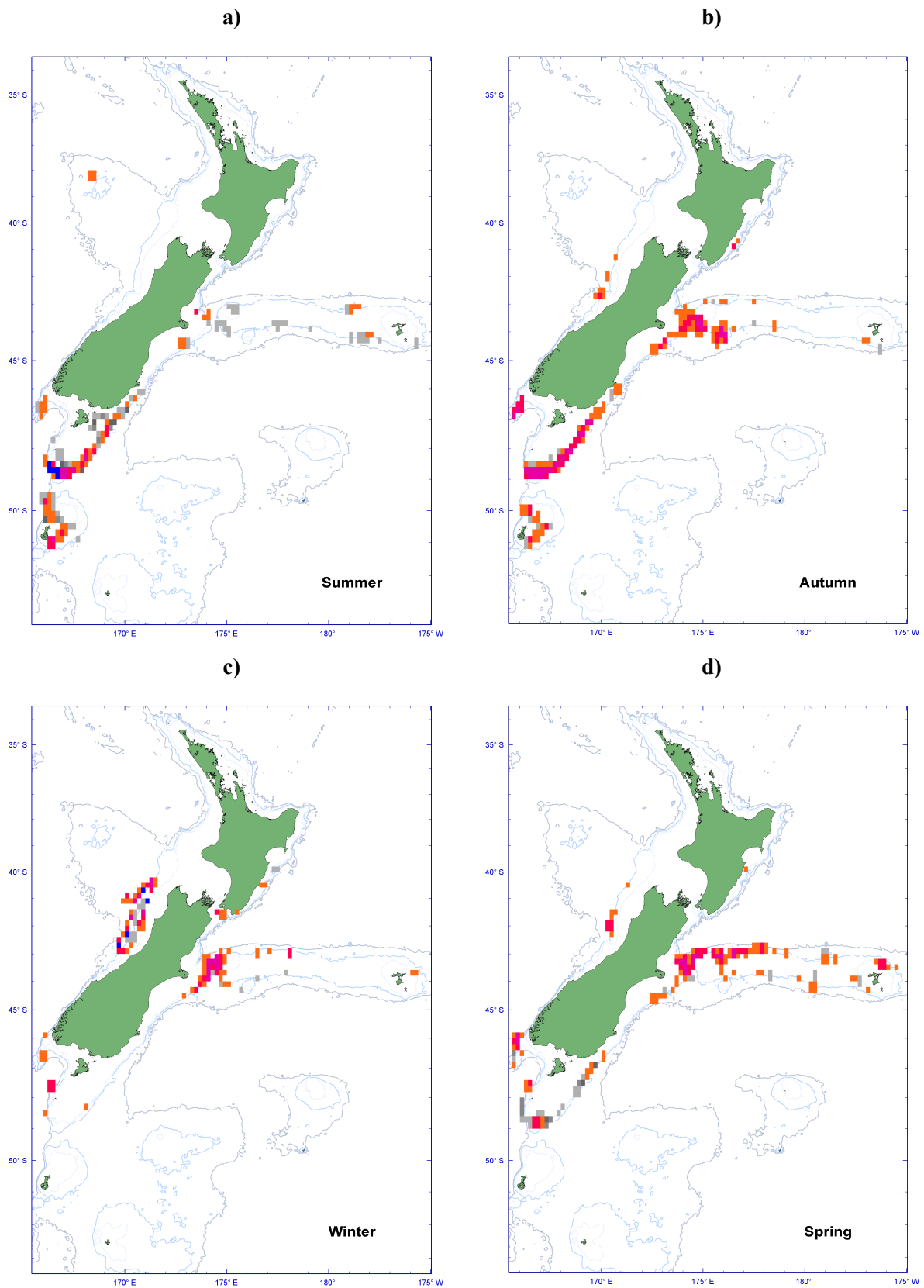


Figure 3: Distribution of total commercial catch 1983–84 to 2007–08. Empty statistical areas had no reported catch and lightest shaded areas reported <1 ton. Darker shades indicate progressively higher catch.



**Figure 4: Location of silver warehou catches from bottom trawl surveys (green dots > 43 cm, black dots < 44 cm) and commercial fishing data (gridded cells) showing sampled fish < 44 cm (grey) and > 43 cm (lavender).**



**Figure 5: Distribution of immature/resting (grey cells), and mature/maturing (orange cells = low numbers of samples scaled to blue cells= high numbers of samples) silver warehou from observed commercial tows for the four quarters of the annual cycle: a) Dec–Feb, b) Mar–May, c) Jun–Aug, d) Sept–Nov from observer programme data 1992–2008. Not all areas are sampled in each quarter.**

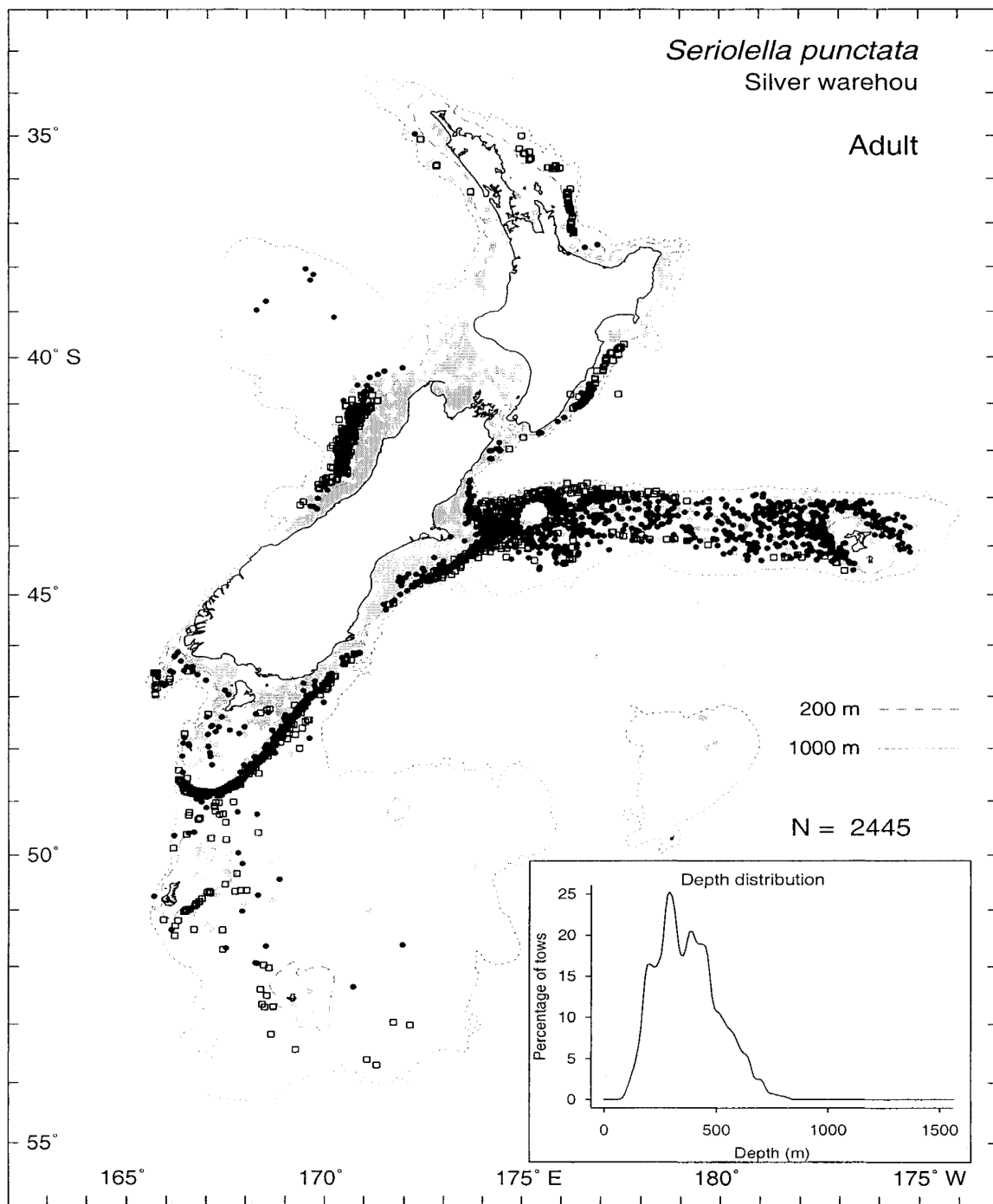
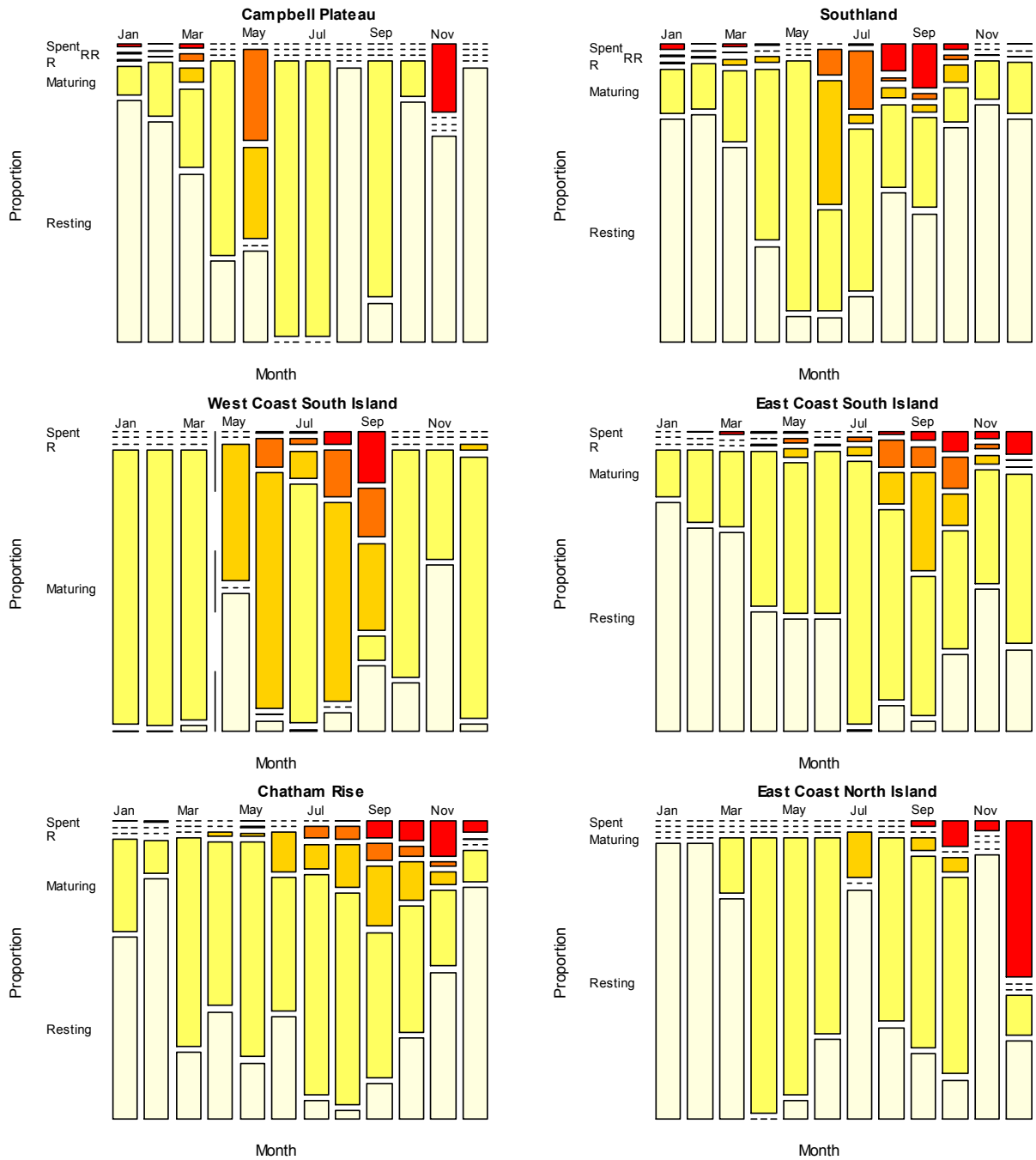
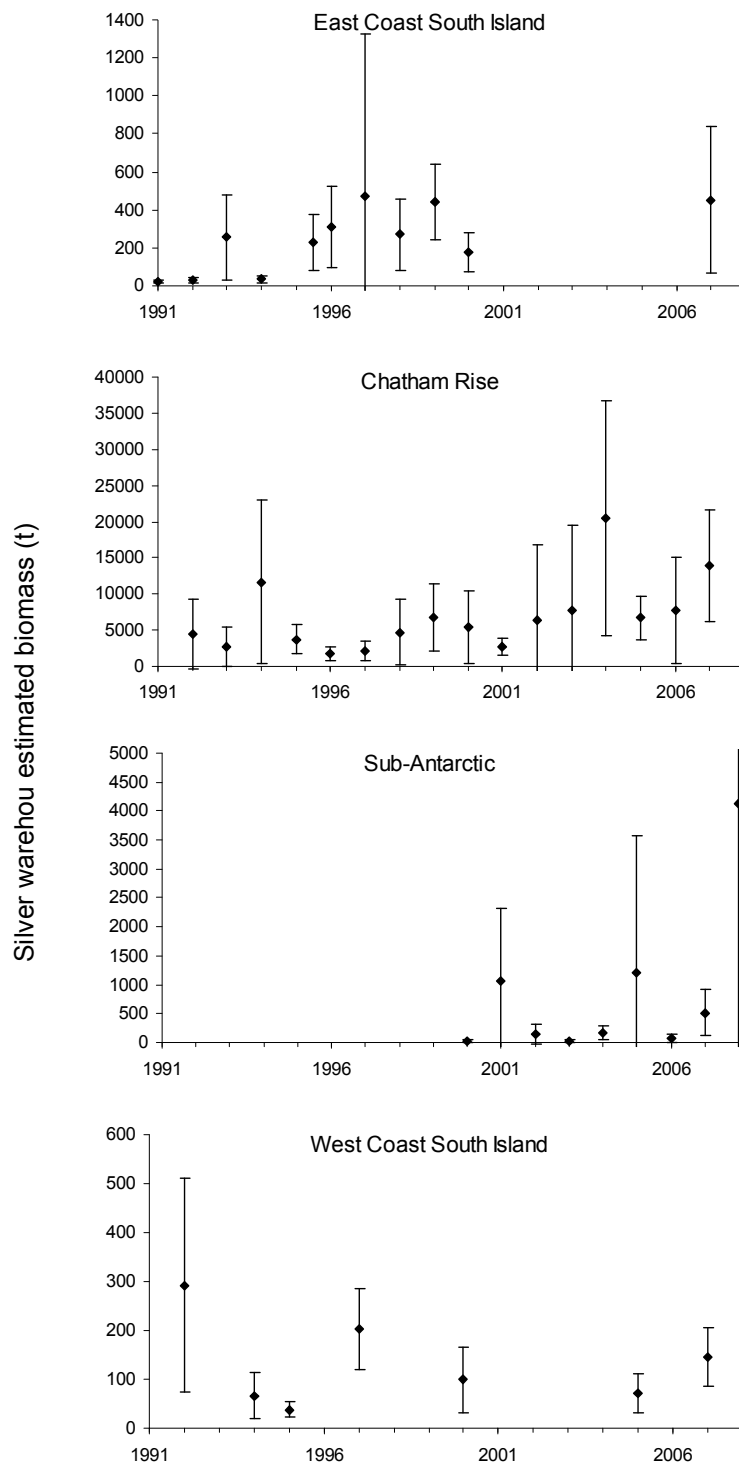


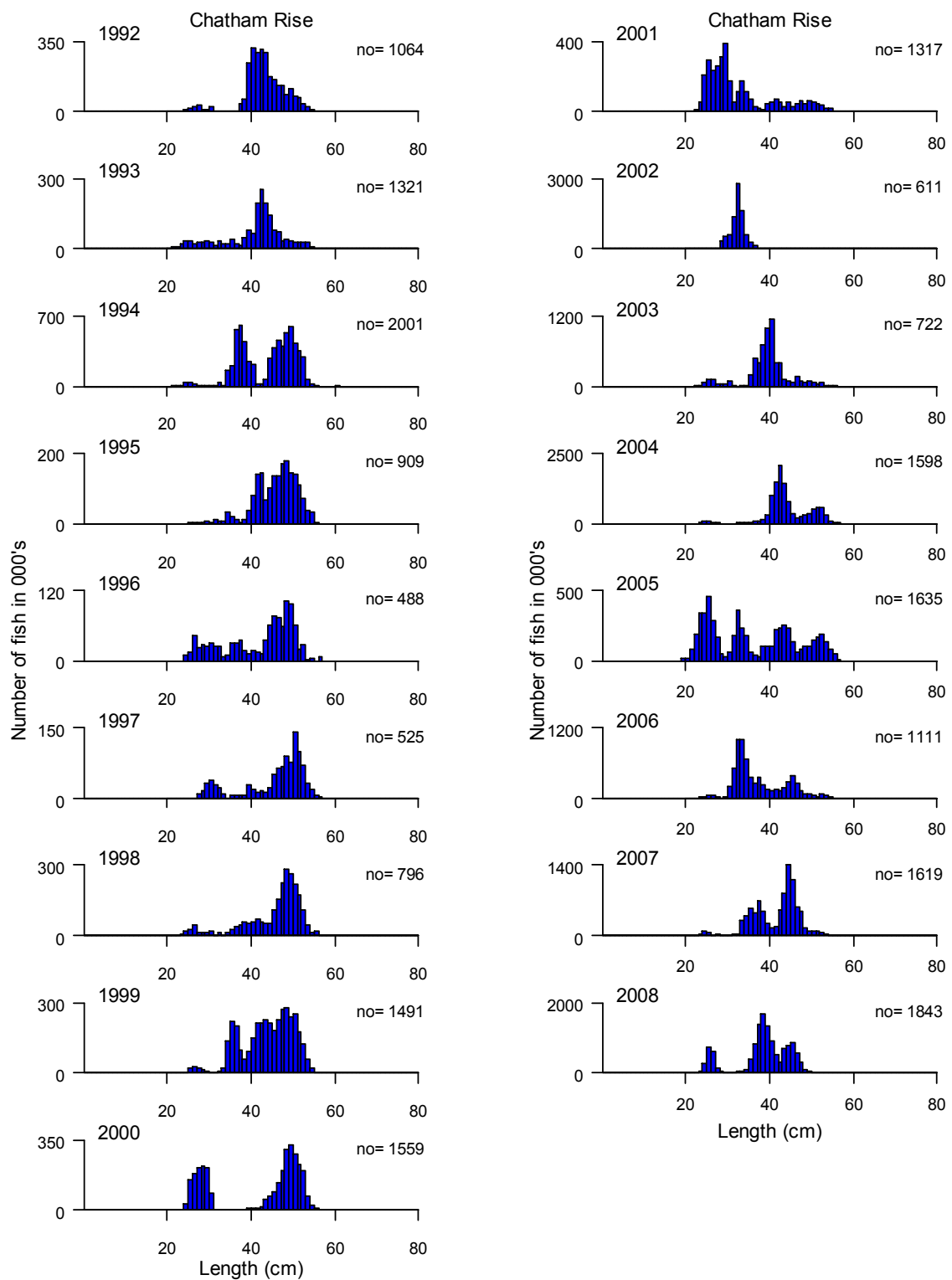
Figure 6: Distribution of adult silver warehou from all research fishing in the trawl database to 2002 (black circles), observer sampled silver warehou (open squares) and locations where any stage silver warehou has been observed (grey dots). Figure is reproduced from O’Driscoll et al. (2003).



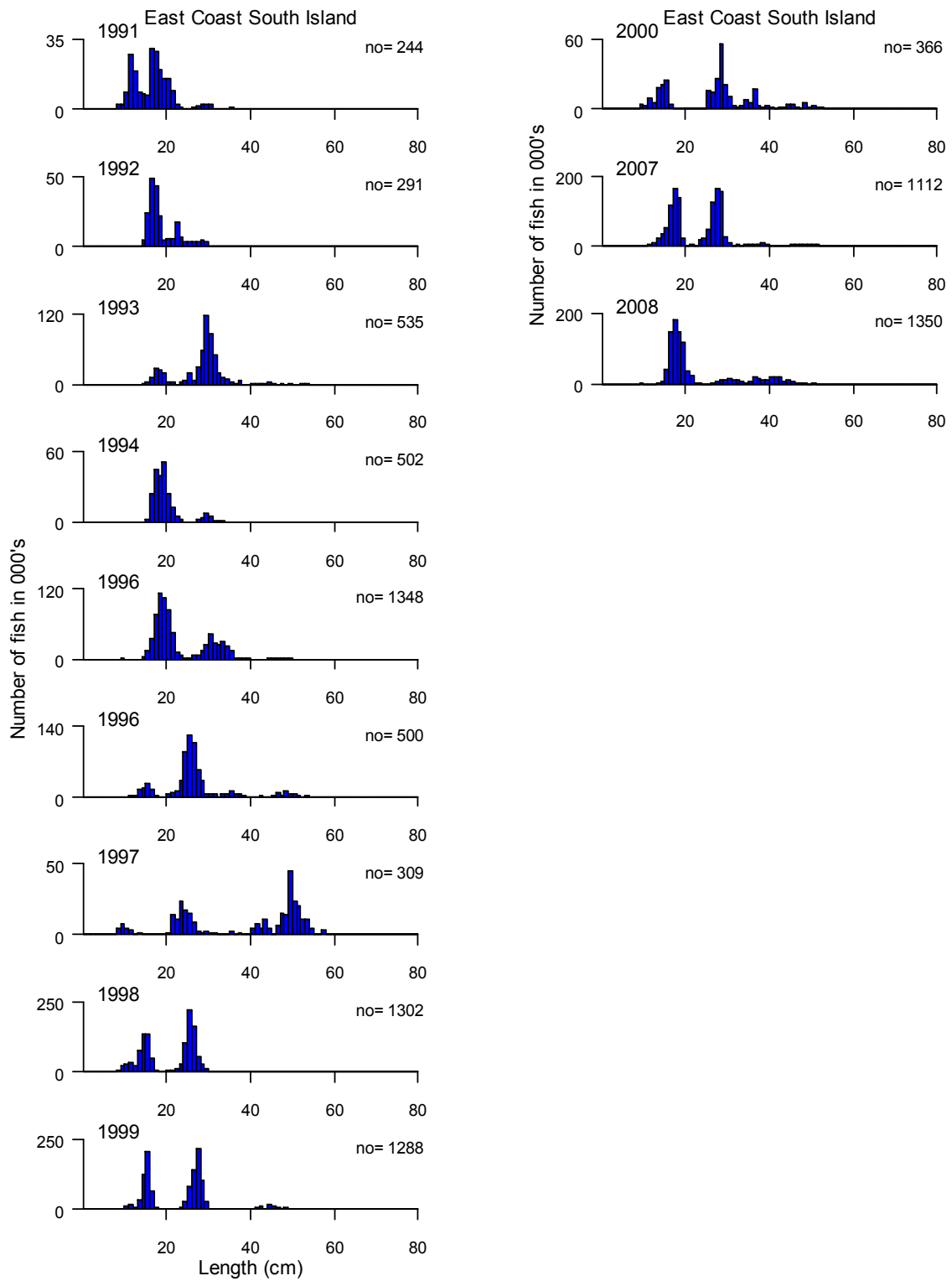
**Figure 7: Monthly proportions of female silver warehou gonad developmental stages collected by the Observer Programme in six main regions around New Zealand. Reproductive stages are coloured Resting: pale yellow, Maturing: yellow, Ripe: gold, Running ripe: orange, and Spent: red.**



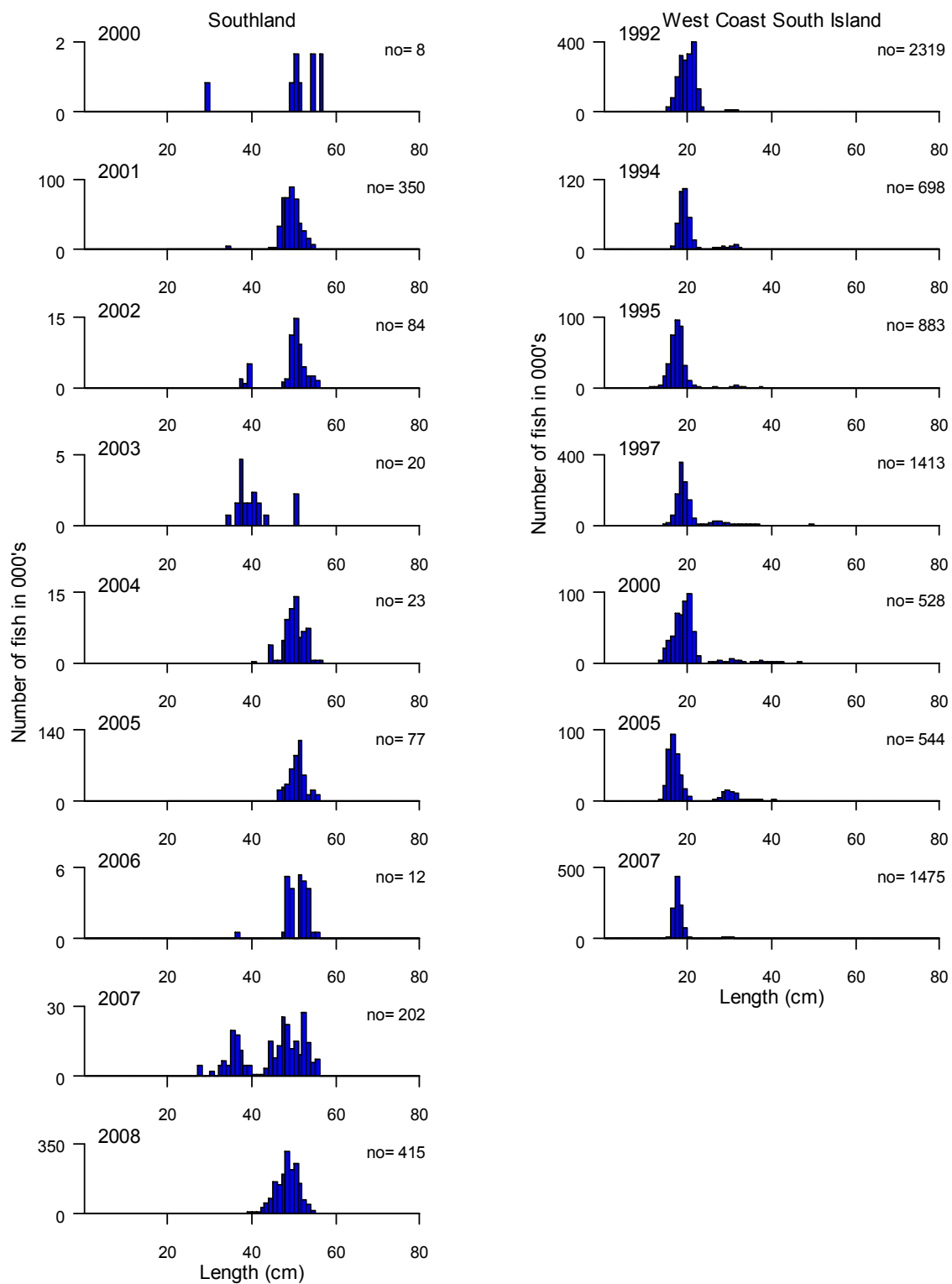
**Figure 8: Biomass estimates ( $\pm$  c.v.) of silver warehou from bottom trawl surveys around the South Island of New Zealand since 1992. The ECSI series consists of three separate survey designs, with the 1996 to 2000 surveys occurring in summer. Note that the 2008 error bar for Sub-Antarctic (Southland) extends to 8649.**



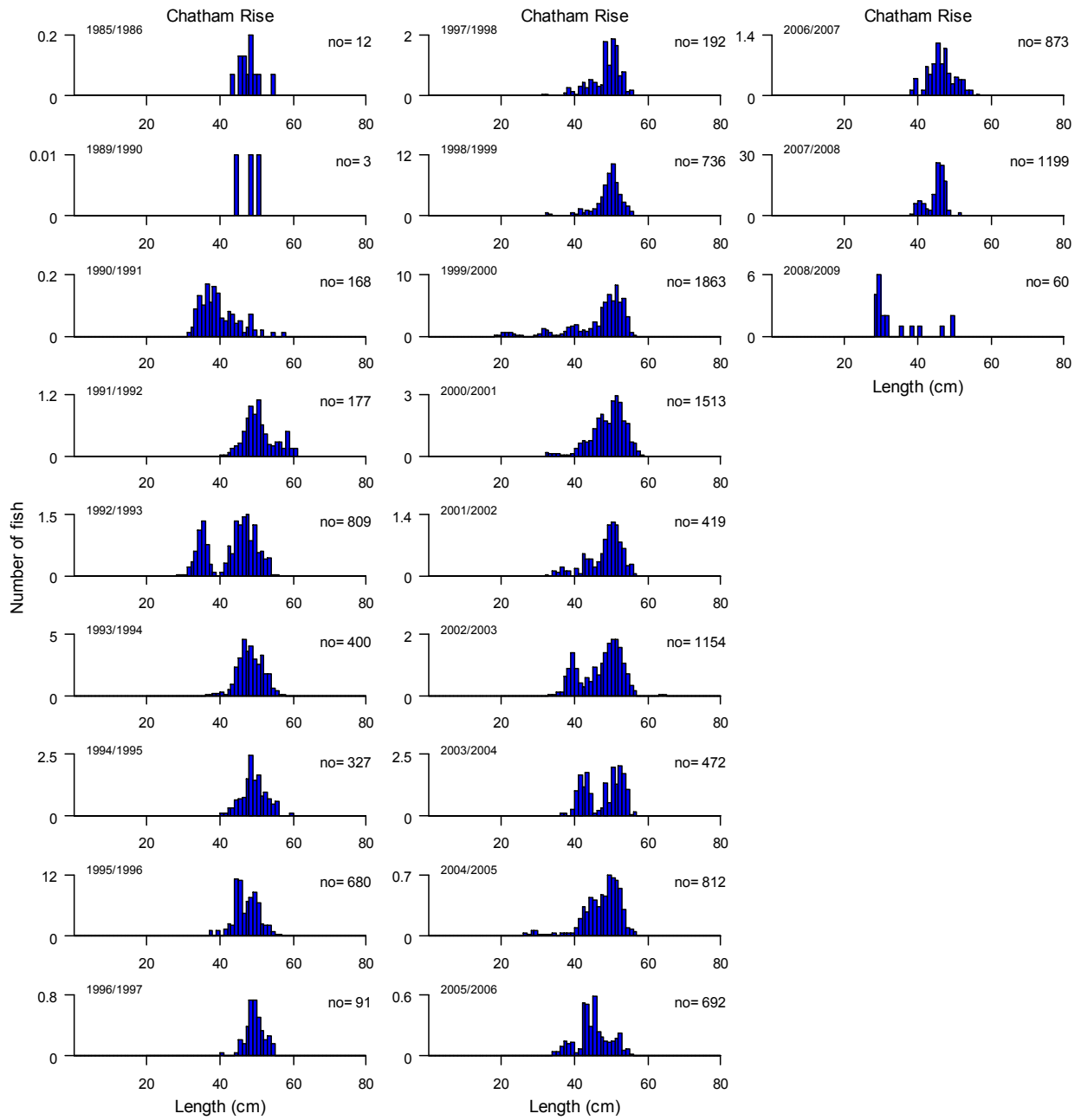
**Figure 9: Scaled length frequency distributions for each bottom trawl survey of the CHATHAM RISE since 1992.**



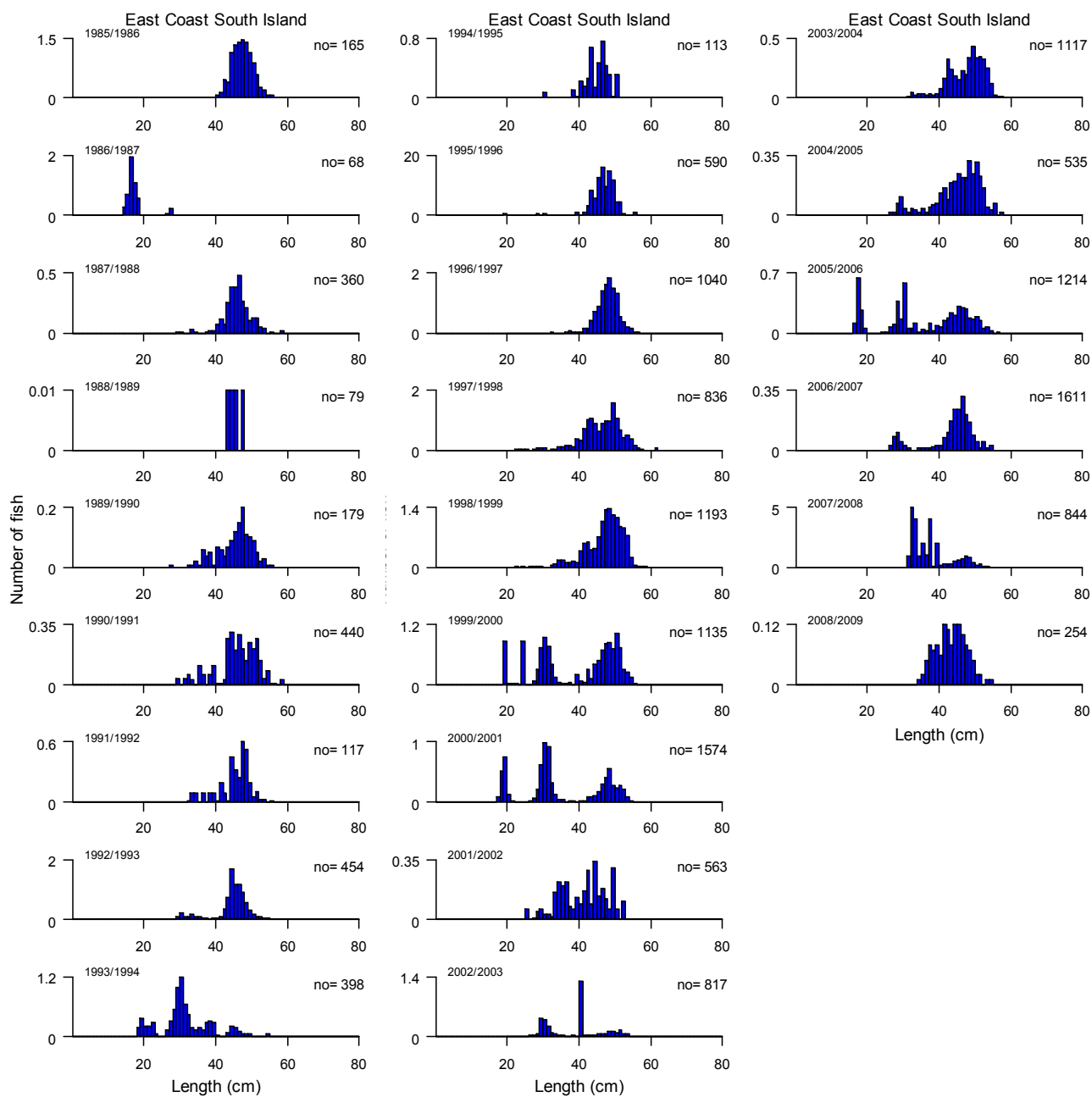
**Figure 10: Scaled length frequency distributions for each bottom trawl survey of the EAST COAST SOUTH ISLAND since 1983. 1996 was surveyed twice, summer and winter.**



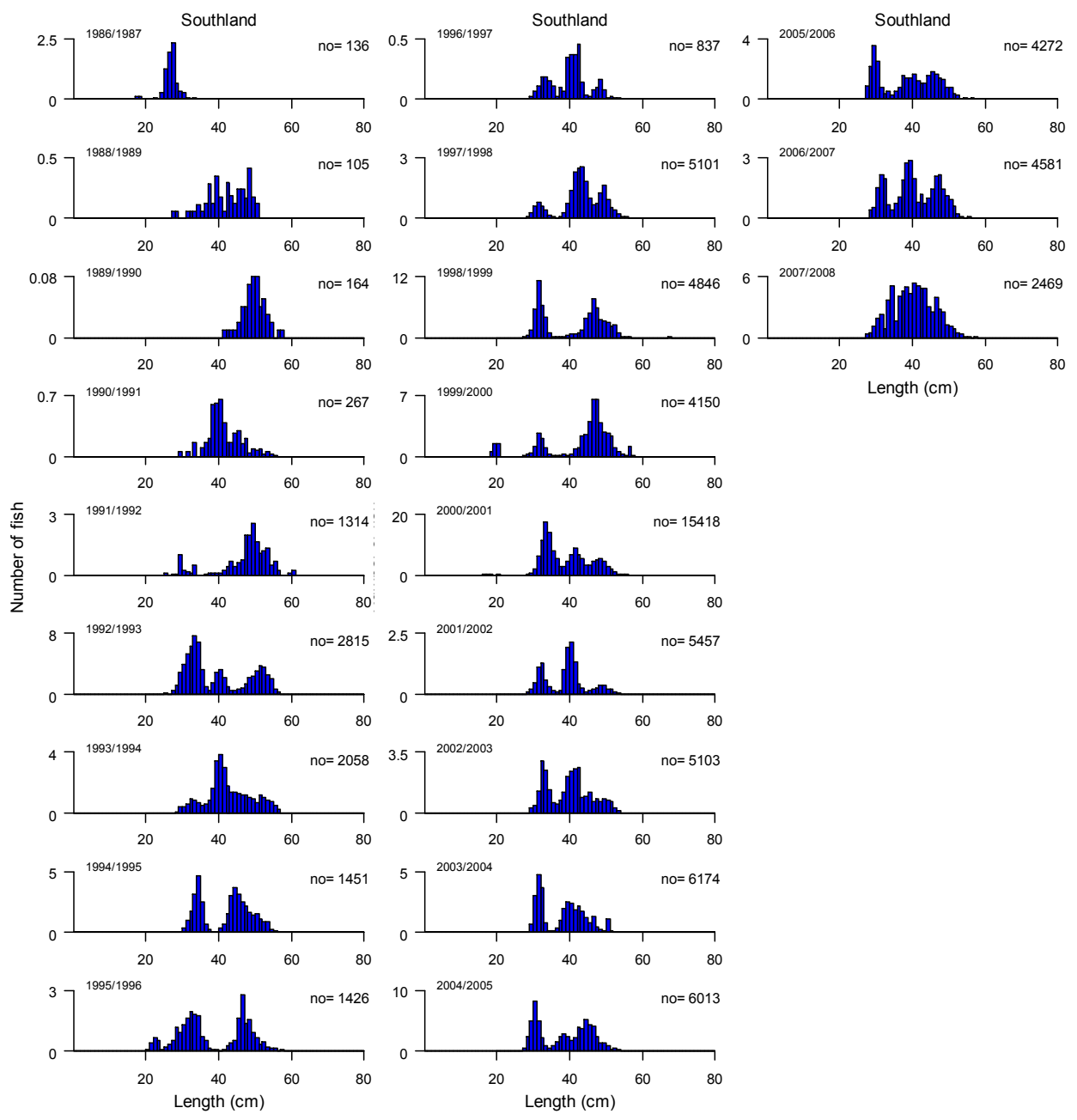
**Figure 11: Scaled length frequency distributions for each bottom trawl surveys of SOUTHLAND (sub-Antarctic) and west coast of the South Island since 1992.**



**Figure 12: Scaled length frequency distributions of silver warehou sampled by the scientific observer programme since 1985 on the CHATHAM RISE.**

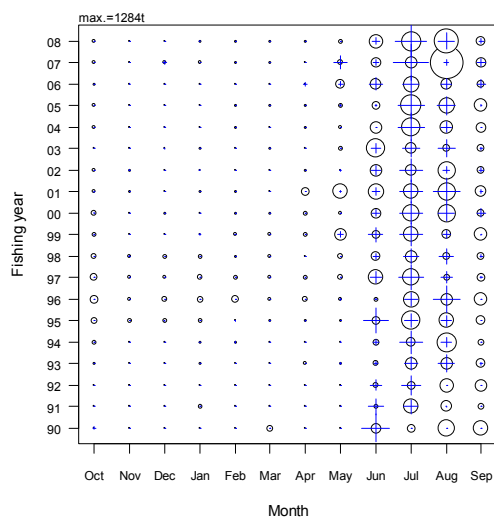
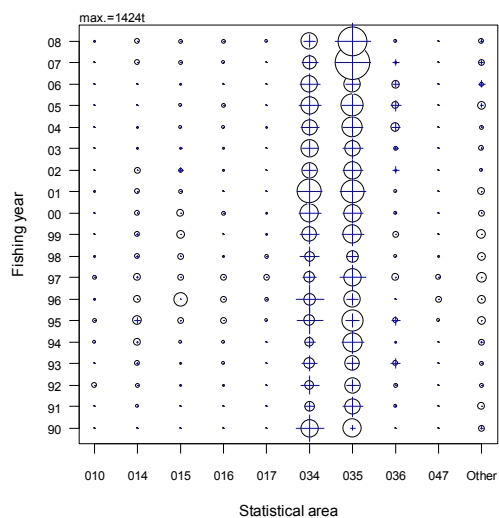


**Figure 13: Scaled length frequency distributions of silver warehou sampled by the scientific observer programme since 1985 on the EAST COAST SOUTH ISLAND.**

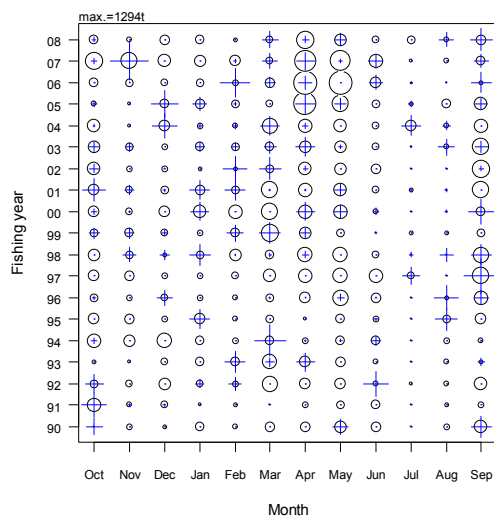
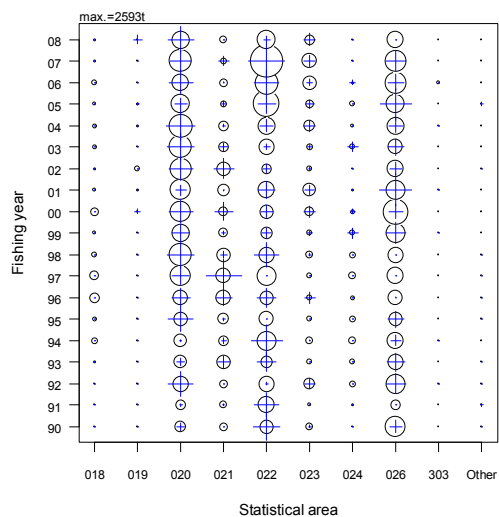


**Figure 14: Scaled length frequency distributions of silver warehou sampled by the scientific observer programme since 1985 in SOUTHLAND.**

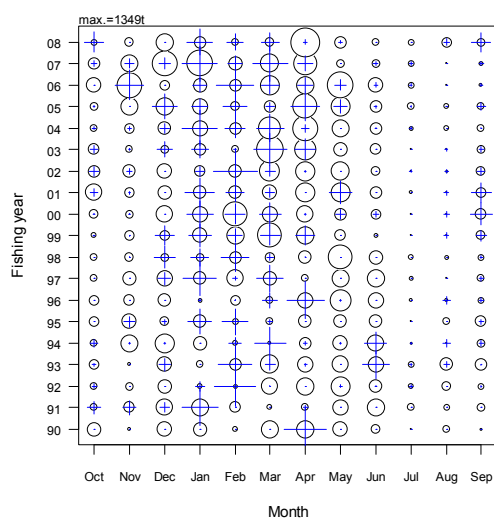
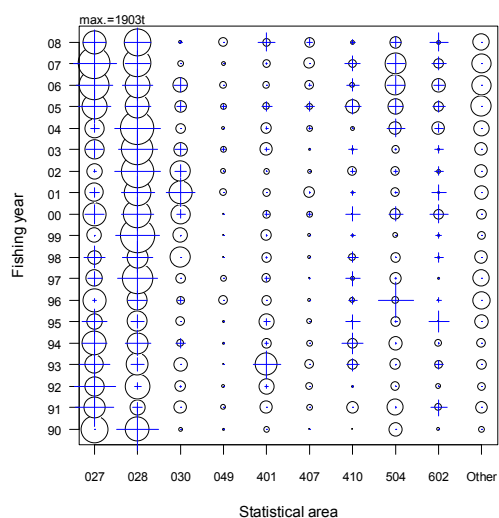
SWA 1



SWA 3



SWA 4



**Figure 15: Representativeness of observer sampling of SWA catch by QMA. Circles show the proportion of catch in for each year and statistical area [left panels] or month [right panels]. Crosses indicate the proportion of observed catch for the same cells. Perfect representation is demonstrated if the cross matches the circle diameter.**

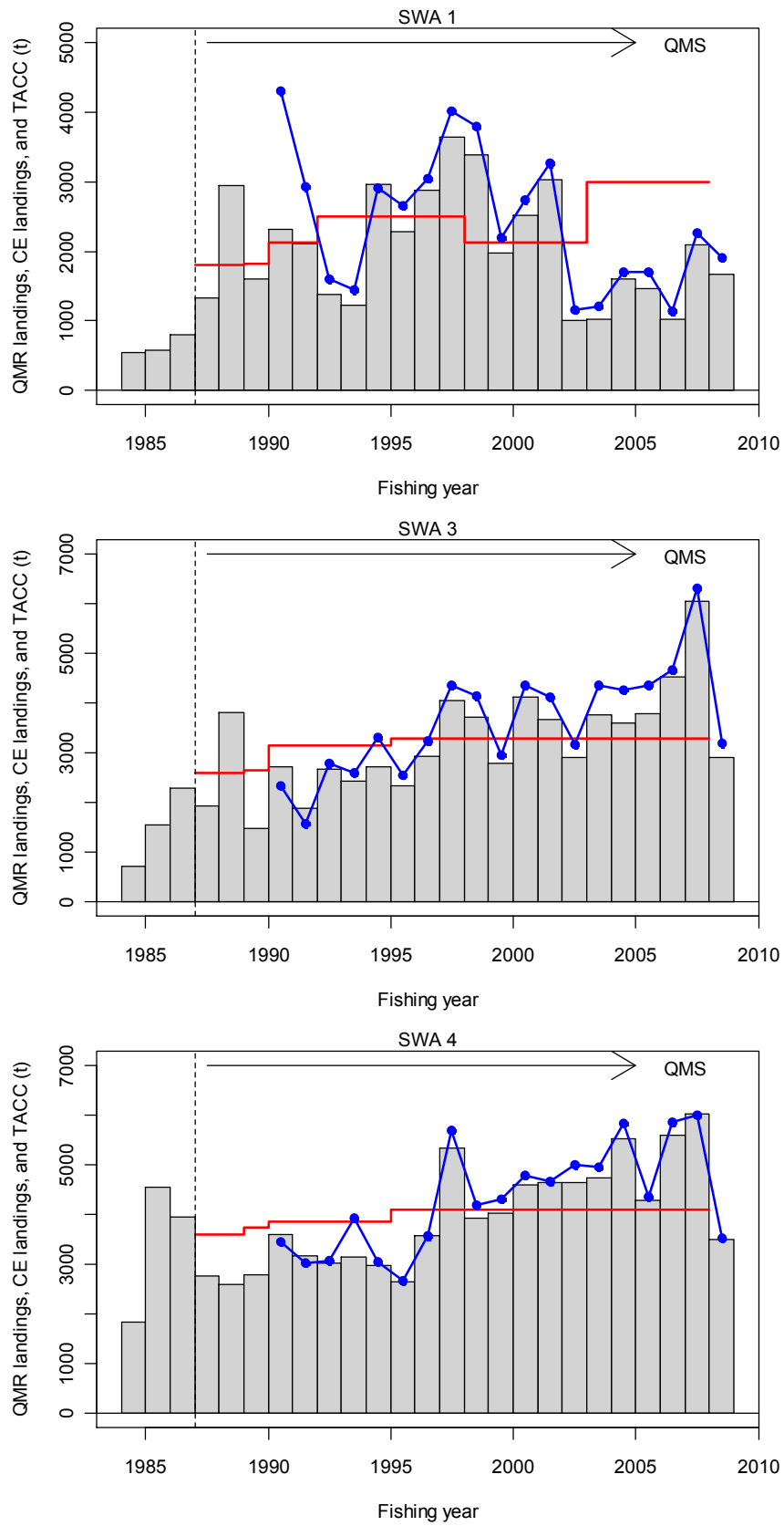
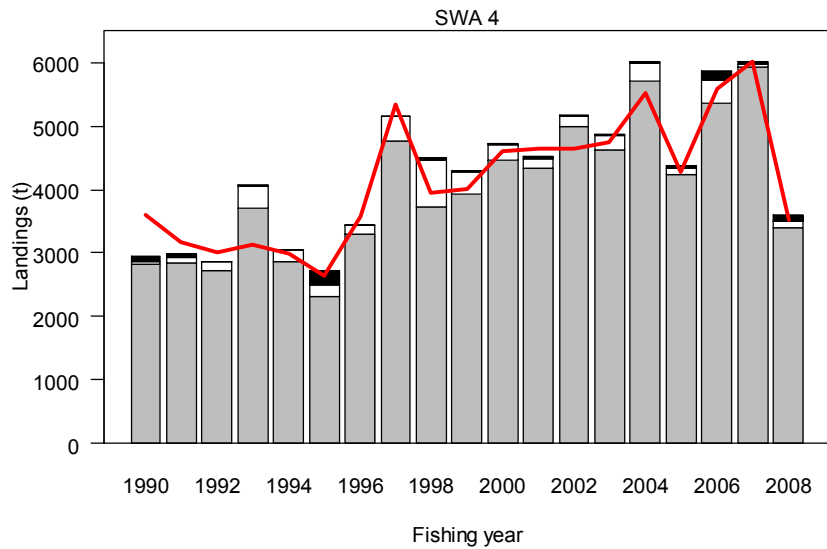
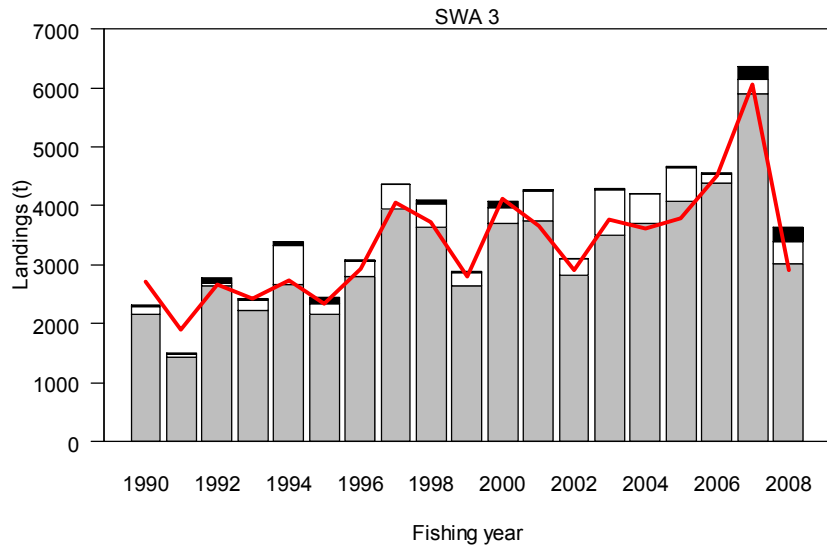
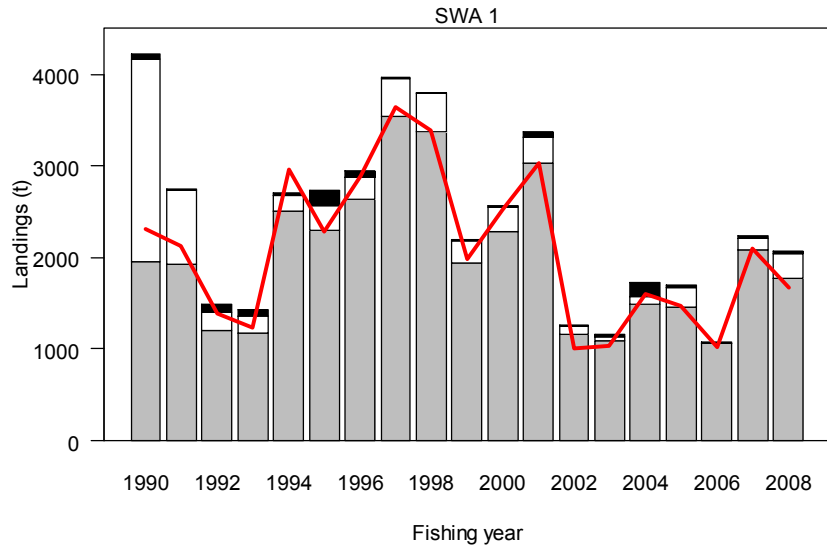


Figure 16: The QMR/MHR landings (gray bars), un-groomed catch effort landings (dotted blue line), and TACC (red line) for SWA 1, 3, and 4 from the 1983–84 to 2007–08 fishing year.



**Figure 17: The retained landings (gray bars), interim landings (white bars), and landings dropped during data grooming (black bars), and MHR landings (red line) for SWA 1, 3, and 4 from the 1989–90 to 2007–08 fishing year.**

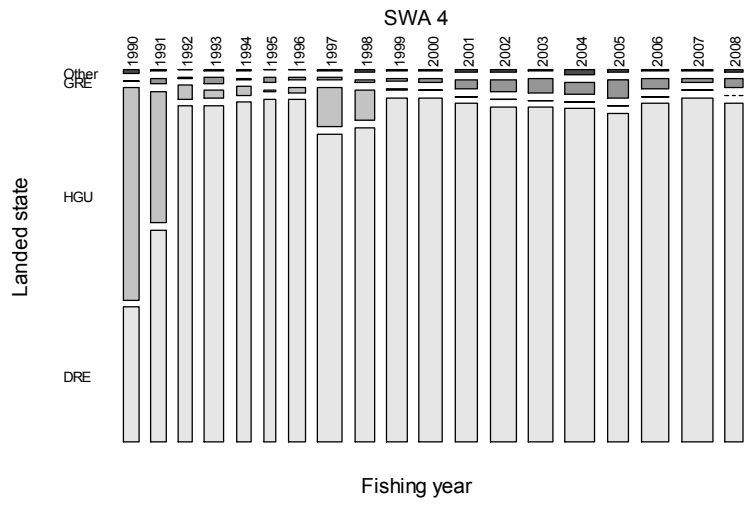
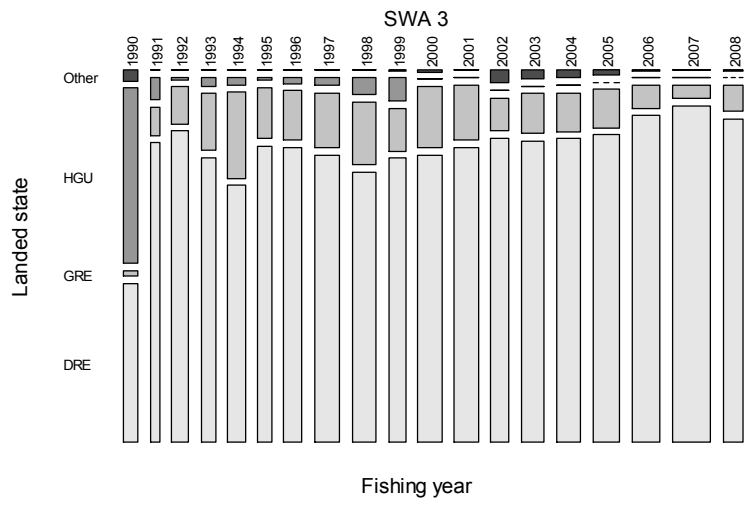
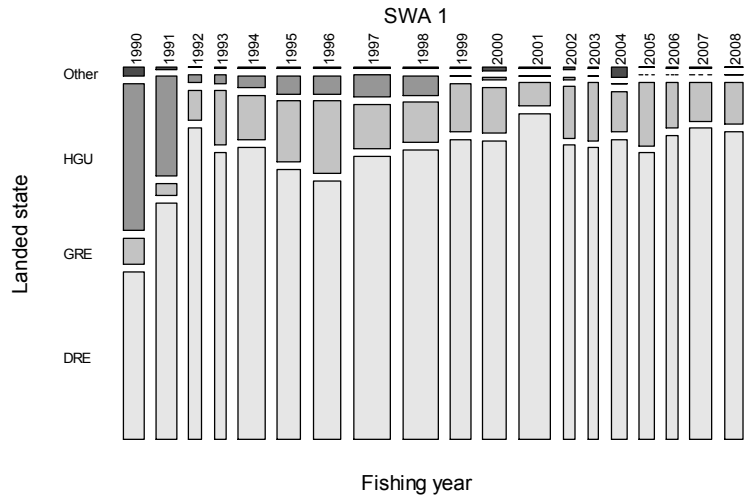
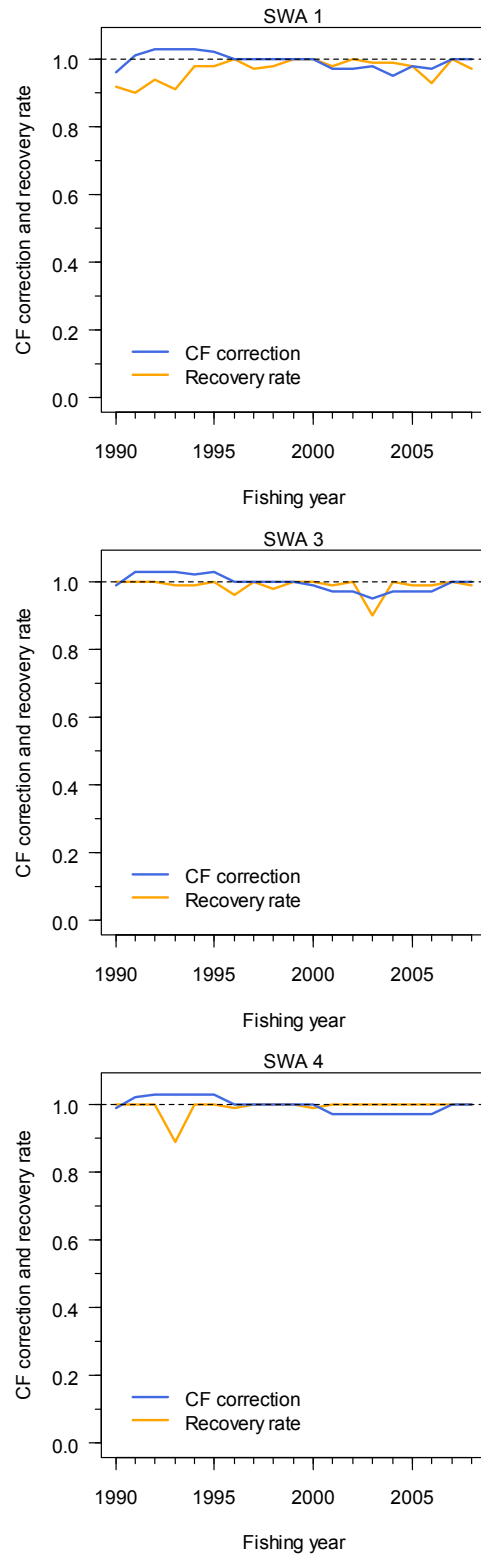
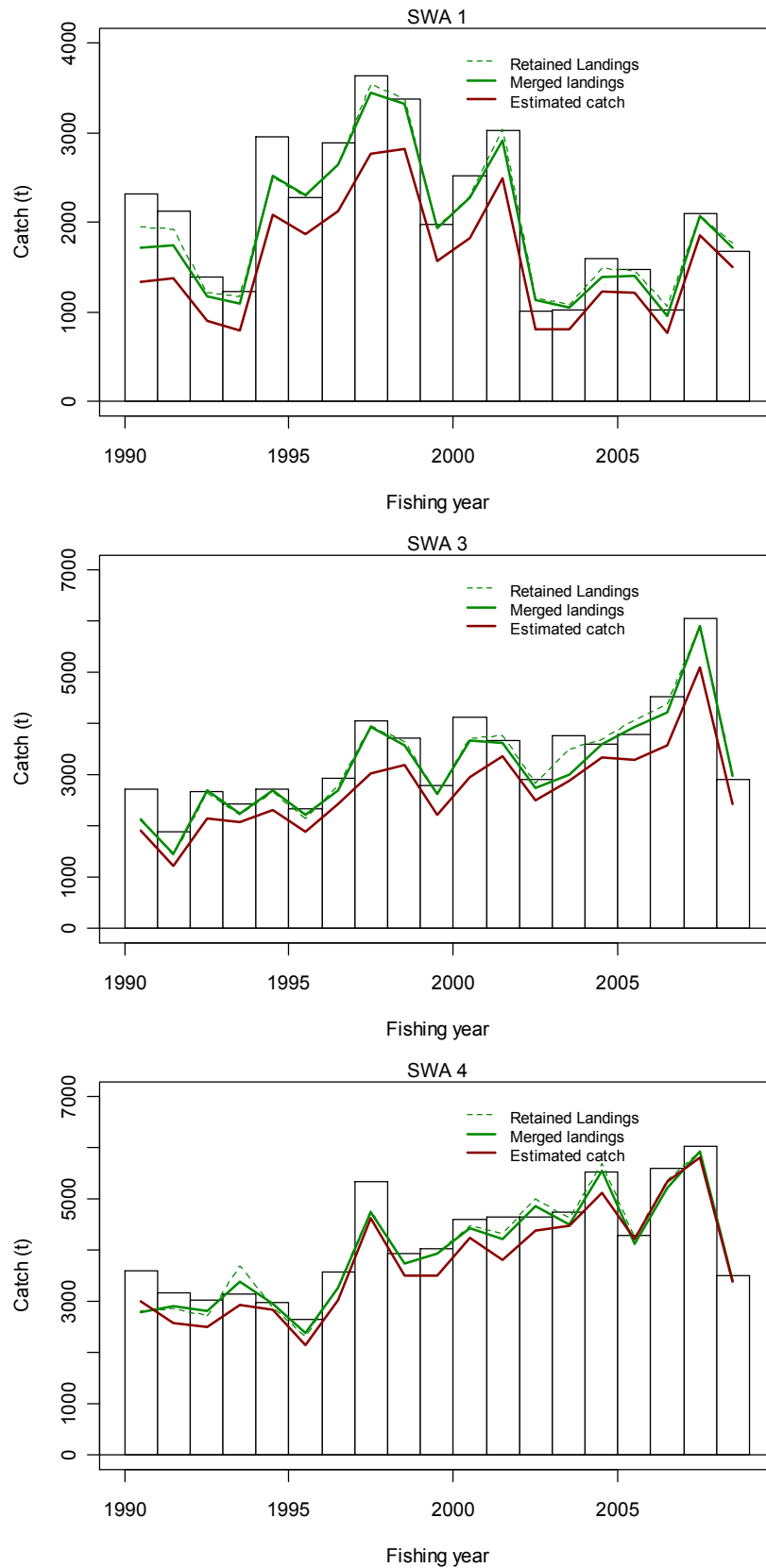


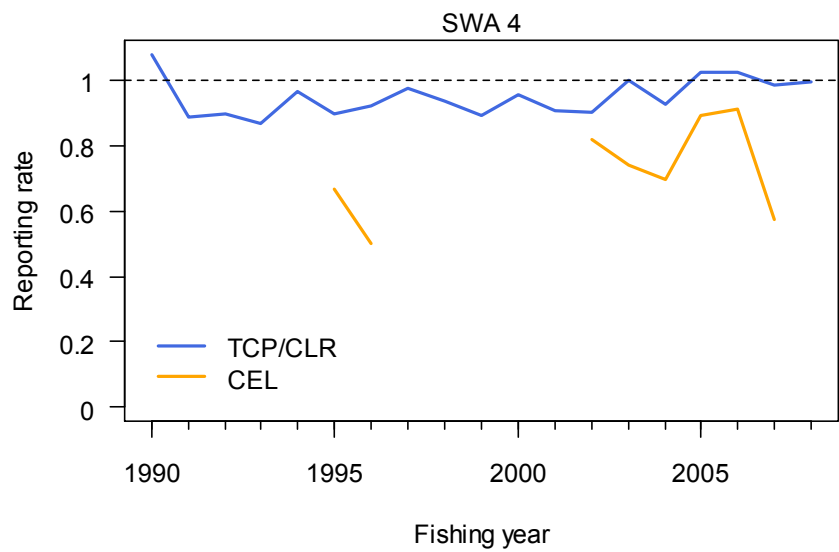
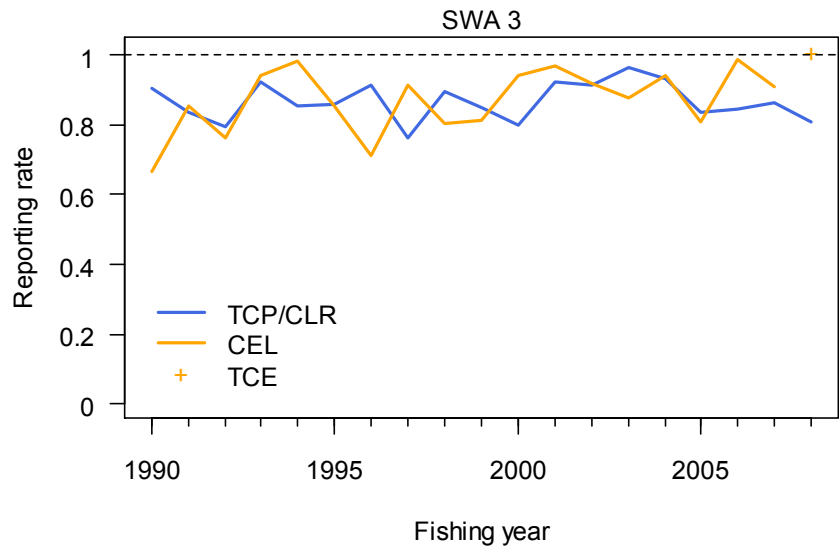
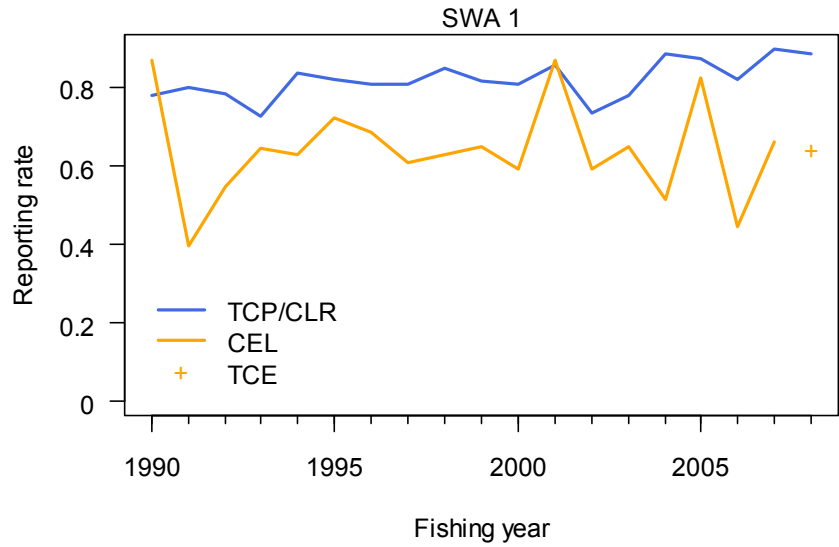
Figure 18: The proportion of retained landings (greenweight) by processed state for SWA 1, 3, and 4 from the 1989–90 to 2007–08 fishing year in the groomed and unmerged dataset. “DRE” includes “Dressed”, “Headed, gutted, and tailed”, and “trunked”; “GRE” refers to “Whole or Green”; “HGU” refers to “Headed and Gutted”



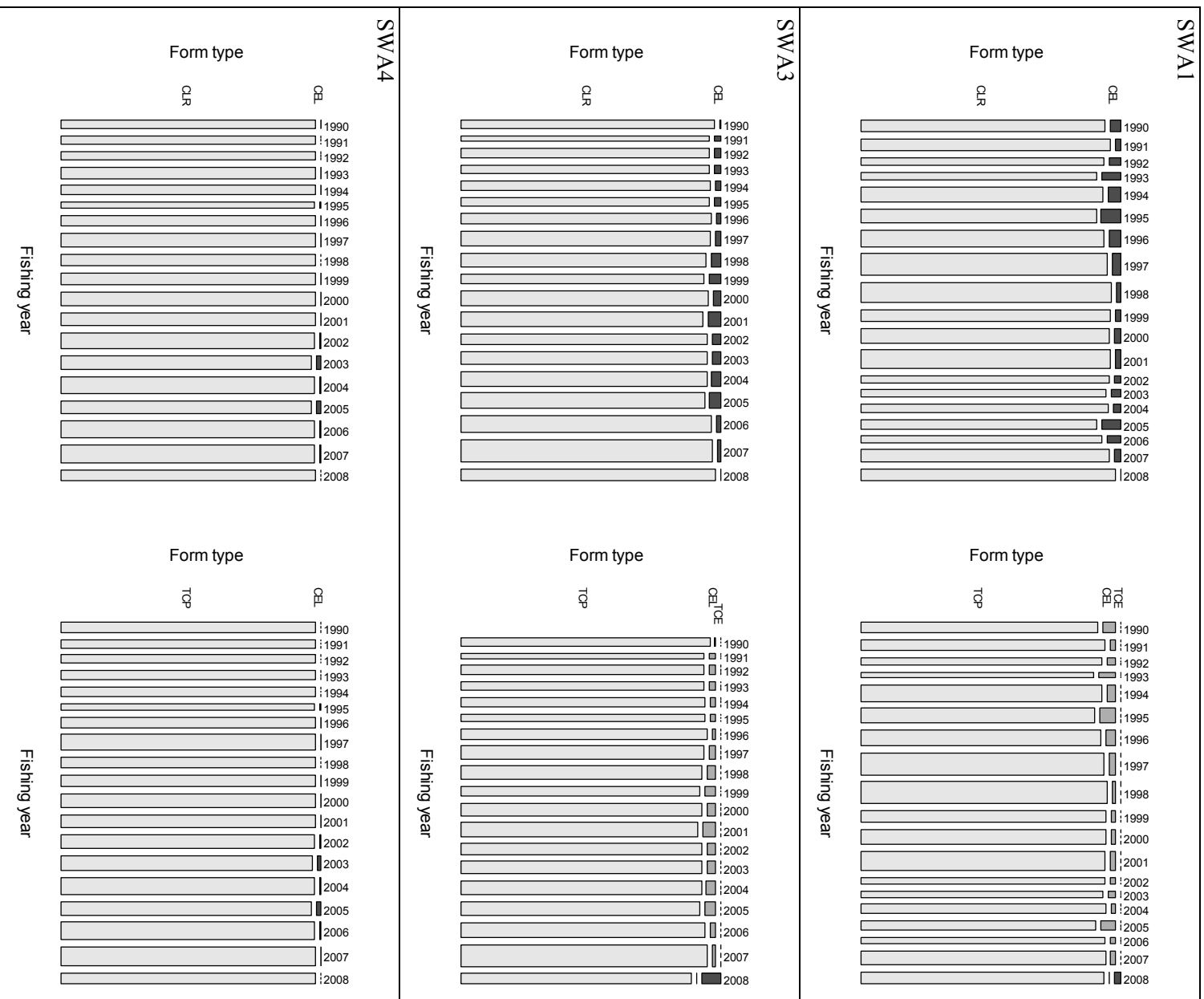
**Figure 19: The conversion factor (CF) corrections, defined as the ratio of annual green weight recalculated using the most recent correction factors for each processed state to the reported green weight, and the recovery rate, defined as the ratio of annual landings in the groomed and merged dataset to those in the groomed and unmerged dataset, for SWA 1, 3, and 4 from the 1989–90 to 2007–08 fishing years.**



**Figure 20: 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 estimated catch in the groomed and merged dataset (red solid line), for SWA 1, 3, and 4 from the 1983–84 to 2007–08 fishing years.**

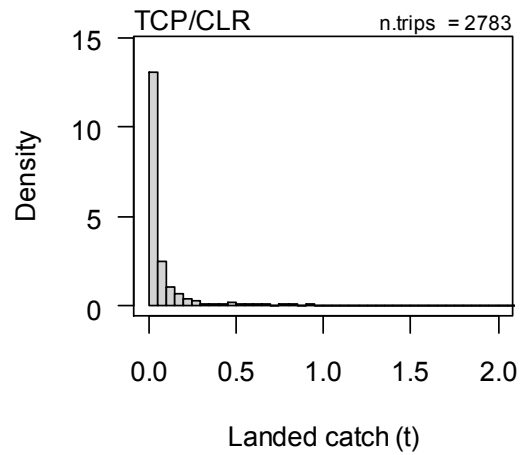
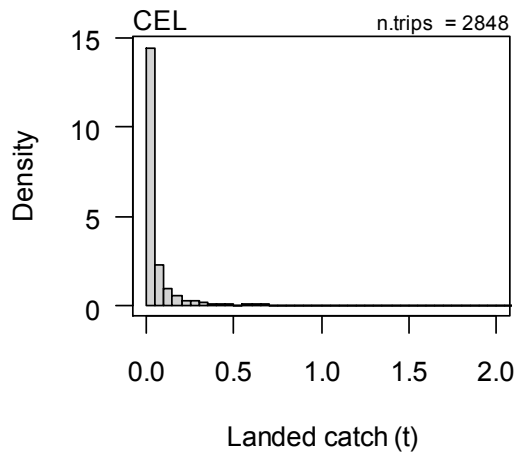


**Figure 21:** The reporting rate, defined as the ratio of estimated catch as a proportion of retained landings in the groomed and merged dataset, for SWA 1, 3, and 4 from the 1989–90 to 2007–08 fishing year. The reporting rates for SWA 1 and 3 were calculated by form type.

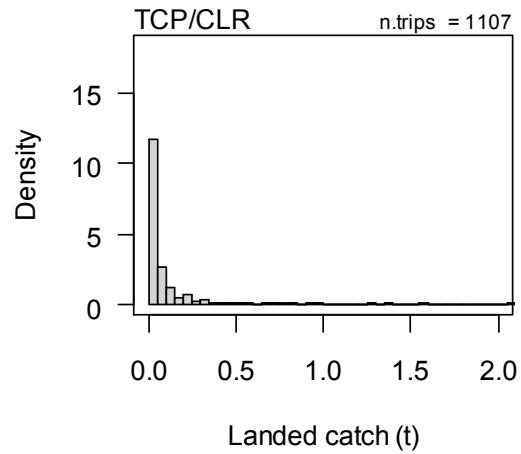
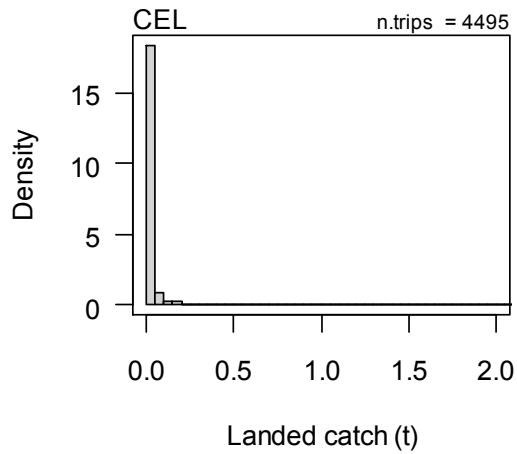


**Figure 22: Proportion of landings by form type (left panel) in the groomed and unmerged dataset, and proportion of estimated catches by form type (right panels) in the groomed and merged dataset, for SWA 1, 3, and 4 from 1989–90 to 2007–08 fishing year. The width of the bar is proportional to the annual catches (only comparable within each panel).**

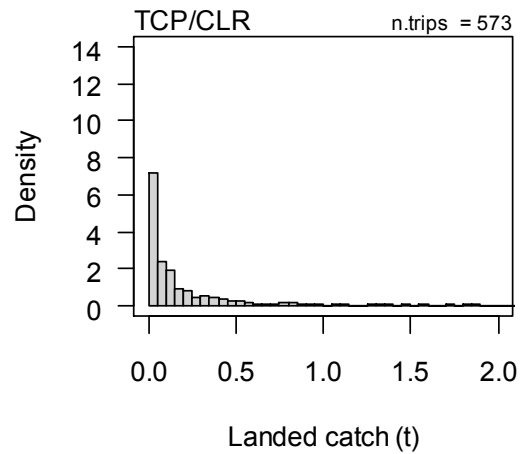
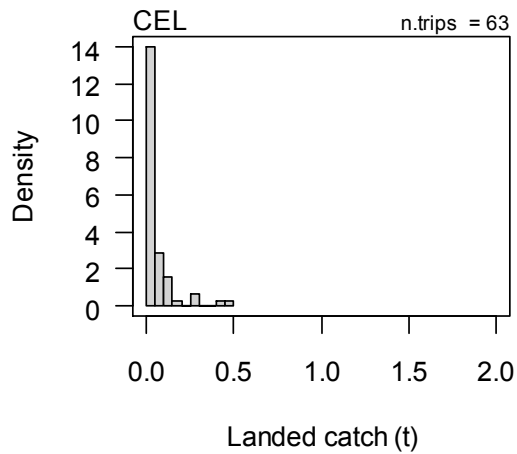
SWA1



SWA3

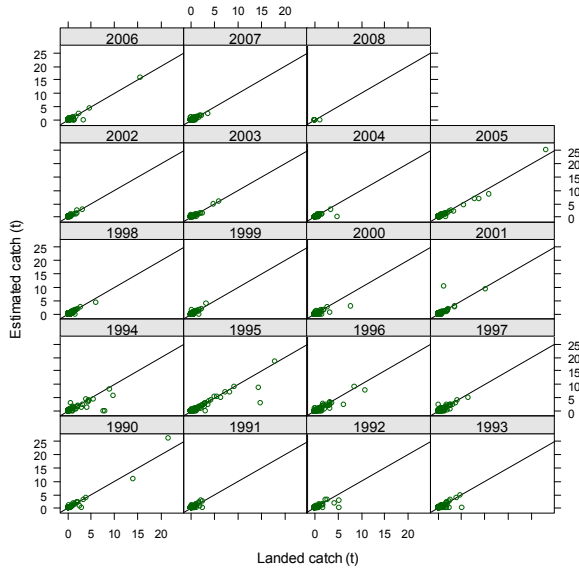


SWA4



**Figure 23: The distribution of reported landing weights for trips that recorded no estimated catch by form type for SWA 1, 3, and 4 from the 1989–90 to 2007–08 fishing years.**

CELR



TCEPR/CLR

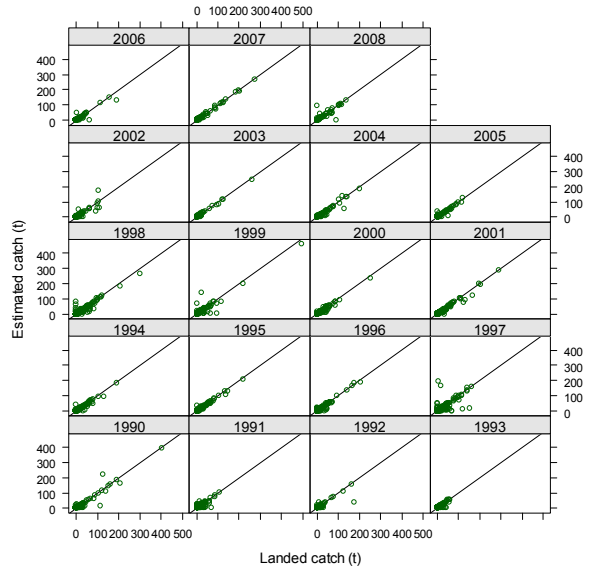
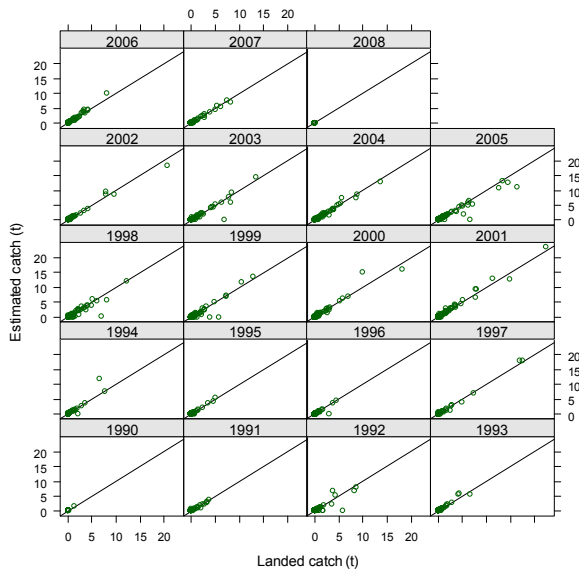


Figure 24: Estimated catches vs. reported landings on a trip basis in the groomed and merged dataset, for SWA 1 from the 1989–90 to 2007–08 fishing years.

CELR



TCEPR/CLR

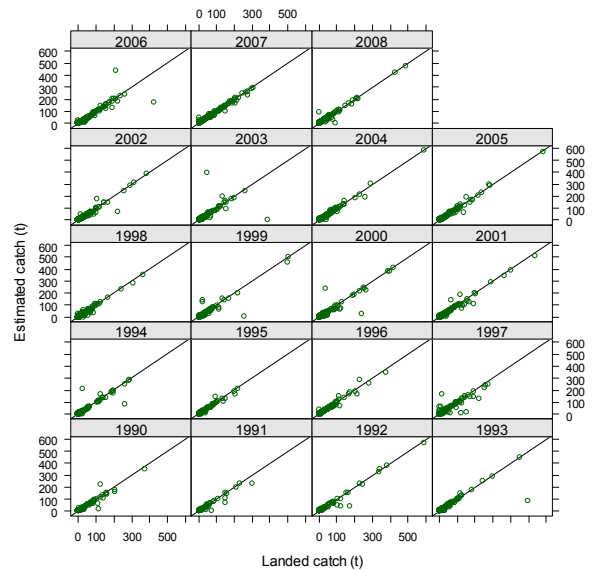
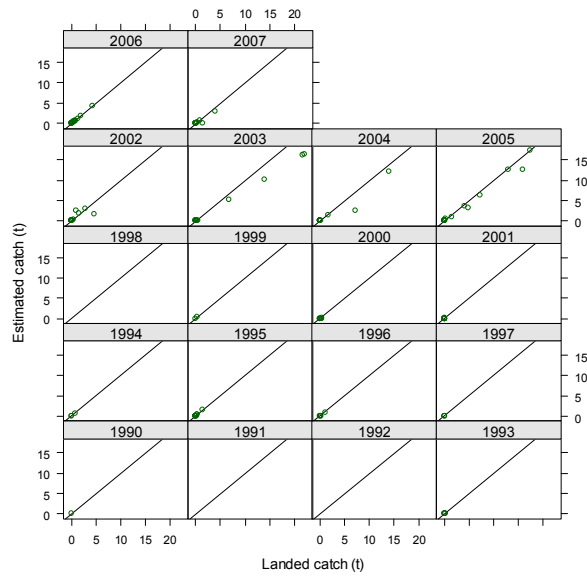
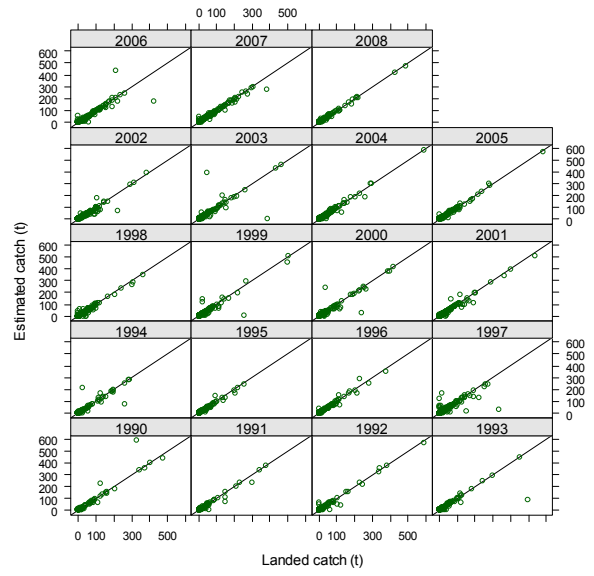


Figure 25: Estimated catches vs. reported landings on a trip basis in the groomed and merged dataset, for SWA 3 from the 1989–90 to 2007–08 fishing years.

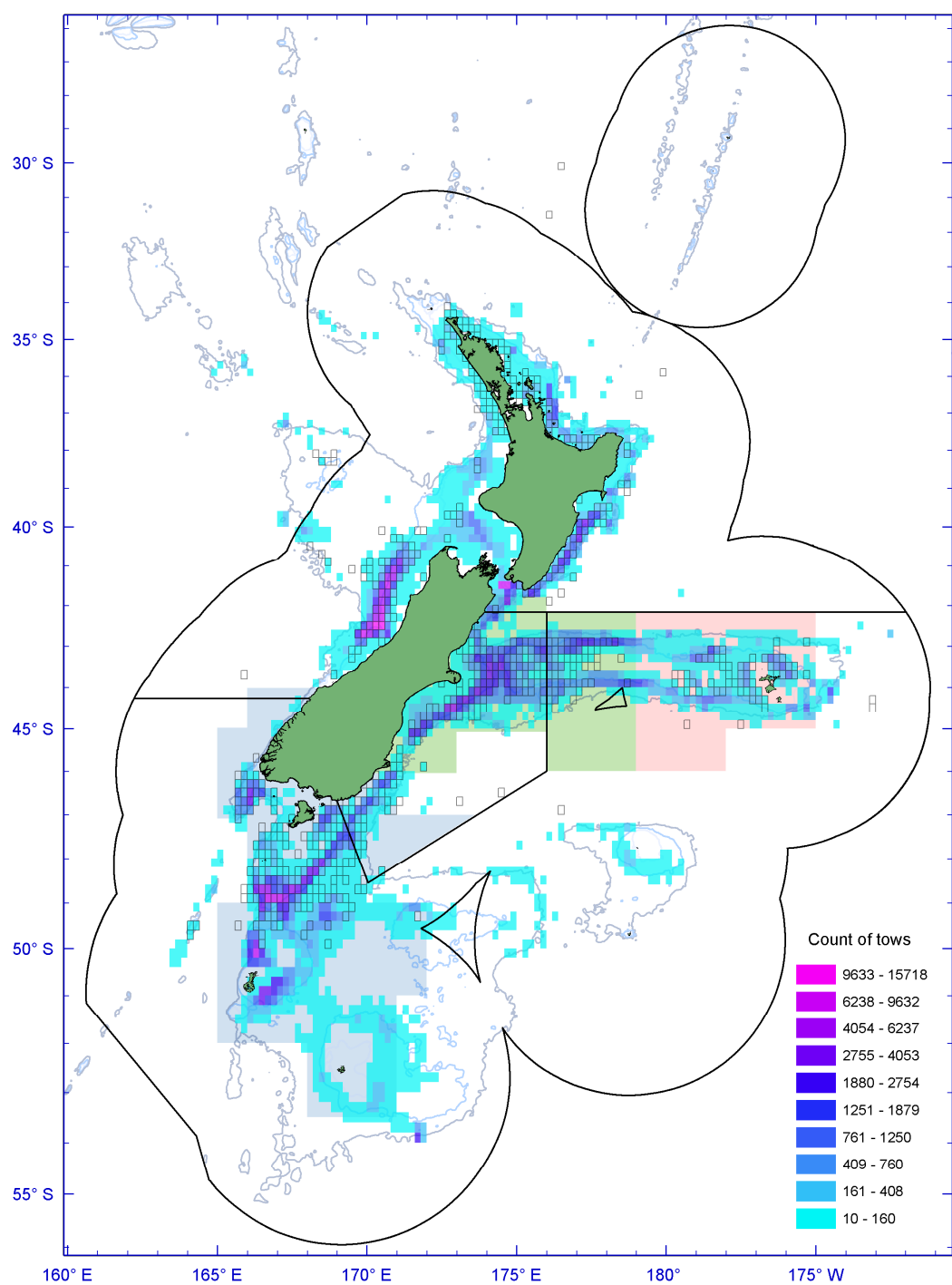
### CELR



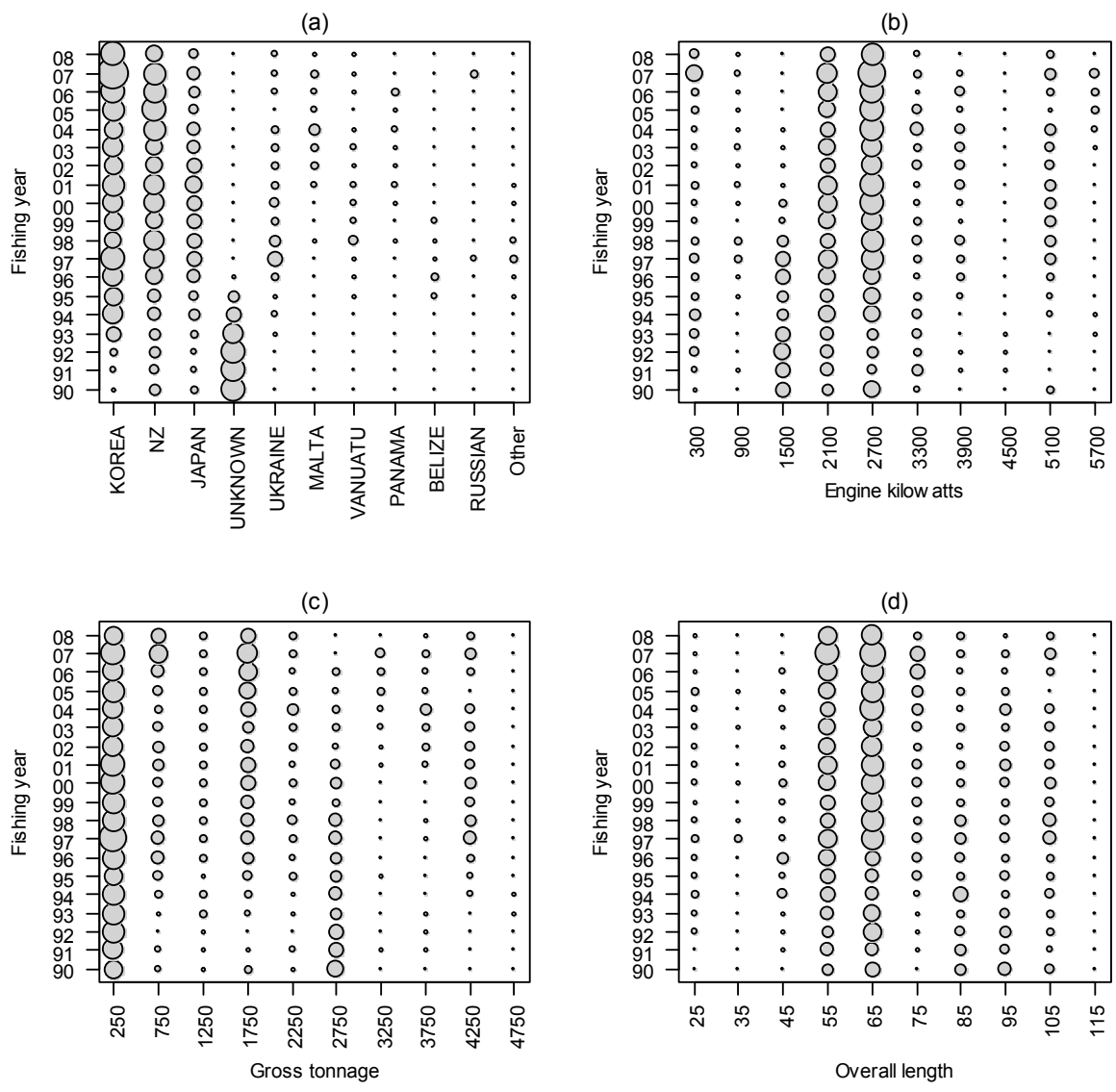
### TCEPR/CLR



**Figure 26: Estimated catches vs. reported landings on a trip basis in the groomed and merged dataset, for SWA 4 from the 1989–90 to 2007–08 fishing years.**



**Figure 27: Distribution of targeted silver warehou tows (outlined cells) and all tows from trips landing silver warehou (blue=low to pink =high) from TCEPR data separated into three regions of statistical areas for use in characterisation and CPUE analysis. Areas with little fishing effort (blue cells) omitted from the three shaded CPUE regions (e.g. Bounty plateau) did not report more than 1 t SWA catch since 1989 within the statistical area.**



$$8000 t = \pi \times [(1/2) \times (0.5 \text{ cm})]^2$$

**Figure 28: Distribution of annual catch by nationality, vessel power, gross tonnage, and length (m) for the three CPUE characterisation regions. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**

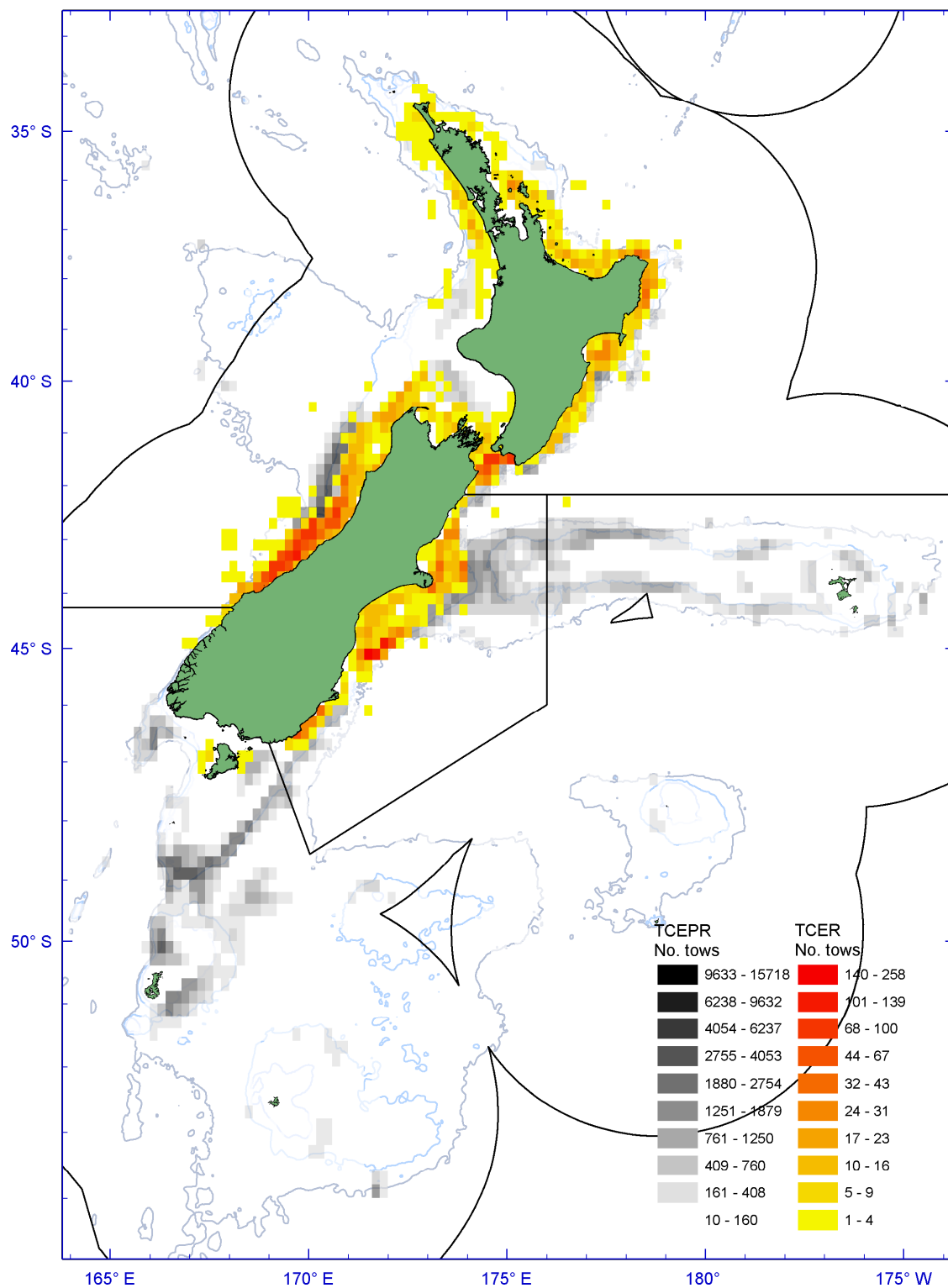
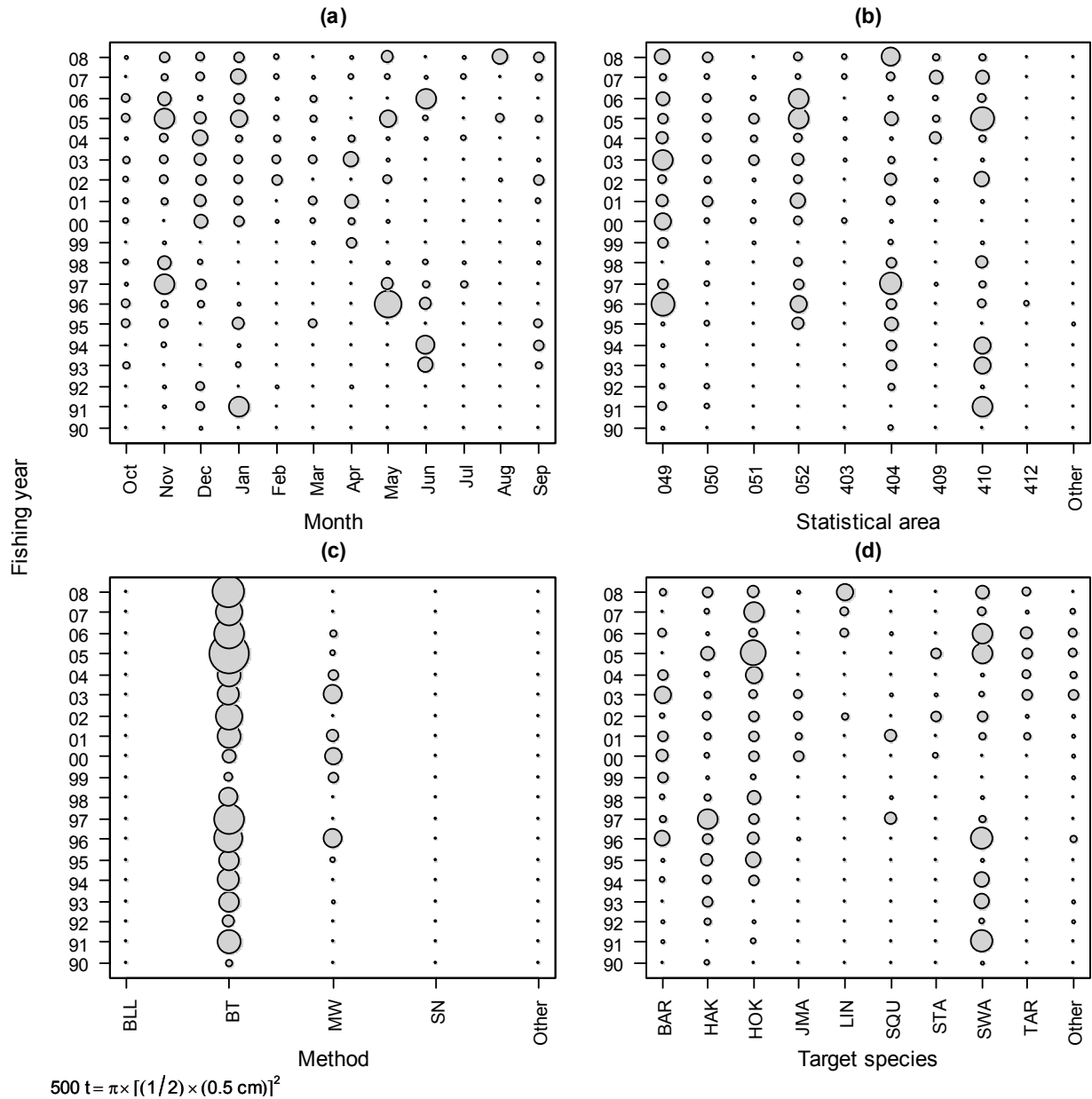
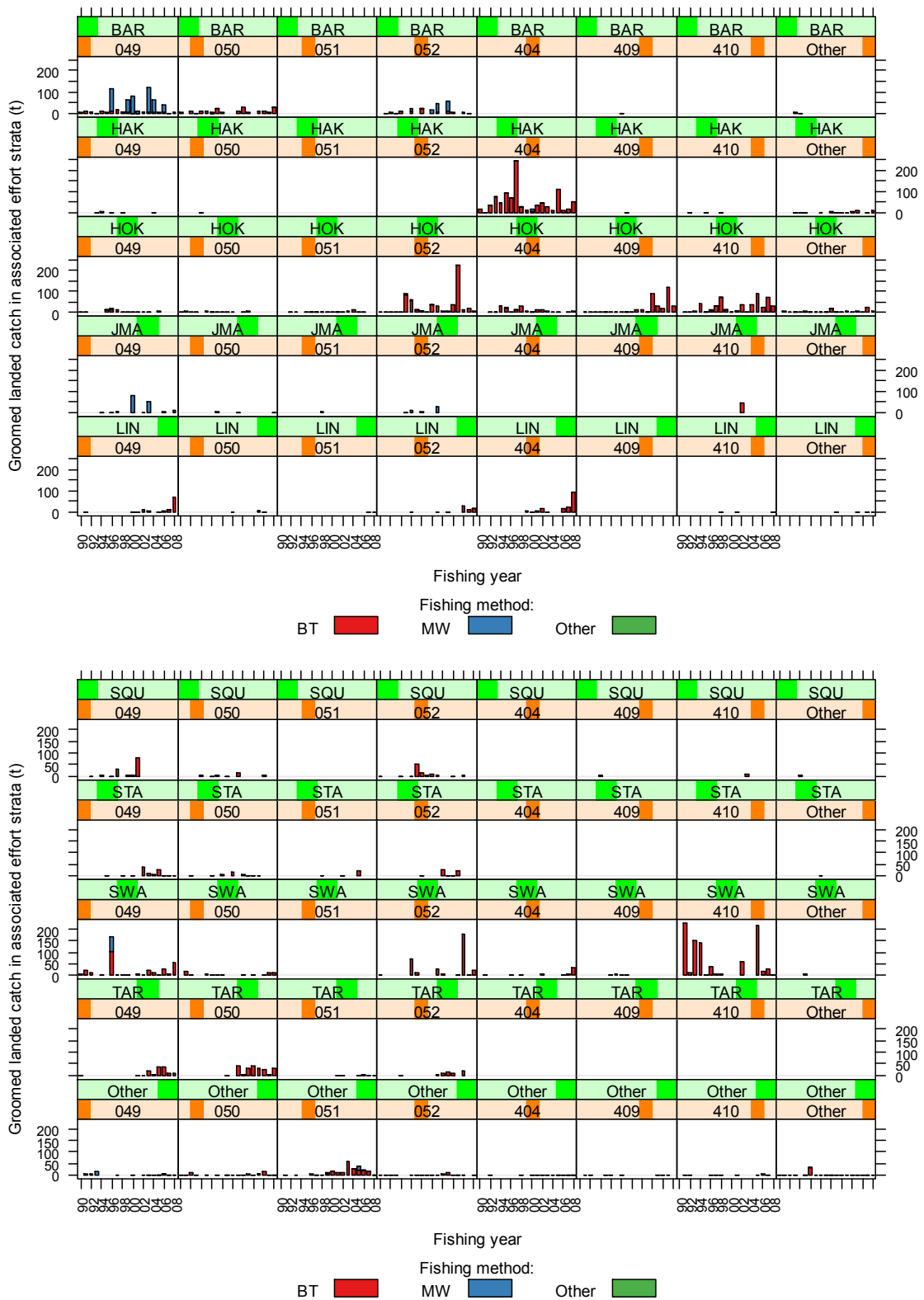


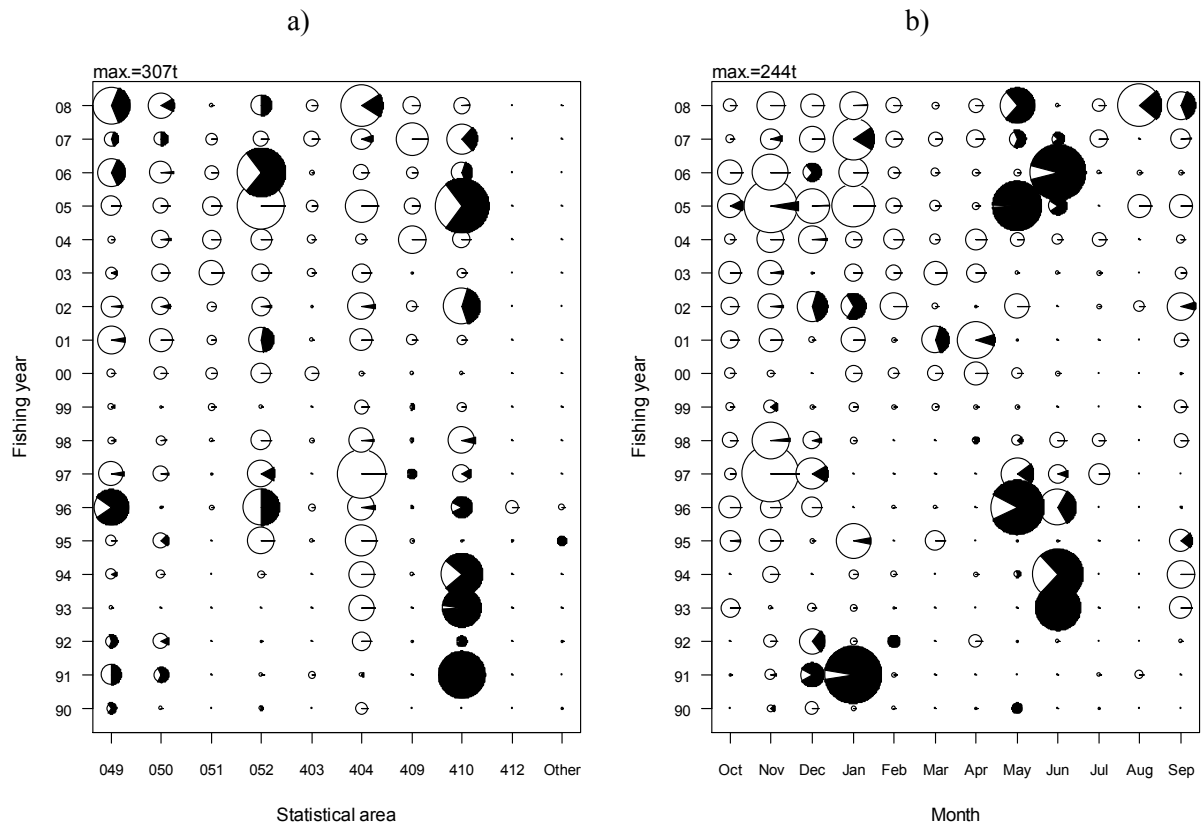
Figure 29: 2007–08 effort by vessels using the new TCER form (coloured cells) overlaid on total fishery (1990 to 2008) TCEPR form effort (grey cells). Effort is gridded into 0.2 degree cells.



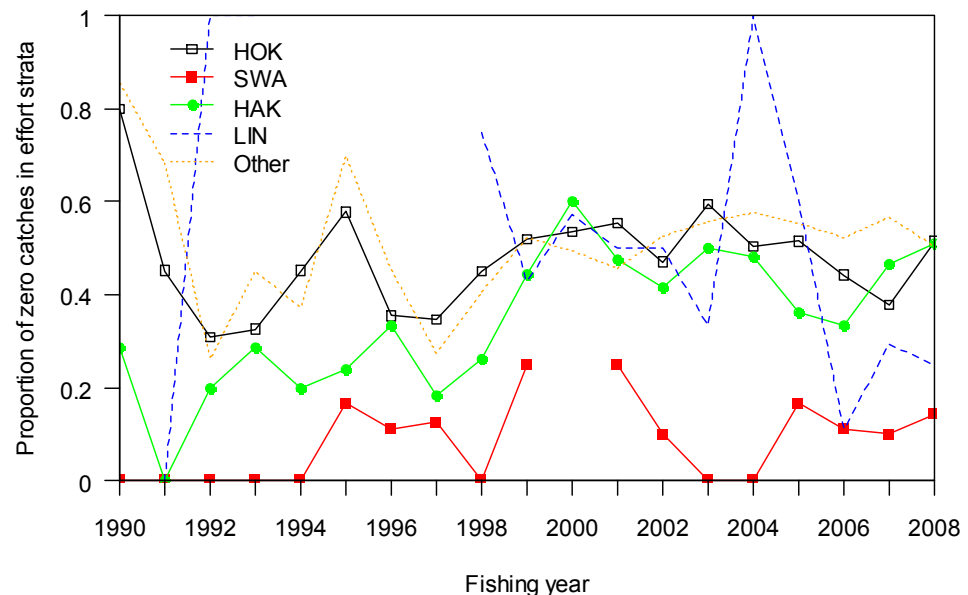
**Figure 30: Distribution of SWA catch in the CHATHAM RISE region (circle size is proportional to catch for 1990–2008 fishing years in relation to a) month, b) statistical area, c) fishing method, and d) target species. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**



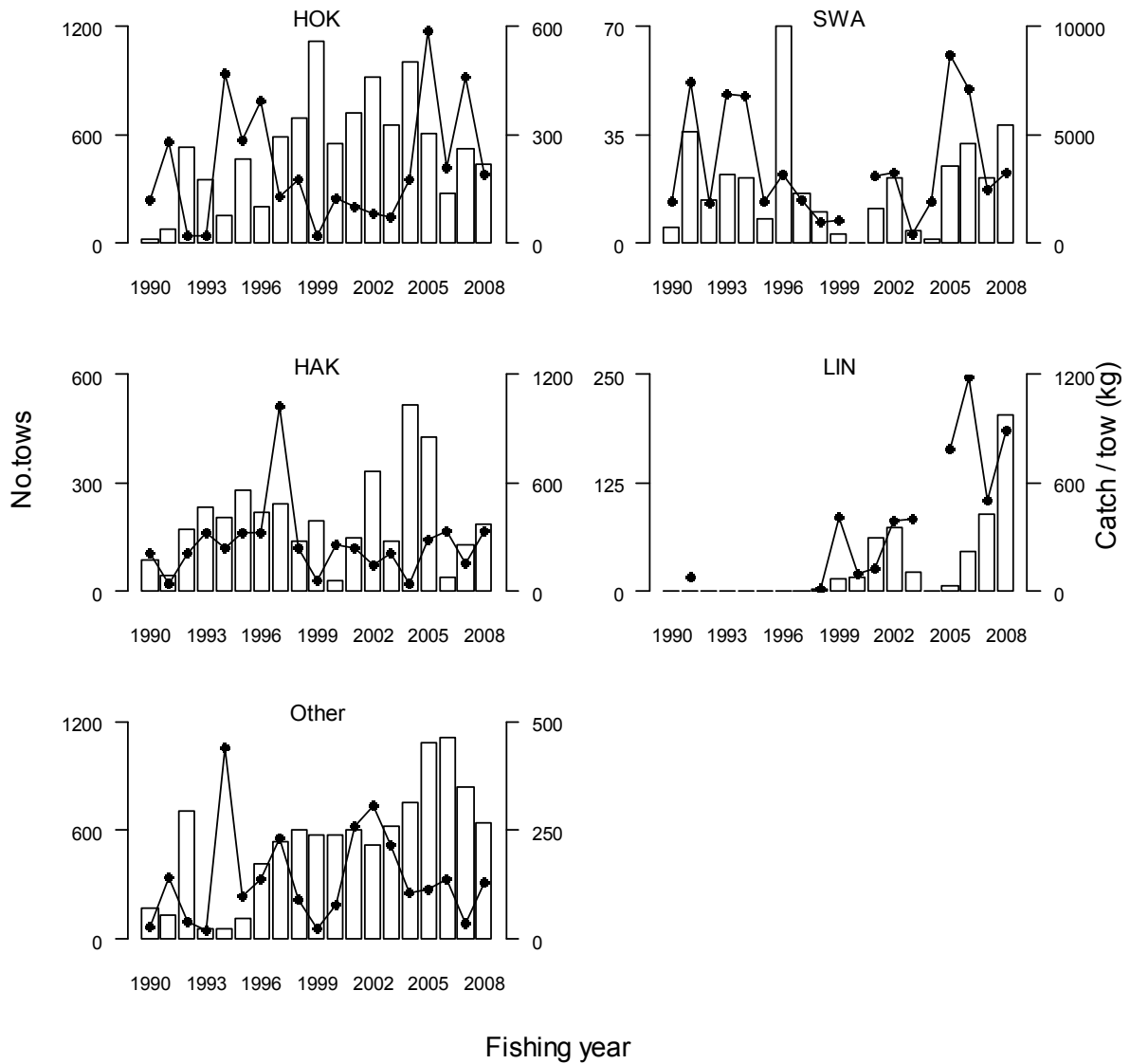
**Figure 31: Distribution of SWA catch in the CHATHAM RISE region in relation to target species and statistical area by fishing method for fishing years 1990–2008.**



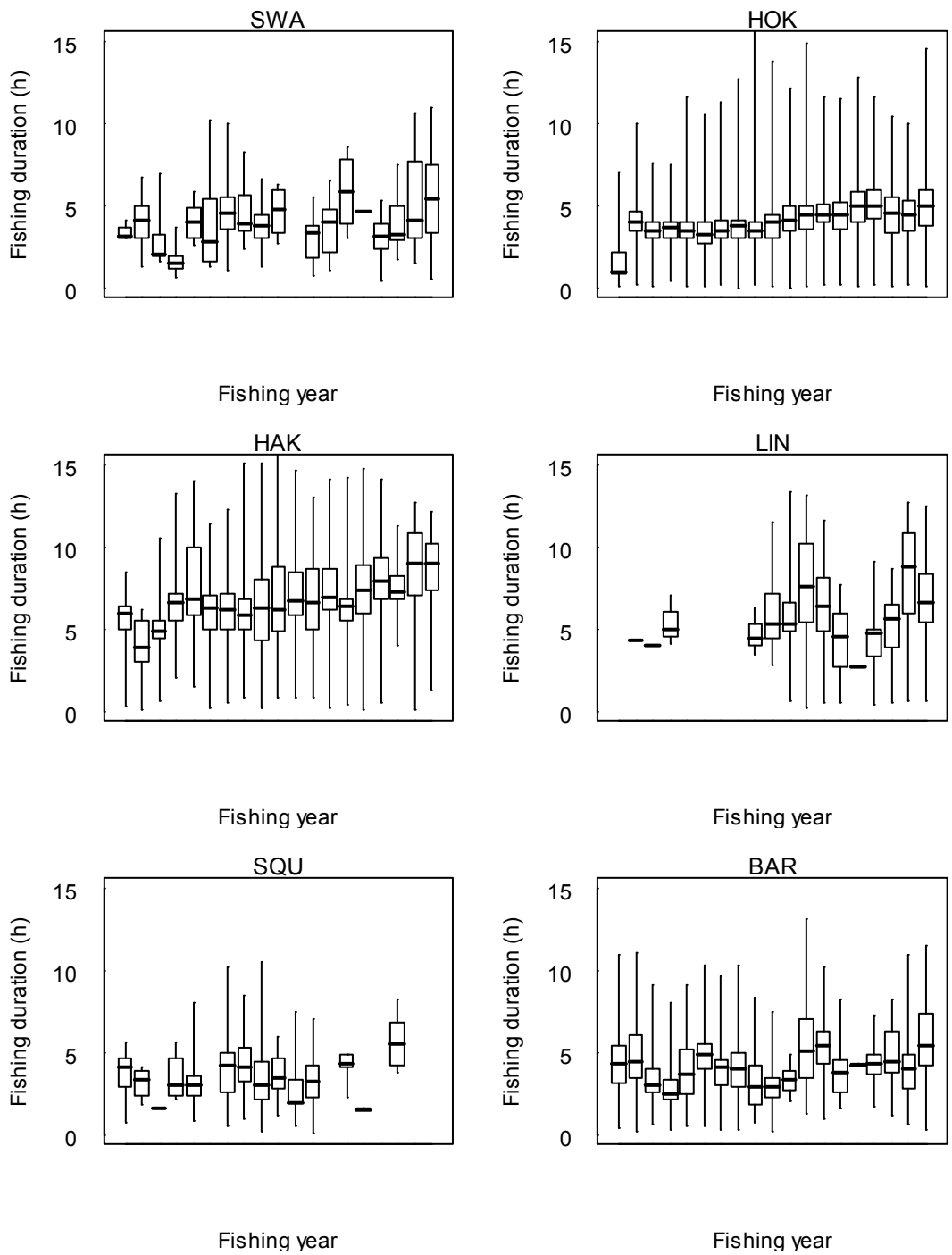
**Figure 32: Distribution of SWA catch by fishing year with circle size proportional to the total catch and black portion of the pie indicating proportion of the catch as targeted SWA by a) statistical area and b) month for the CHATHAM RISE region.**



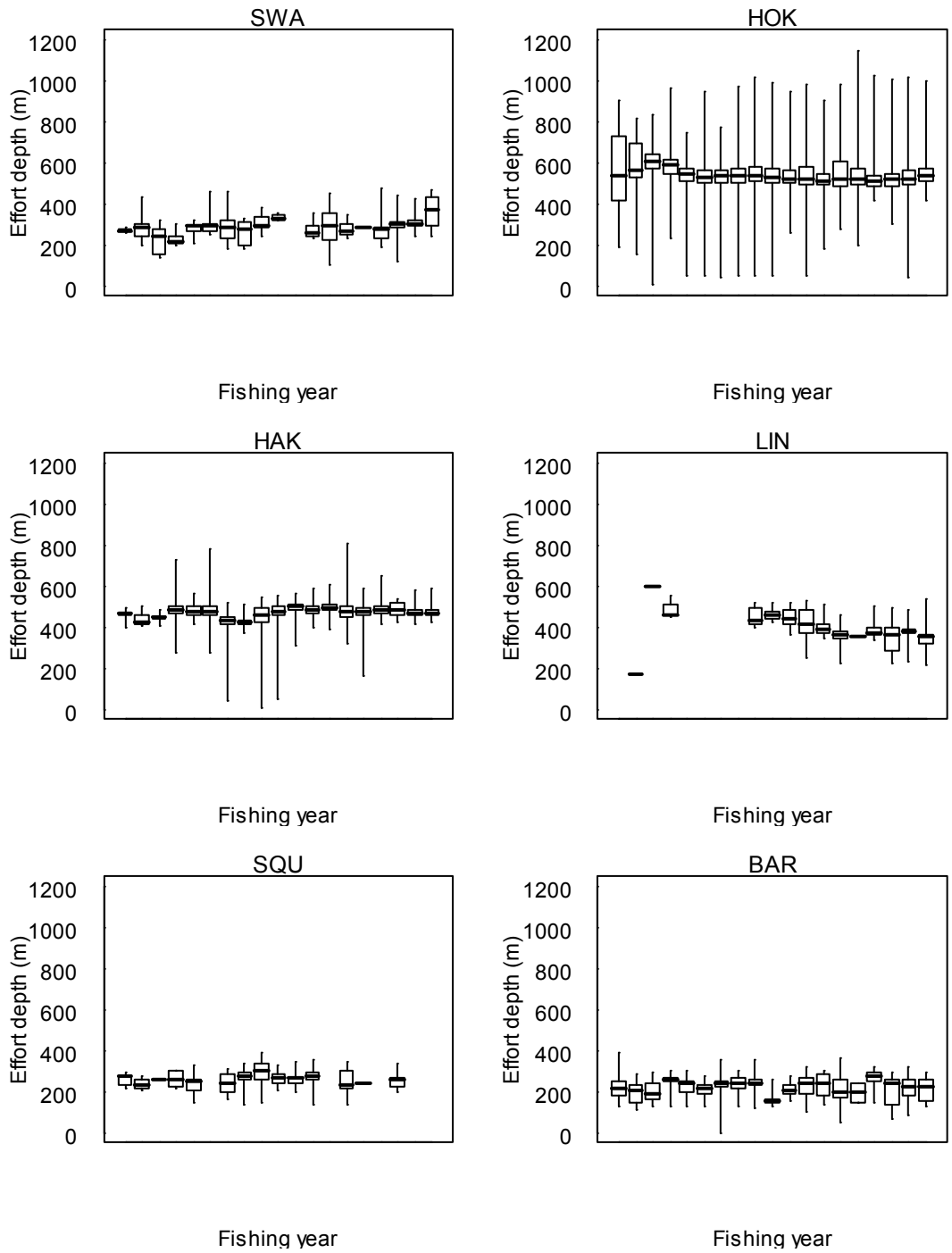
**Figure 33: Proportion of tows with zero reported SWA catch for major target species for the CHATHAM RISE region.**



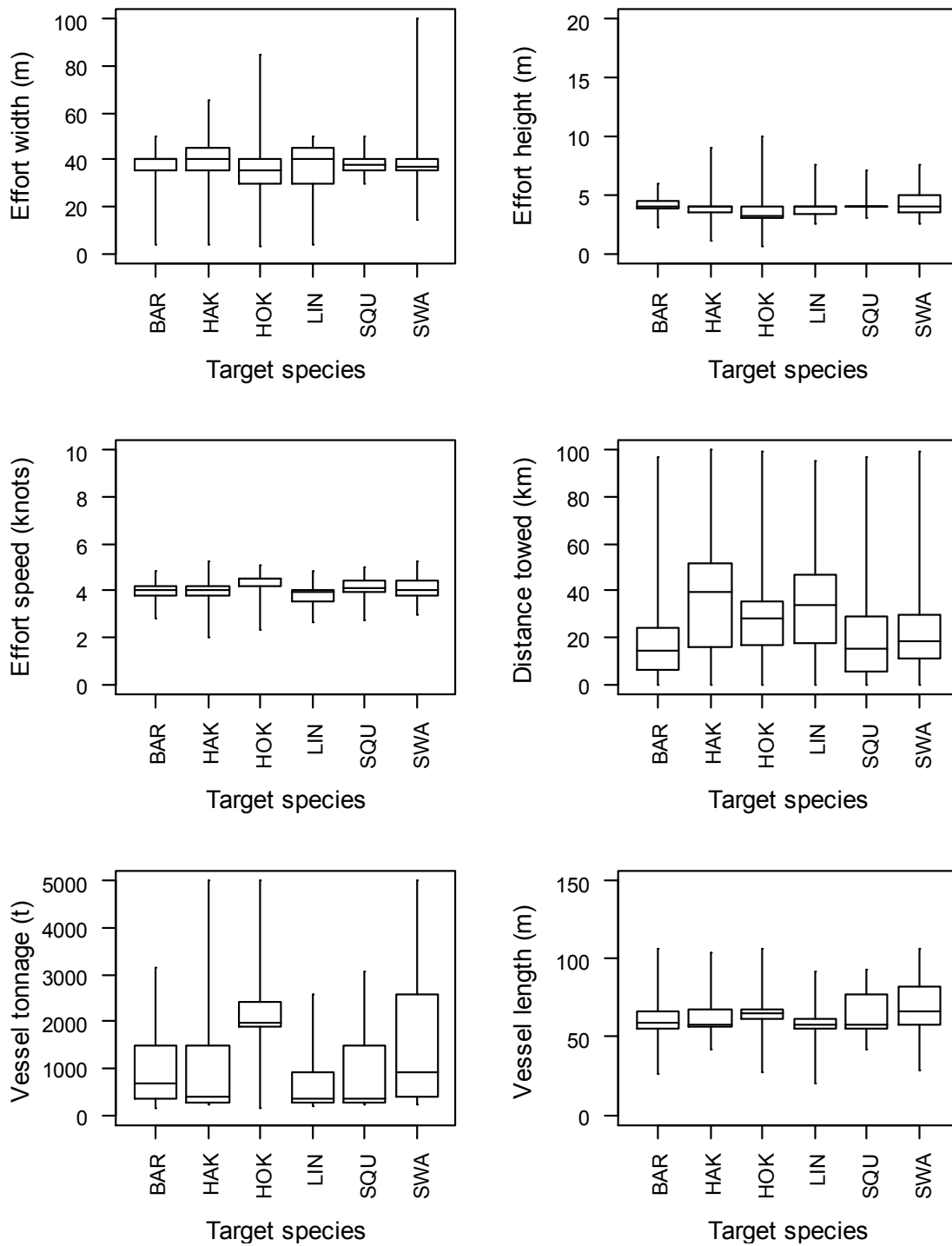
**Figure 34: Annual catch rate of silver warehou for various target species tows in kg silver warehou (catch/tow) and the number of tows for the CHATHAM RISE region.**



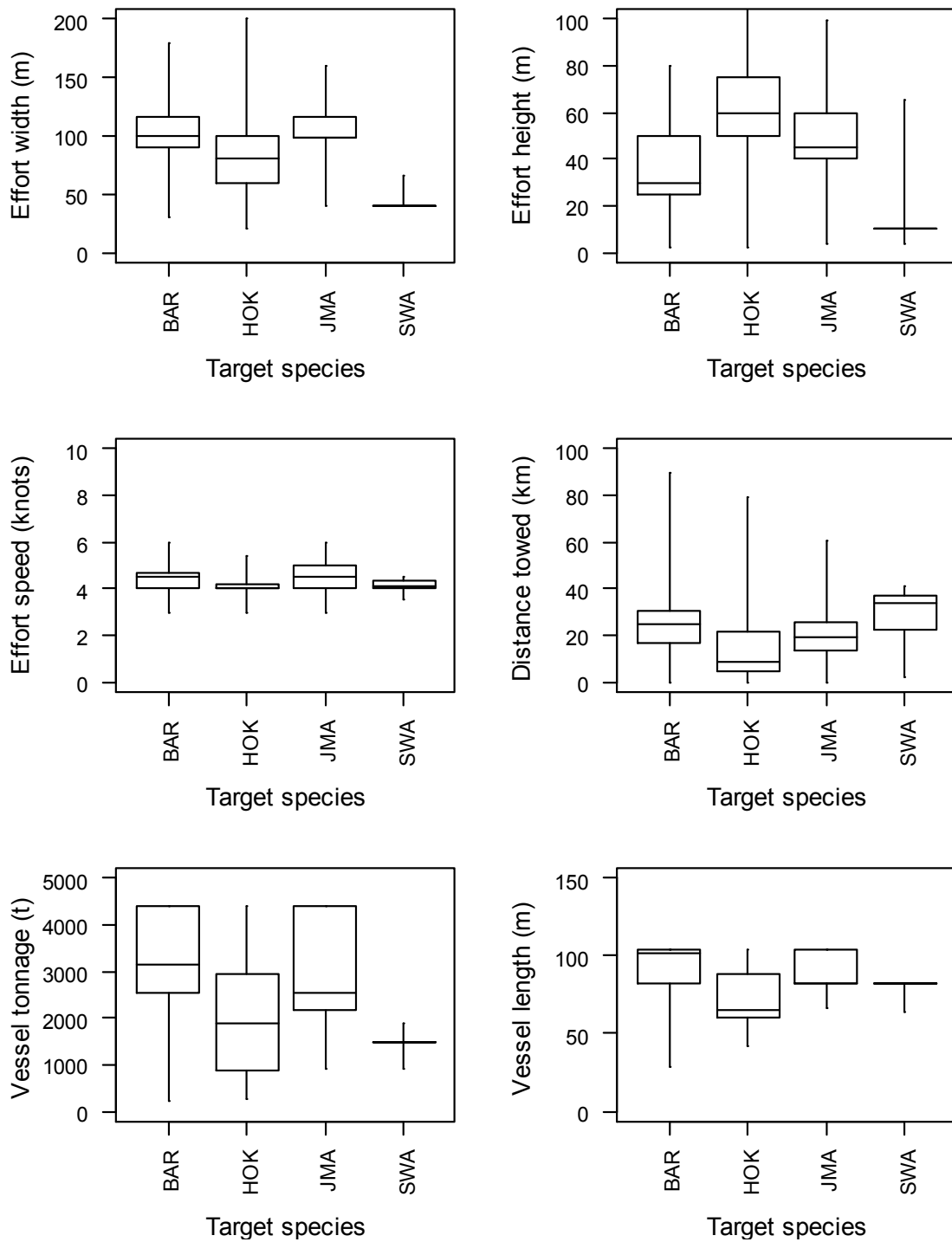
**Figure 35: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for tow durations reported for various target species capturing SWA in the CHATHAM RISE region.**



**Figure 36: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for various target species capturing SWA in the CHATHAM RISE region.**



**Figure 37: Distribution of fishing effort variables and vessel characteristics for the CHATHAM RISE area for four major target species taken by bottom trawl gear.**



**Figure 38: Distribution of fishing effort variables and vessel characteristics for the CHATHAM RISE area for four major target species taken by midwater trawl gear.**

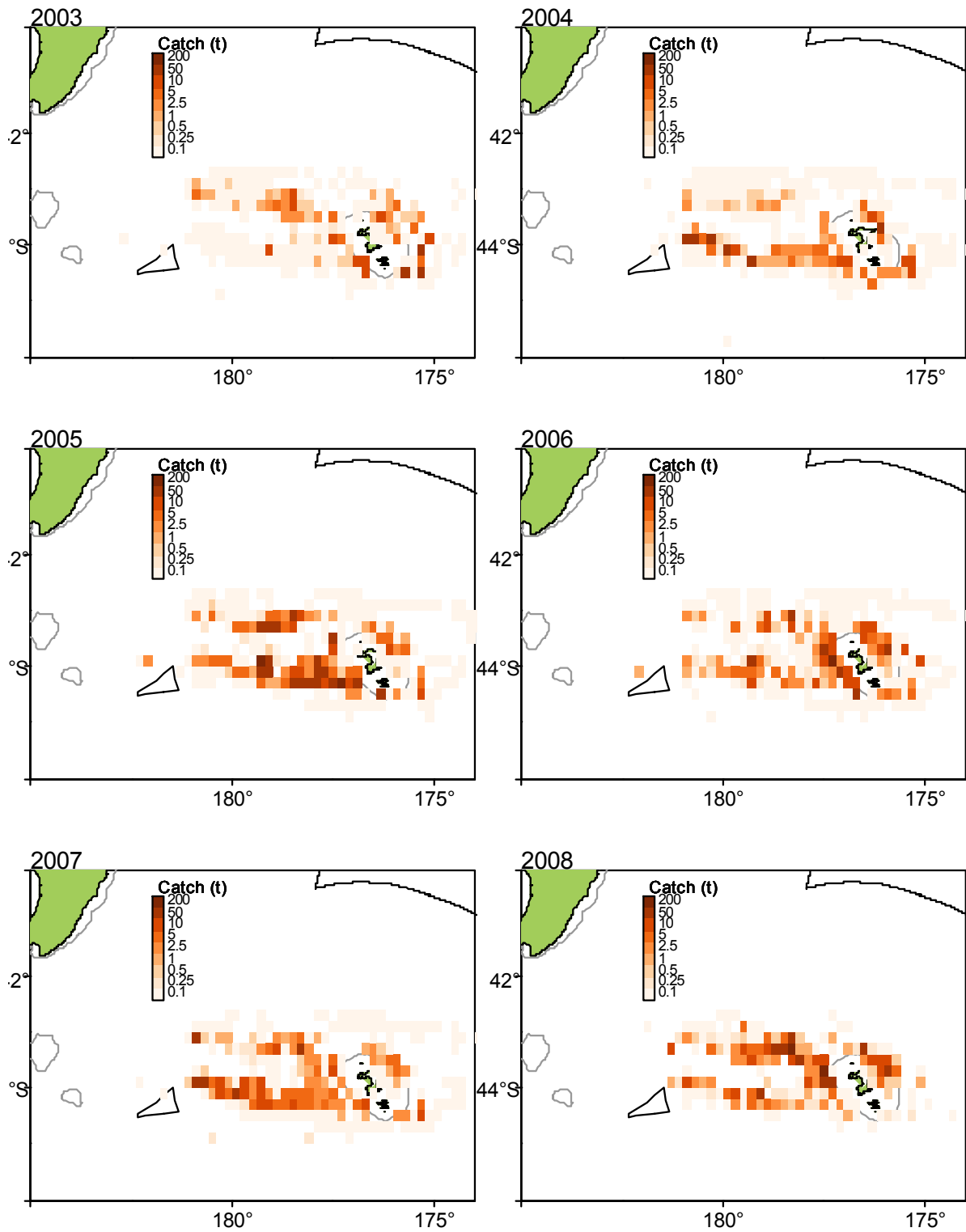
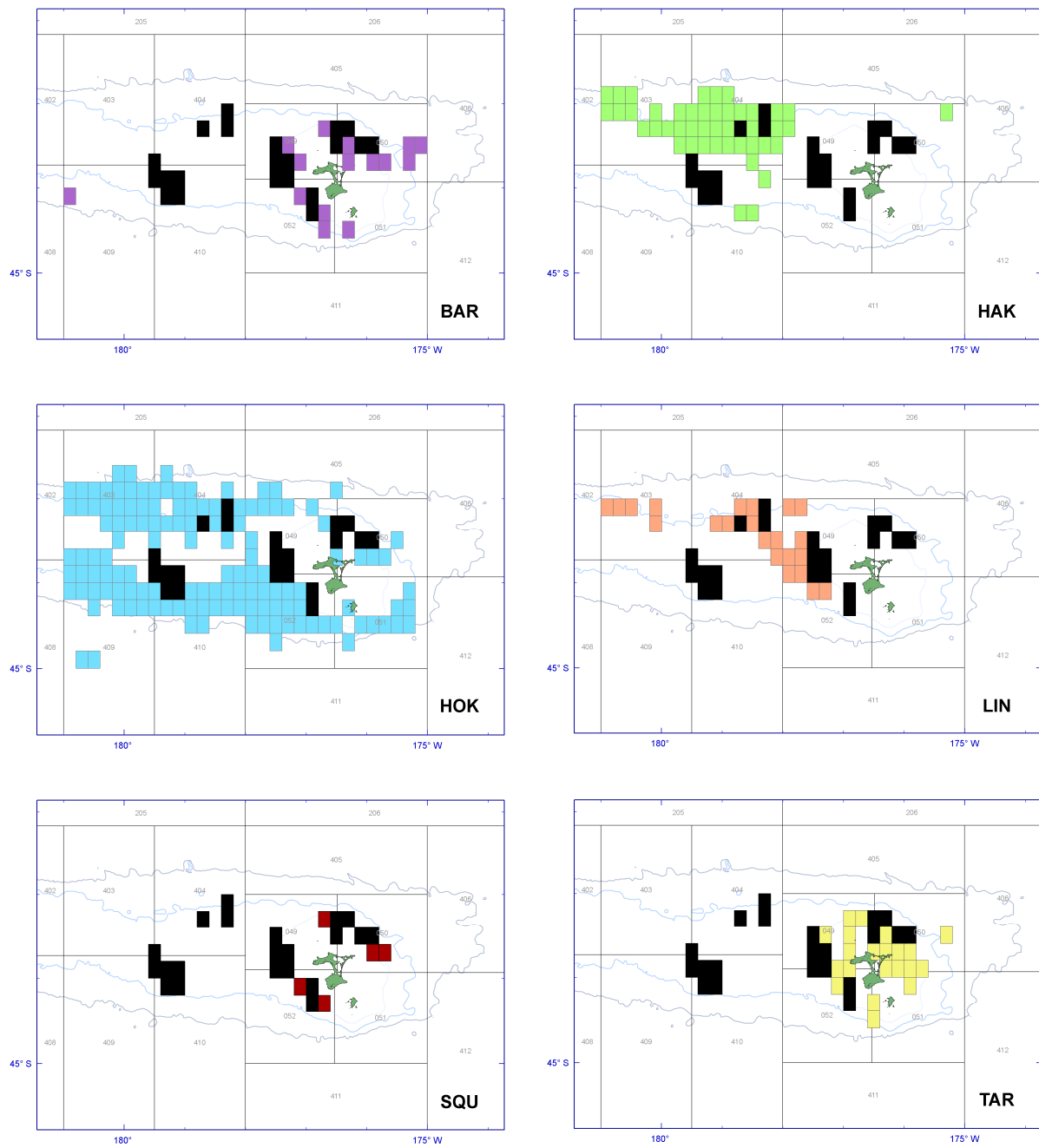
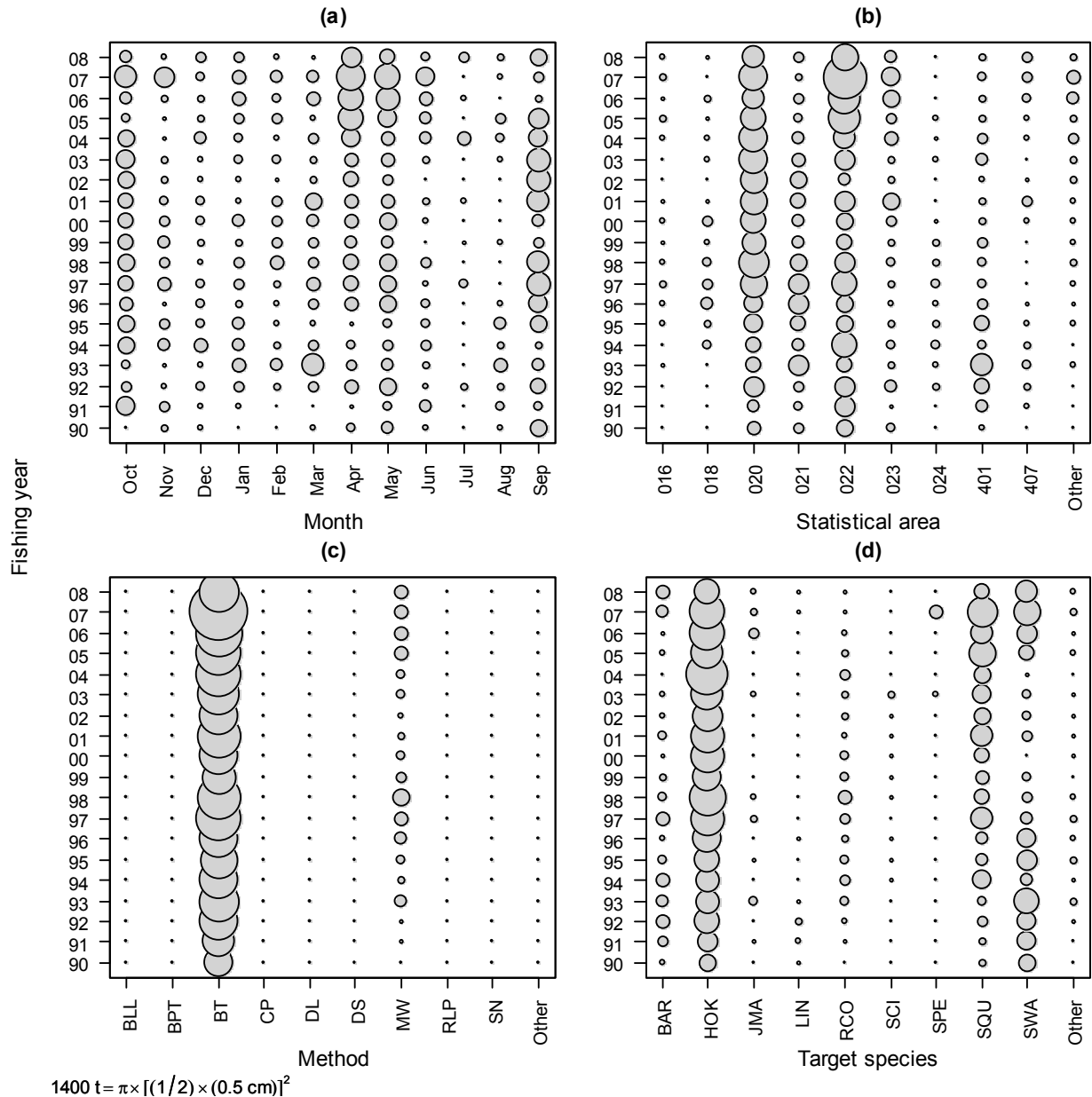


Figure 39: Distribution of SWA catch within the CHATHAM RISE region aggregated into 0.2 degree spatial blocks for fishing years 2003–2007.



**Figure 40: Eastern CHATHAM RISE statistical areas and bathymetry showing the distribution of bottom trawls by target species for the main target species (coloured cells) compared to the distribution of SWA target effort distribution (black cells) for all years combined. Each colour is a separate species.**



**Figure 41: Distribution of SWA catch in the EAST COAST SOUTH ISLAND region (circle size is proportional to catch) for 1990–2008 fishing years in relation to a) month, b) statistical area, c) fishing method, and d) target species. Catch from statistical areas 017 and 019 are included in “other”. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**

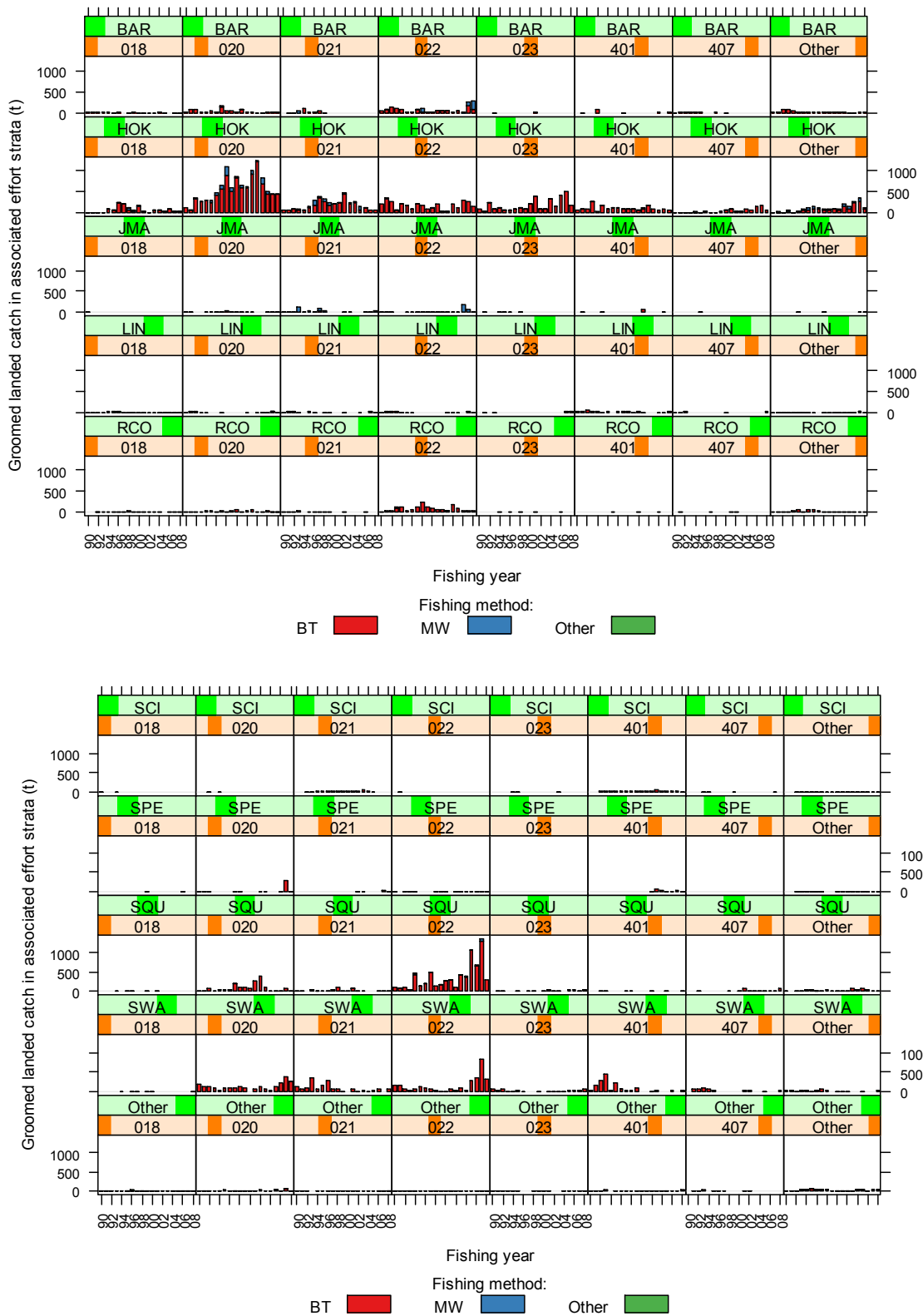
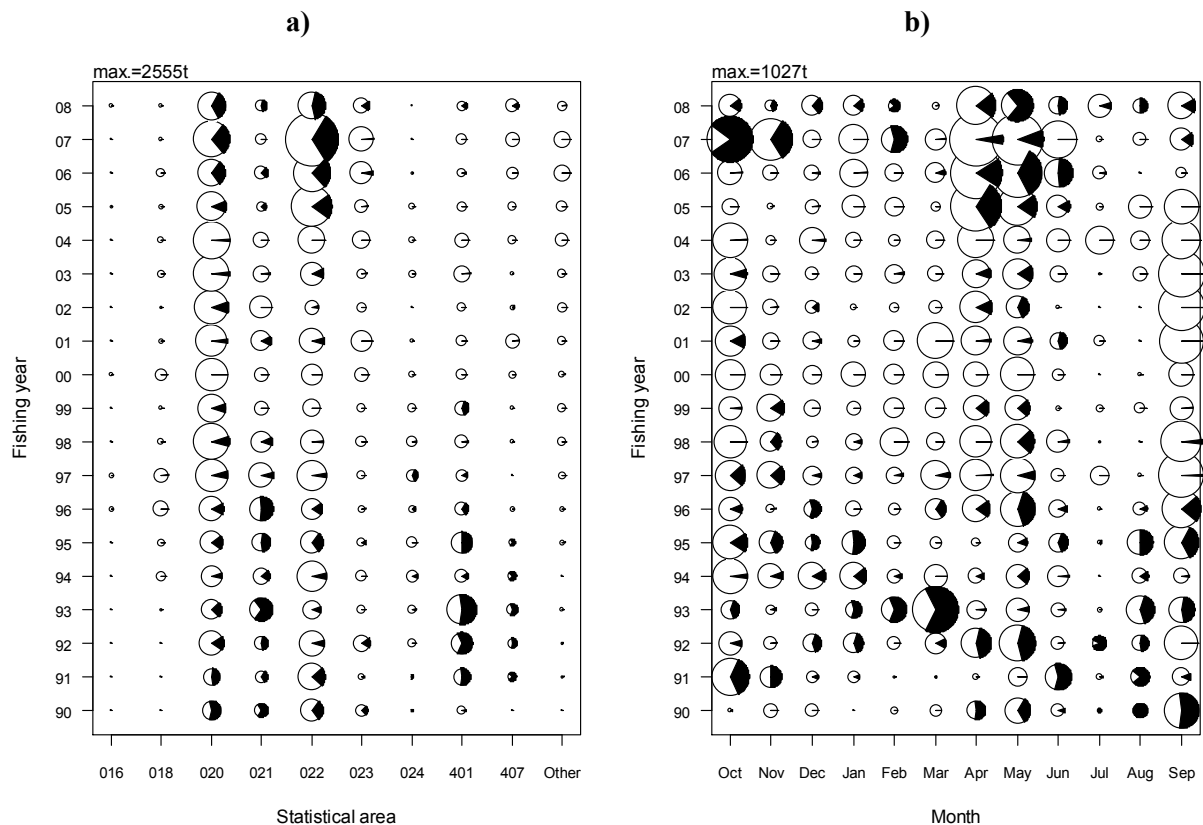
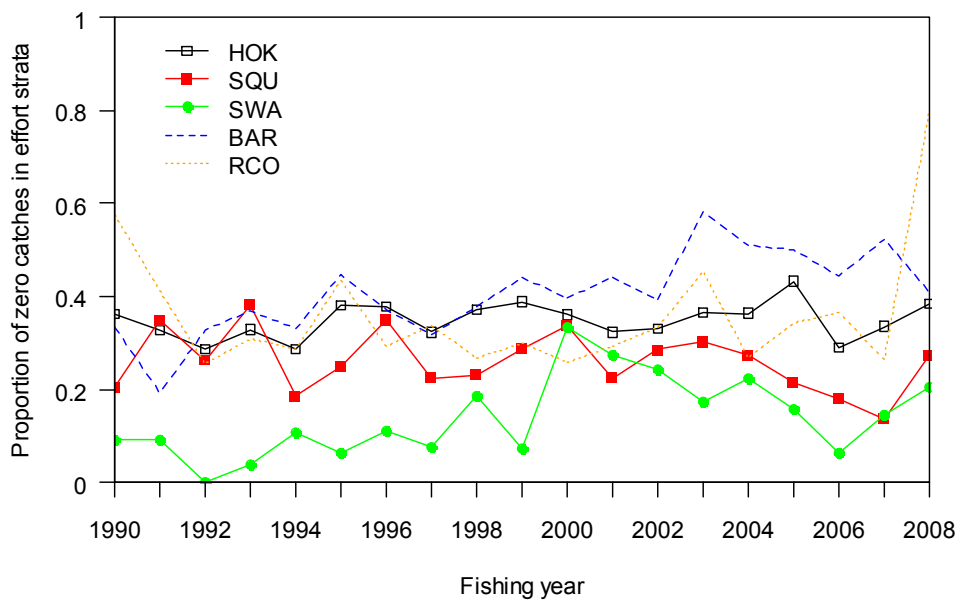


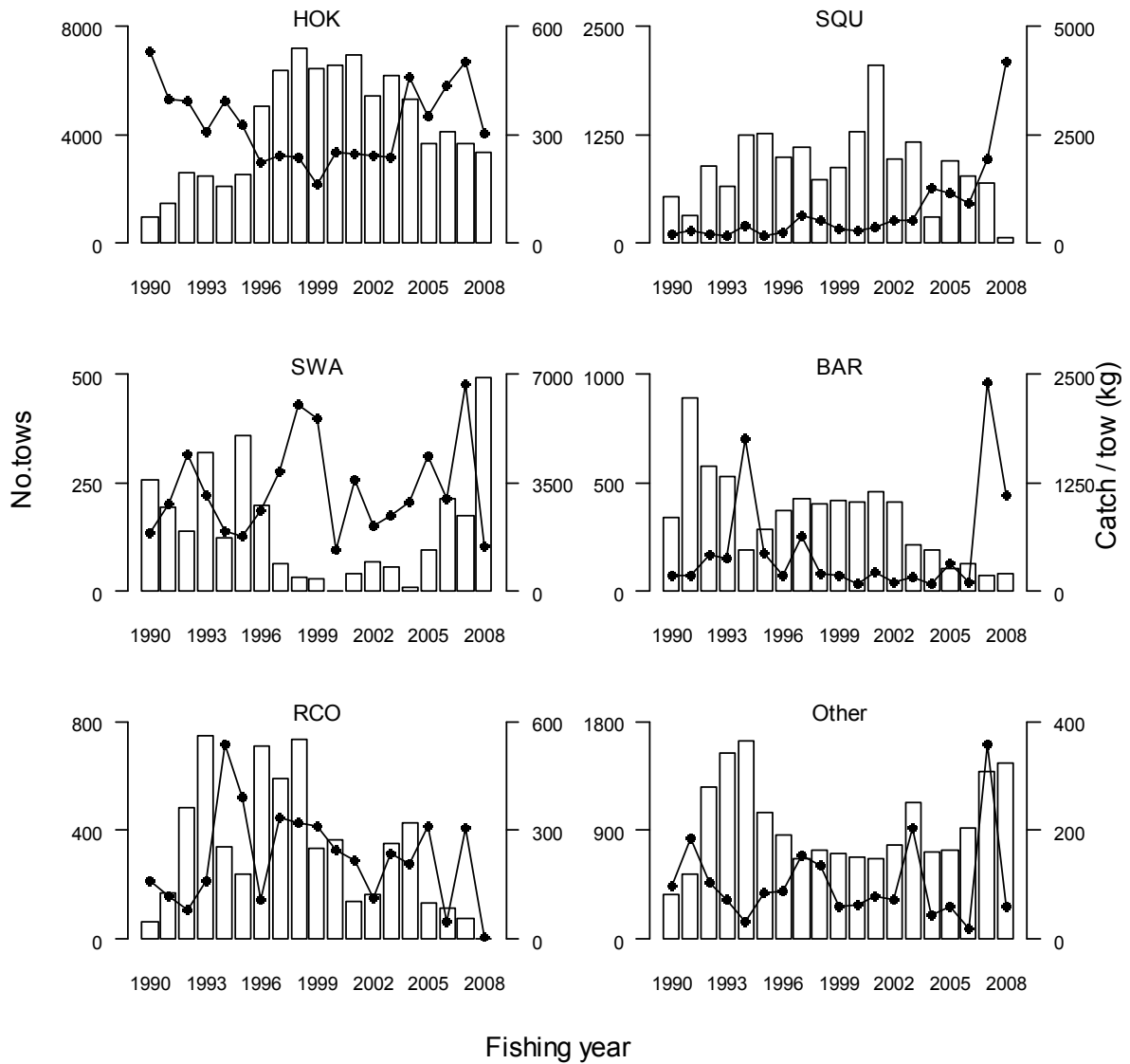
Figure 42: Distribution of SWA catch in the EAST COAST SOUTH ISLAND region in relation to target species and statistical area by fishing method for fishing years 1990–2008.



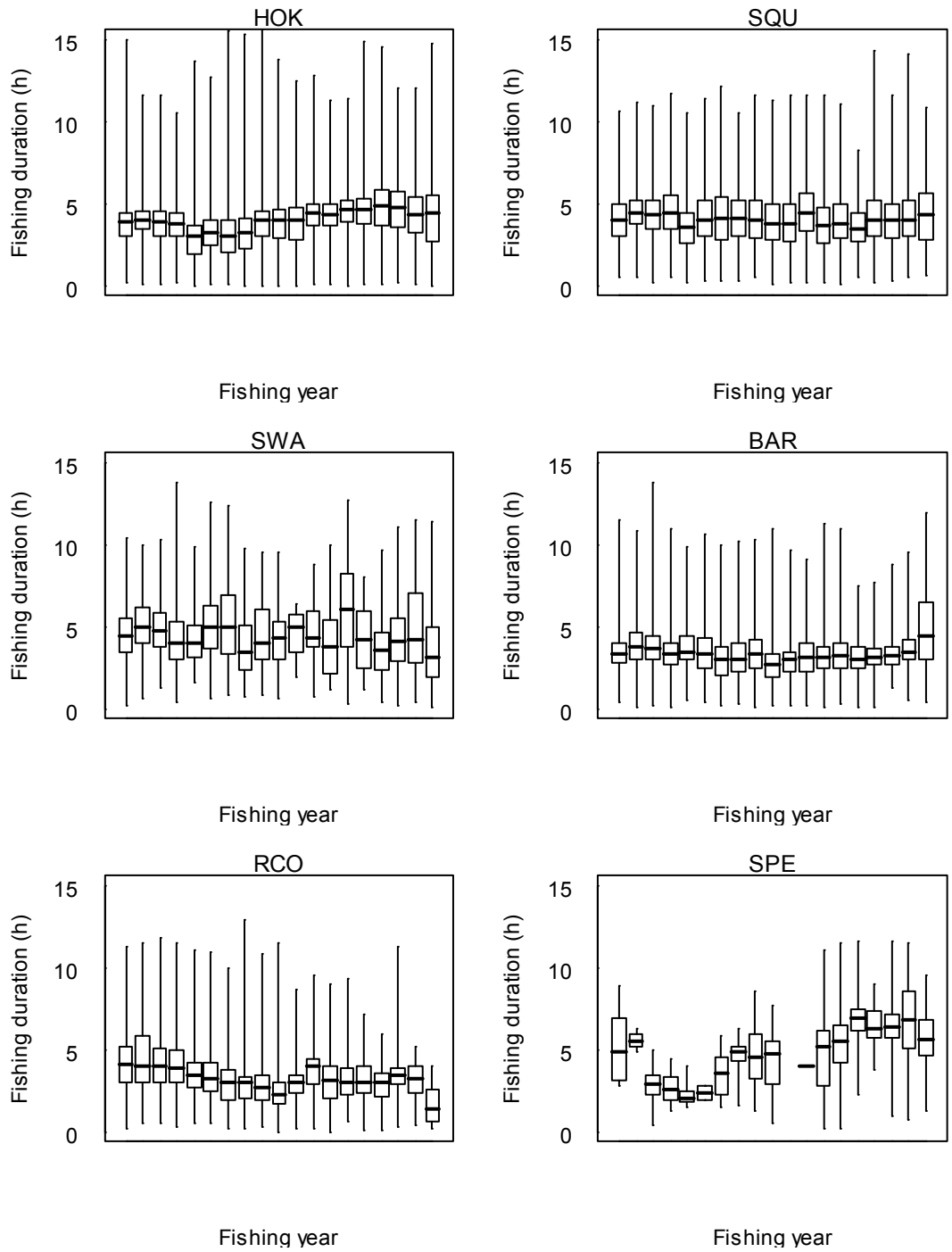
**Figure 43: Distribution of SWA catch by fishing year with circle size proportional to the total catch and black portion of the pie indicating proportion of the catch as targeted SWA by a) statistical area and b) month for the EAST COAST SOUTH ISLAND region.**



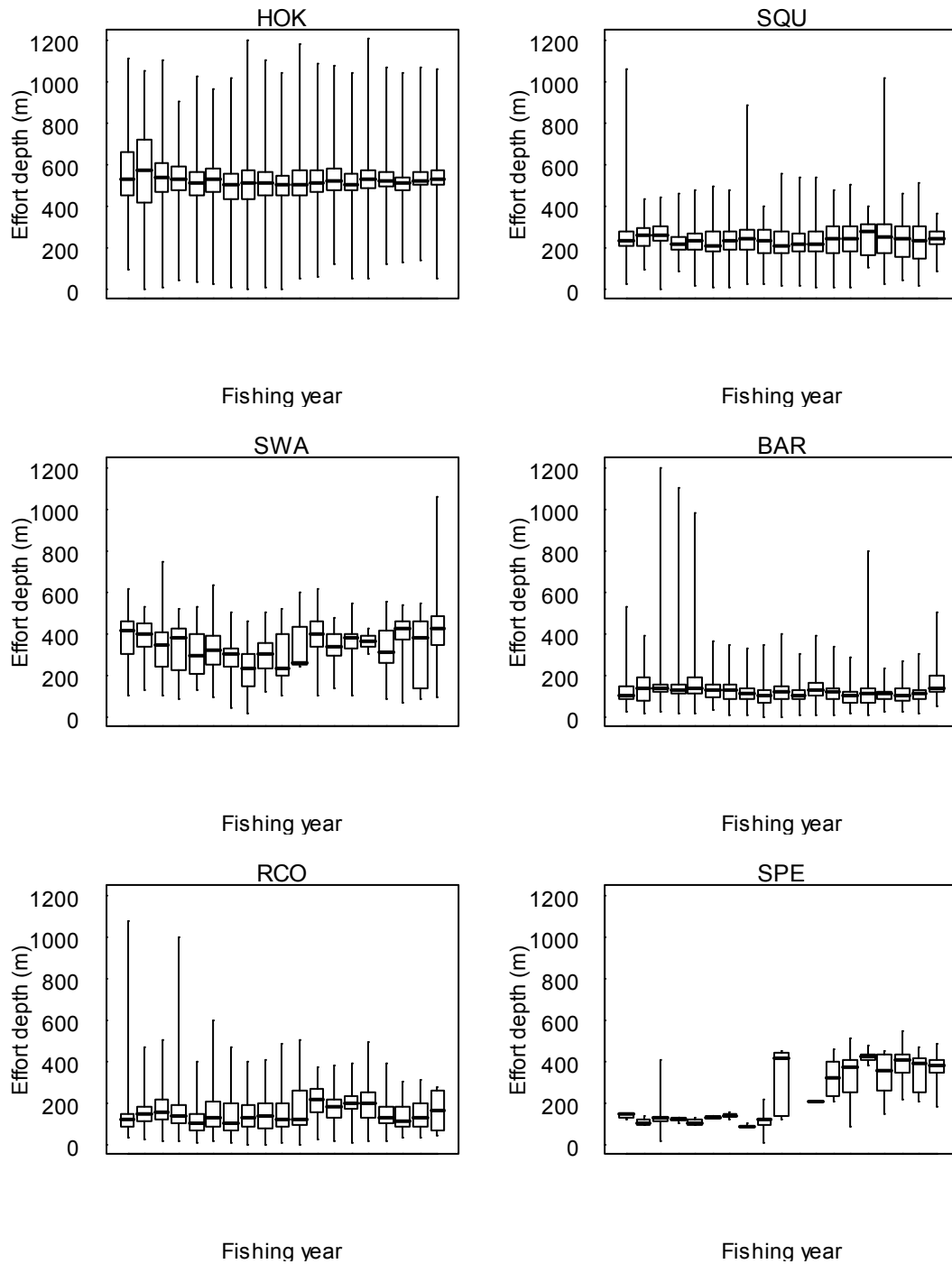
**Figure 44: Proportion of tows with zero reported SWA catch for major target species in the EAST COAST SOUTH ISLAND region.**



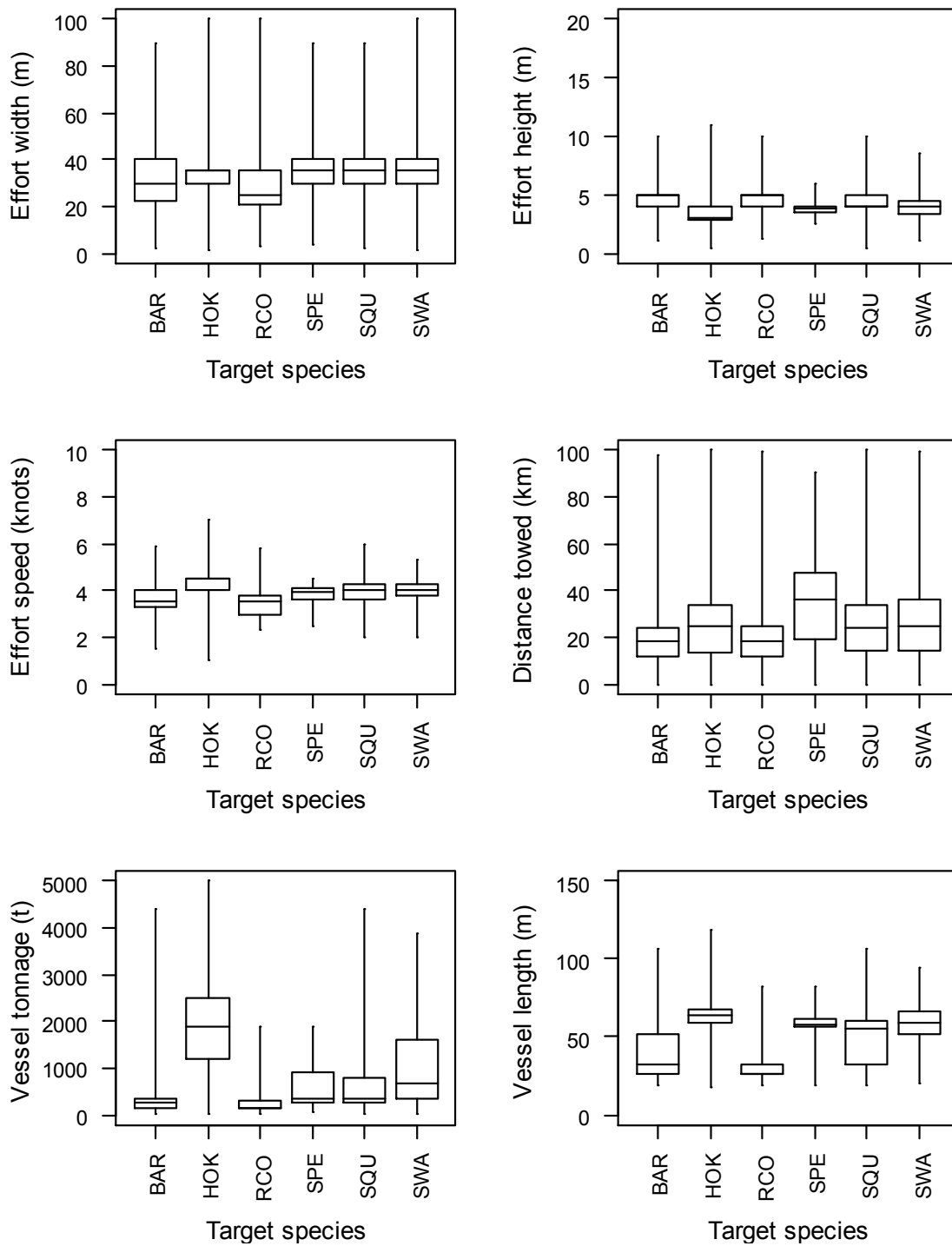
**Figure 45: Annual catch rate of silver warehou for various target species tows in kg silver warehou (catch/tow) and the number of tows for the EAST COAST SOUTH ISLAND region.**



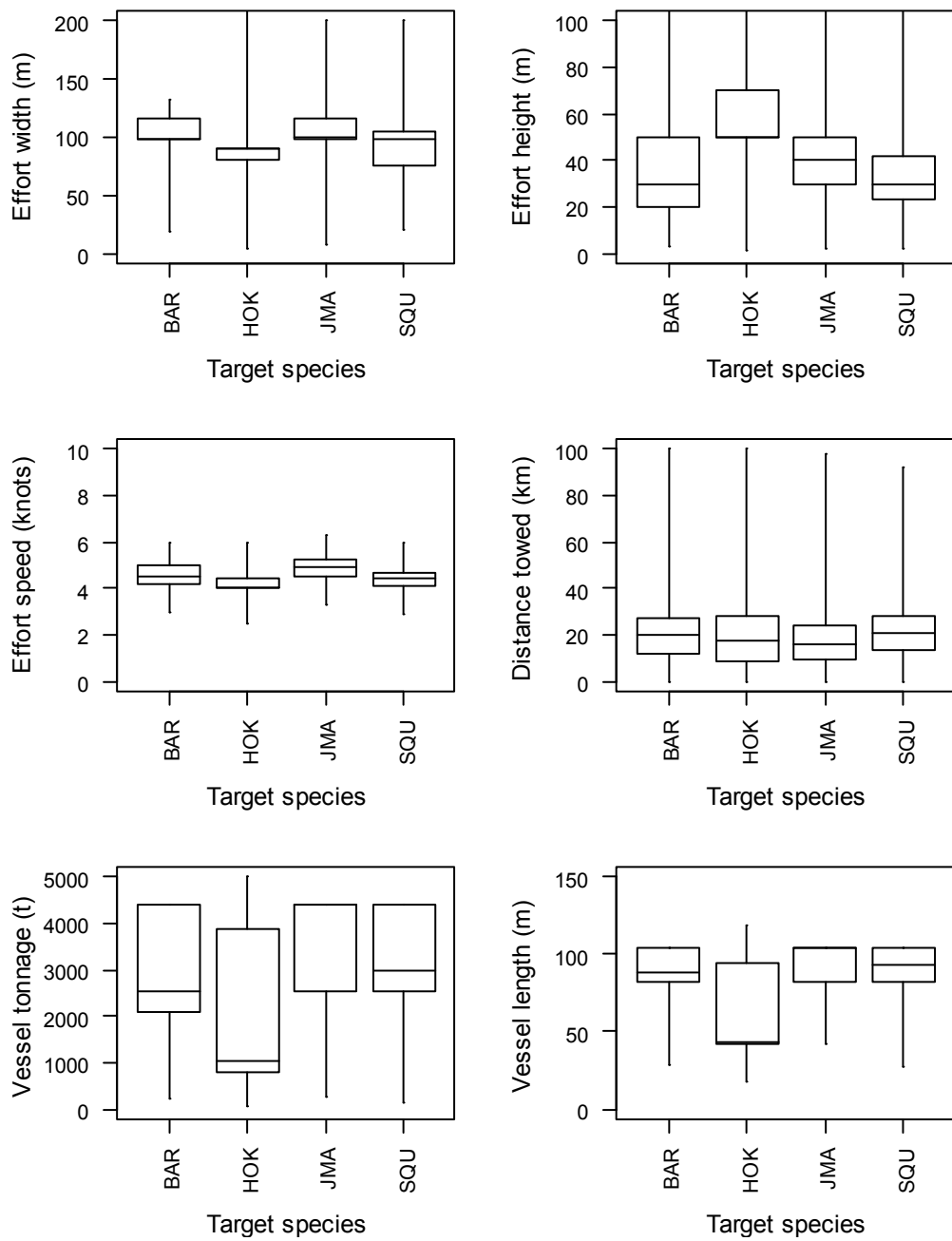
**Figure 46: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for tow durations reported for various target species capturing SWA in the EAST COAST SOUTH ISLAND Region.**



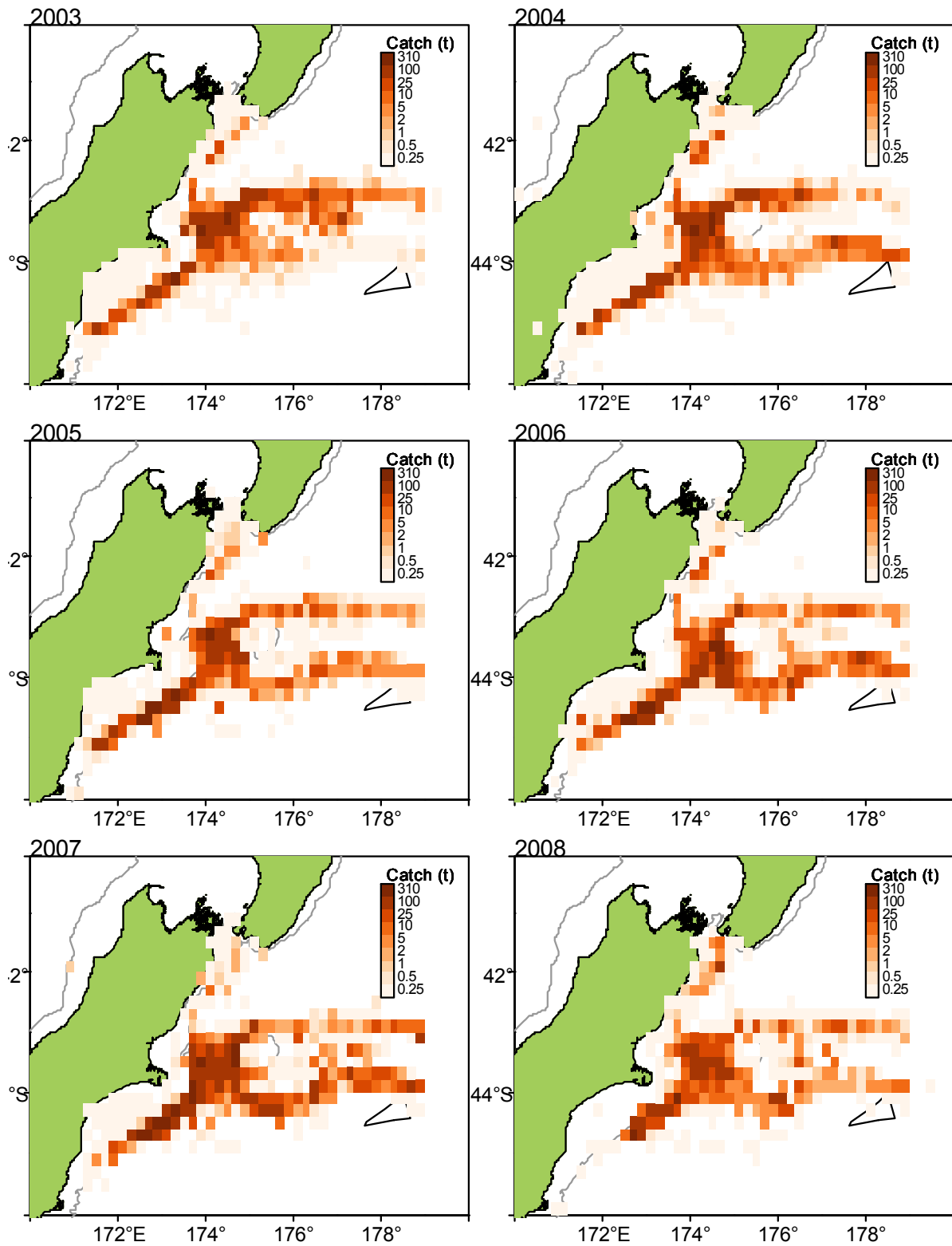
**Figure 47: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for various target species capturing SWA in the EAST COAST SOUTH ISLAND Region.**



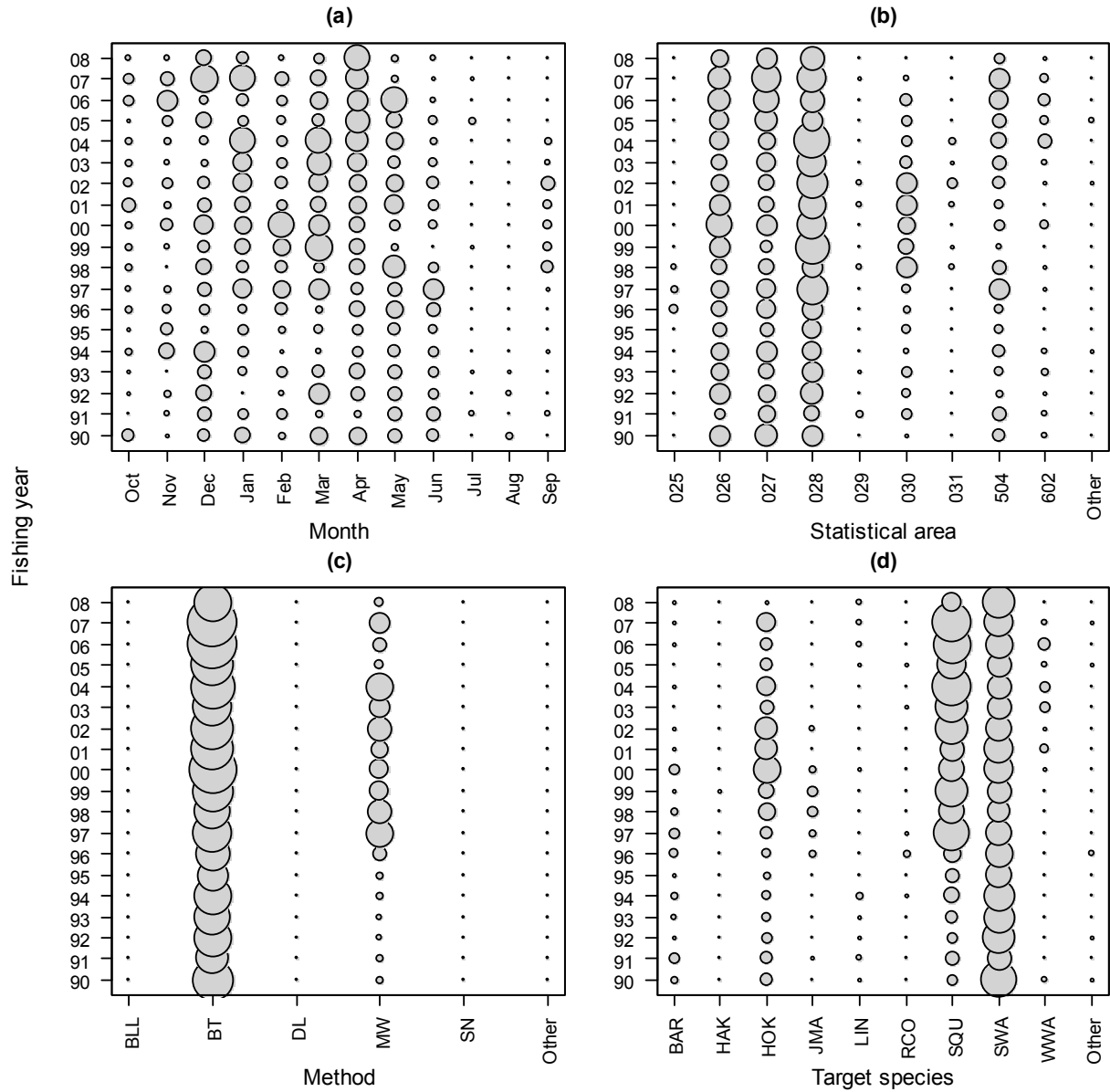
**Figure 48: Distribution of fishing effort variables and vessel characteristics for the EAST COAST SOUTH ISLAND area for four major target species taken by bottom trawl gear.**



**Figure 49: Distribution of fishing effort variables and vessel characteristics for the EAST COAST SOUTH ISLAND area for four major target species taken by midwater trawl gear.**

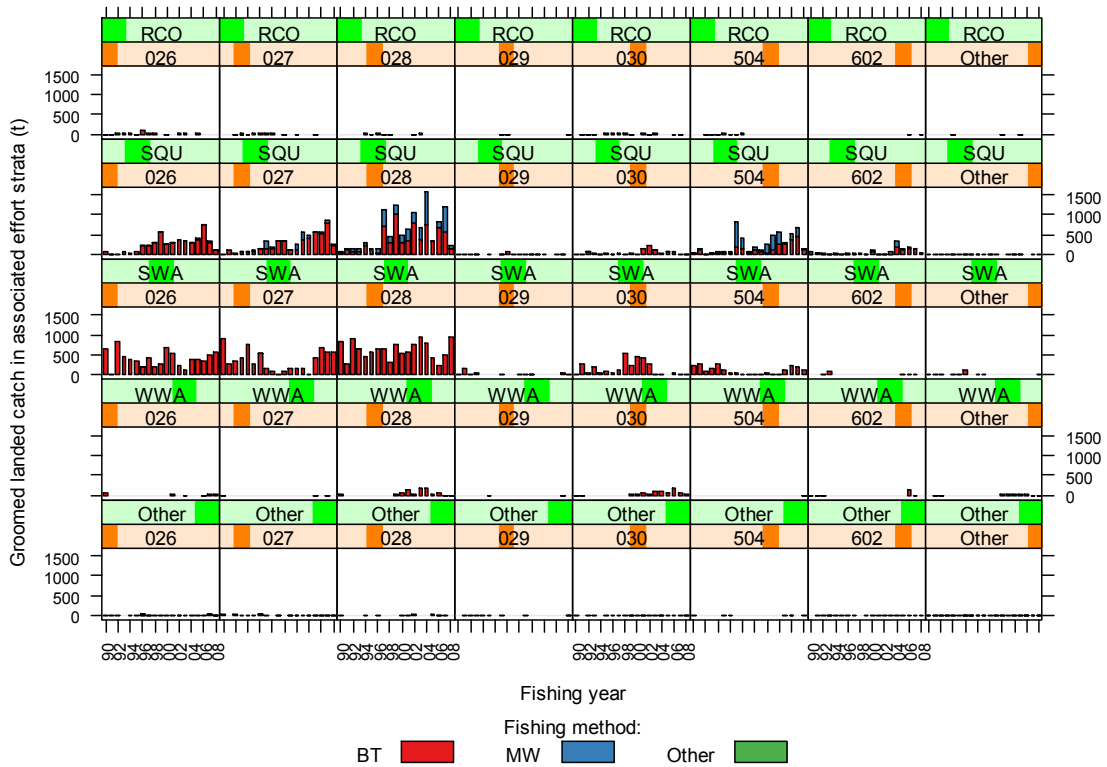
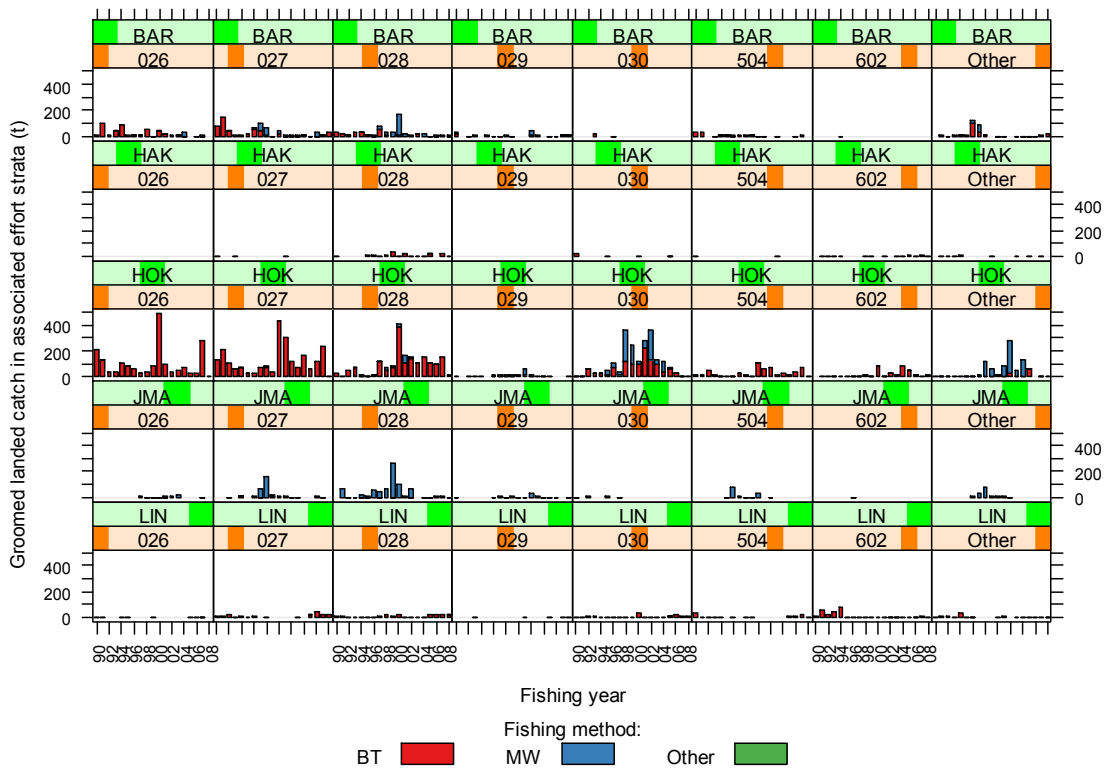


**Figure 50: Distribution of SWA catch within the EAST COAST SOUTH ISLAND region aggregated into 0.2 degree spatial blocks for fishing years 2003–2007.**

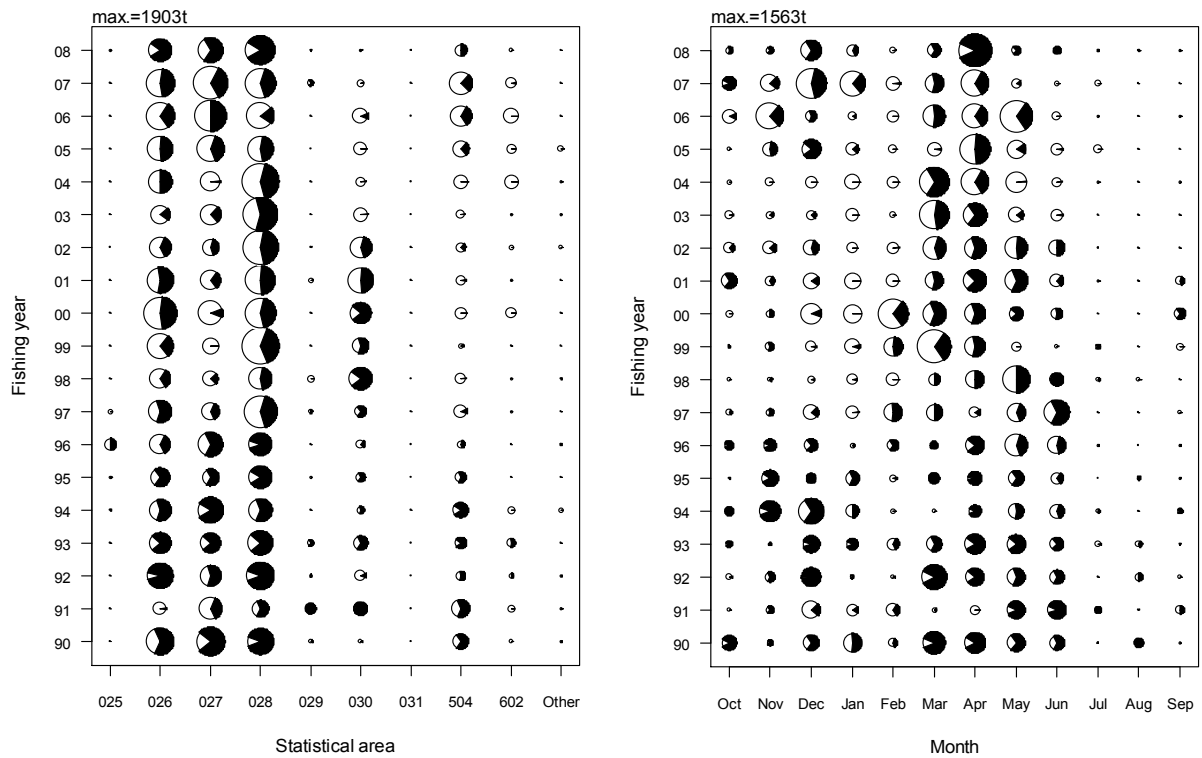


$$2000 t = \pi \times [(1/2) \times (0.5 \text{ cm})]^2$$

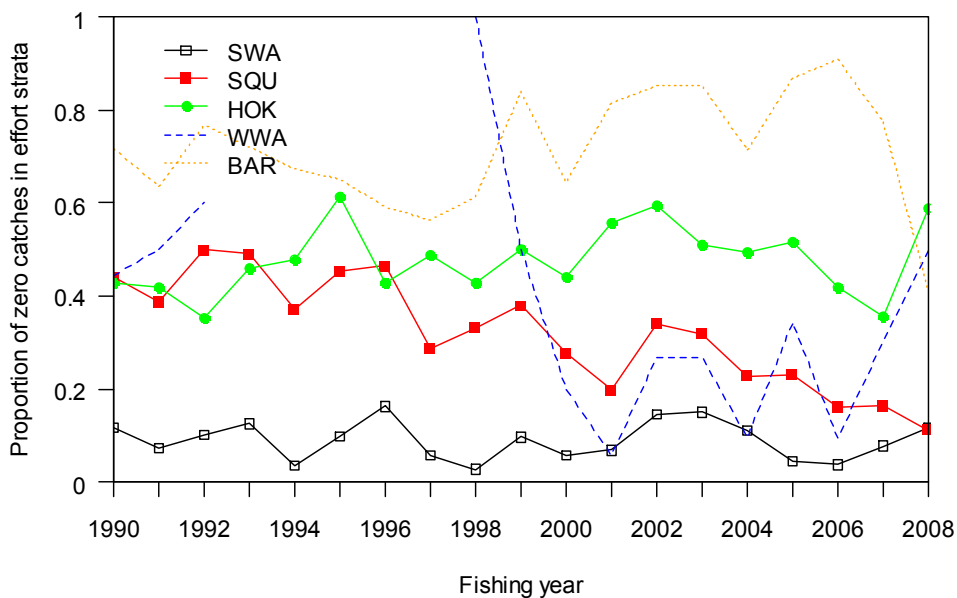
**Figure 51: Distribution of SWA catch in the SOUTHLAND region (circle size is proportional to catch) for 1990–2008 fishing years in relation to a) month, b) statistical area, c) fishing method, and d) target species. Circle size is proportional to catch; maximum circle size is indicated in lower left hand corner.**



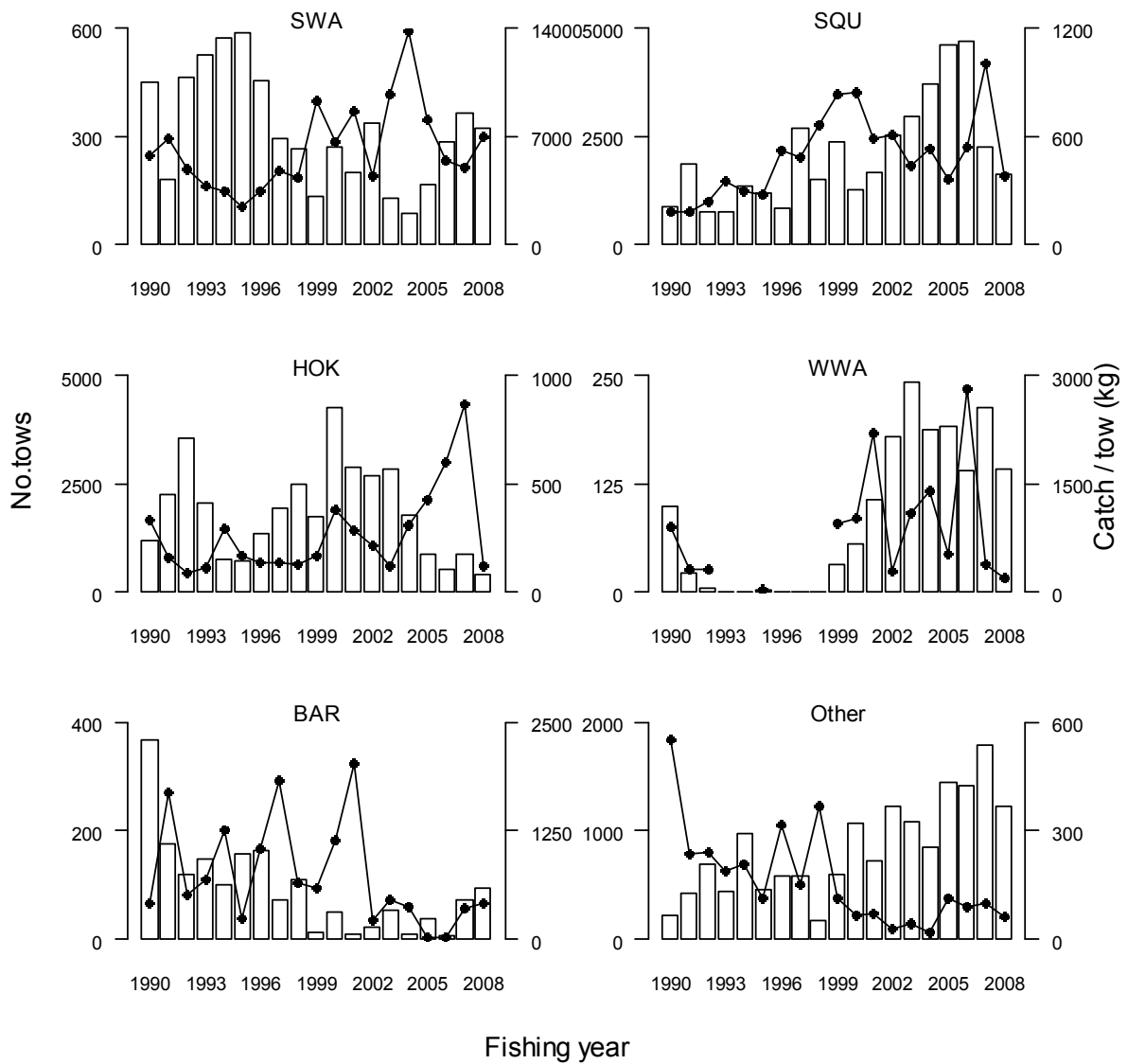
**Figure 52: Distribution of SWA catch in the SOUTHLAND region in relation to target species and statistical area by fishing method for fishing years 1990–2008.**



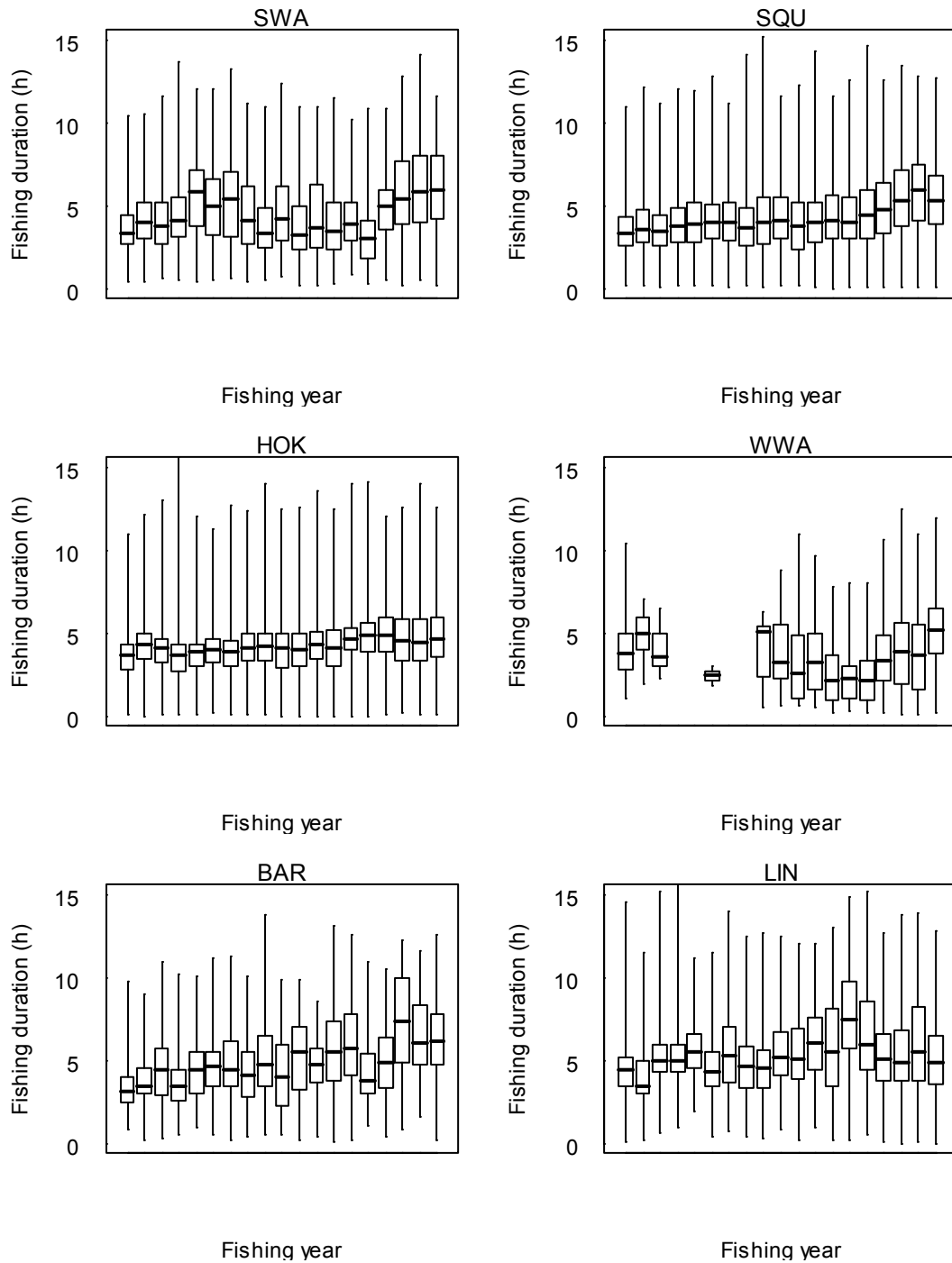
**Figure 53: Distribution of SWA catch by fishing year with circle size proportional to the total catch and black portion of the pie indicating proportion of the catch as targeted SWA in the SOUTHLAND region by a) statistical area and b) month.**



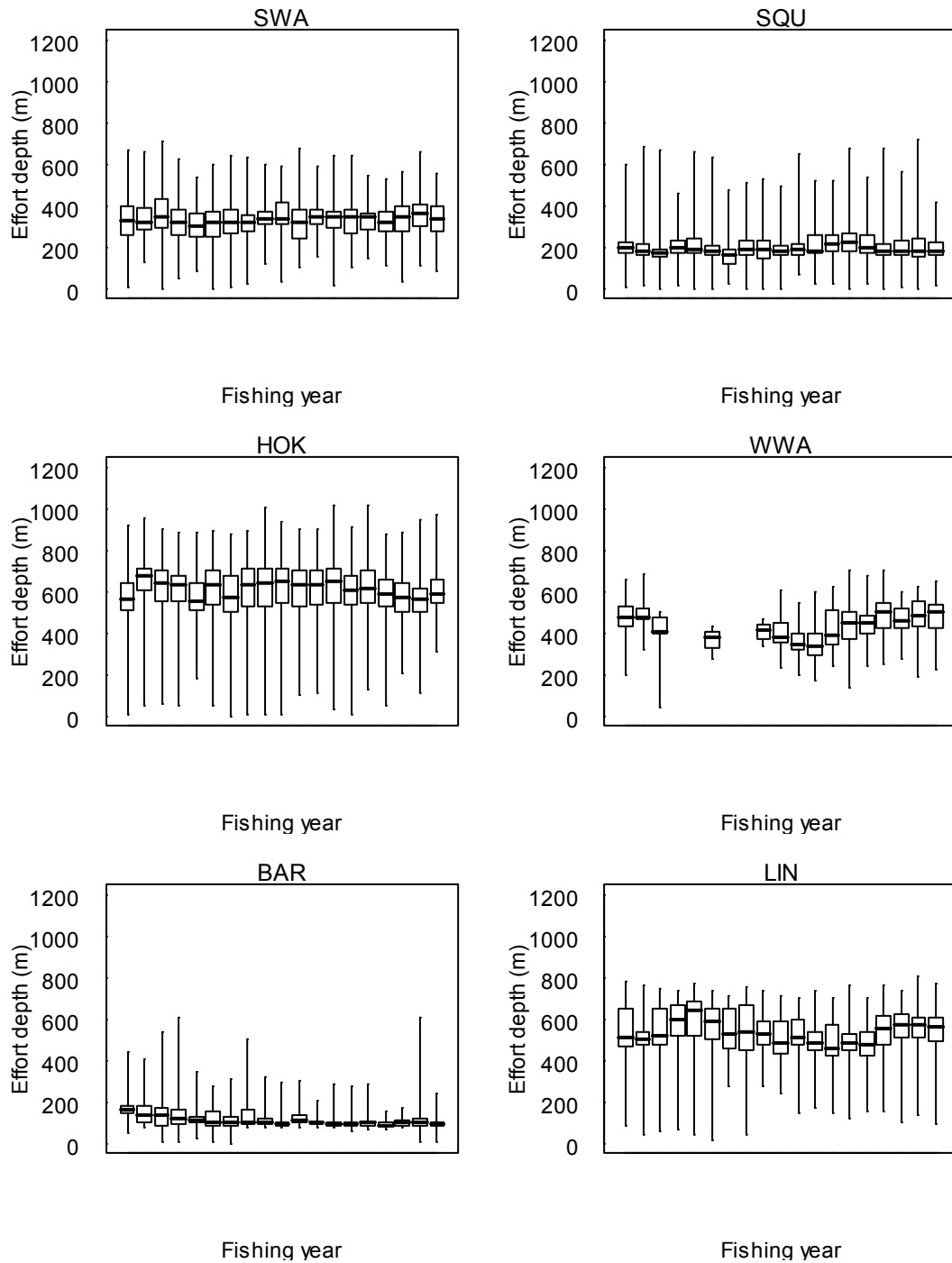
**Figure 54: Proportion of tows with zero reported SWA catch for major target species in the SOUTHLAND region.**



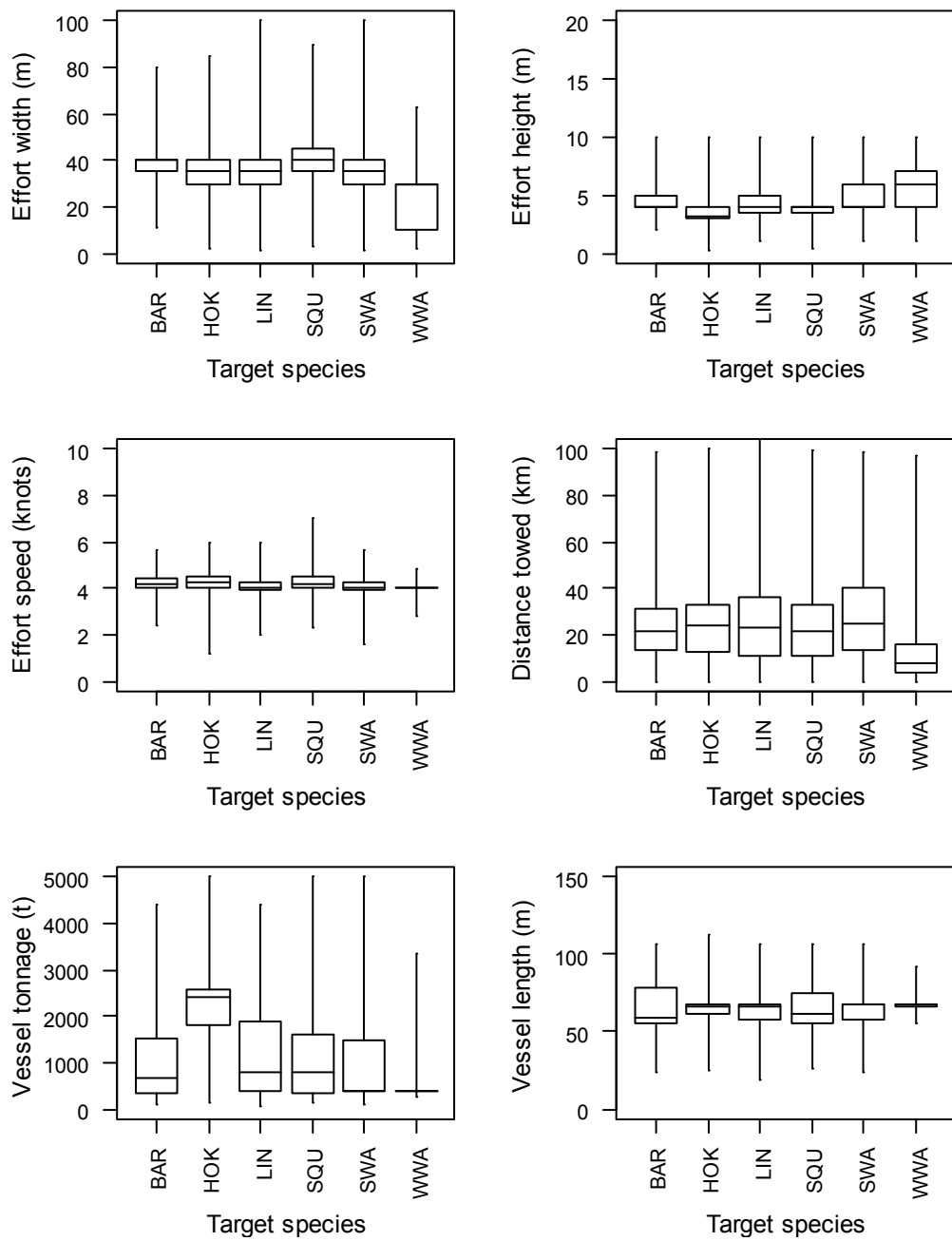
**Figure 55: Annual catch rate of silver warehou for various target species tows in kg silver warehou (catch/tow) and the number of tows for the SOUTHLAND region.**



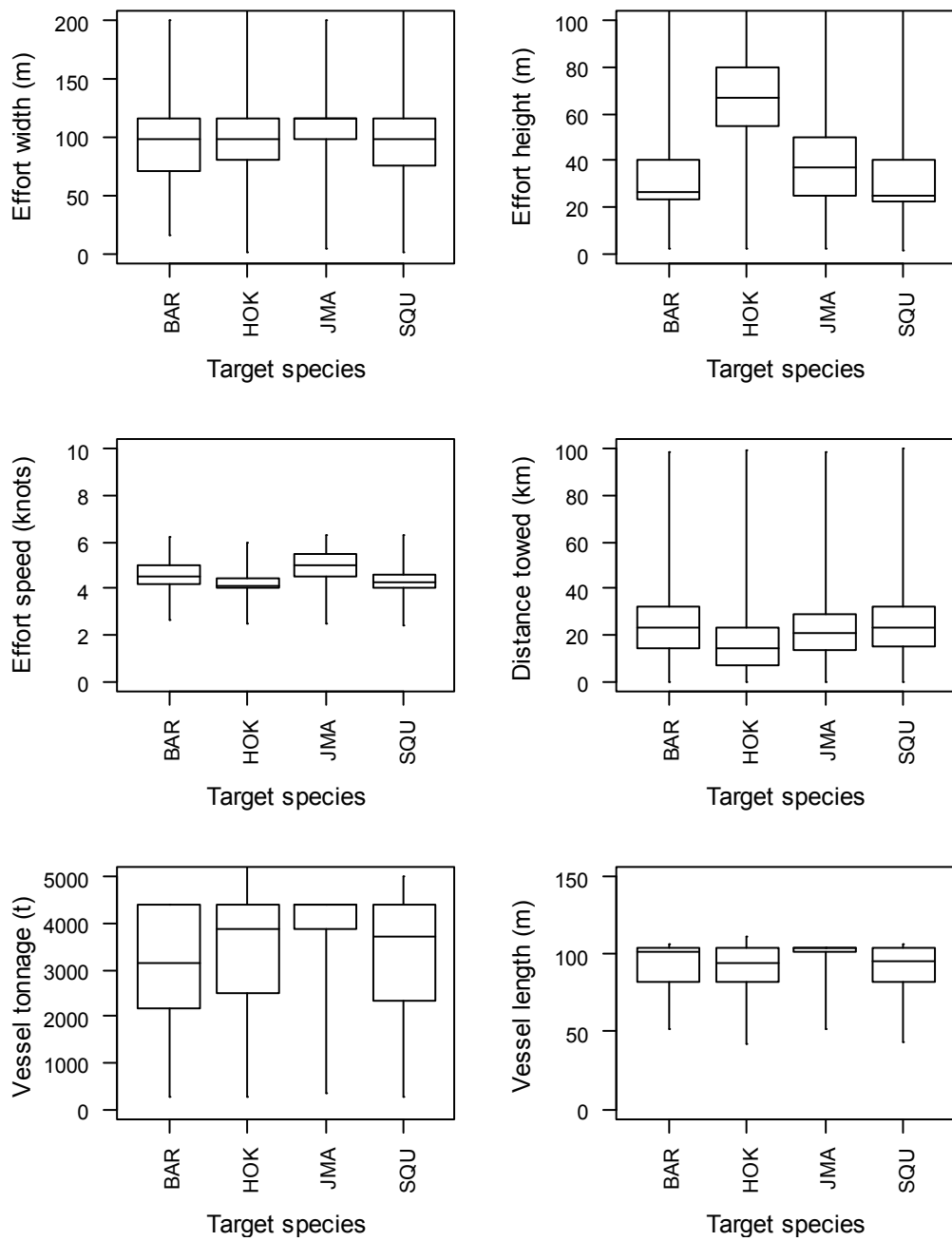
**Figure 56: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for tow durations reported for various target species capturing SWA in the SOUTHLAND Region.**



**Figure 57: Annual median (horizontal line), inter-quartile ranges (box), and range (vertical lines) for depths (m) fished for various target species capturing SWA in the SOUTHLAND Region.**



**Figure 58: Distribution of fishing effort variables and vessel characteristics for the SOUTHLAND area for four major target species taken by bottom trawl gear.**



**Figure 59: Distribution of fishing effort variables and vessel characteristics for the SOUTHLAND area for four major target species taken by midwater trawl gear.**

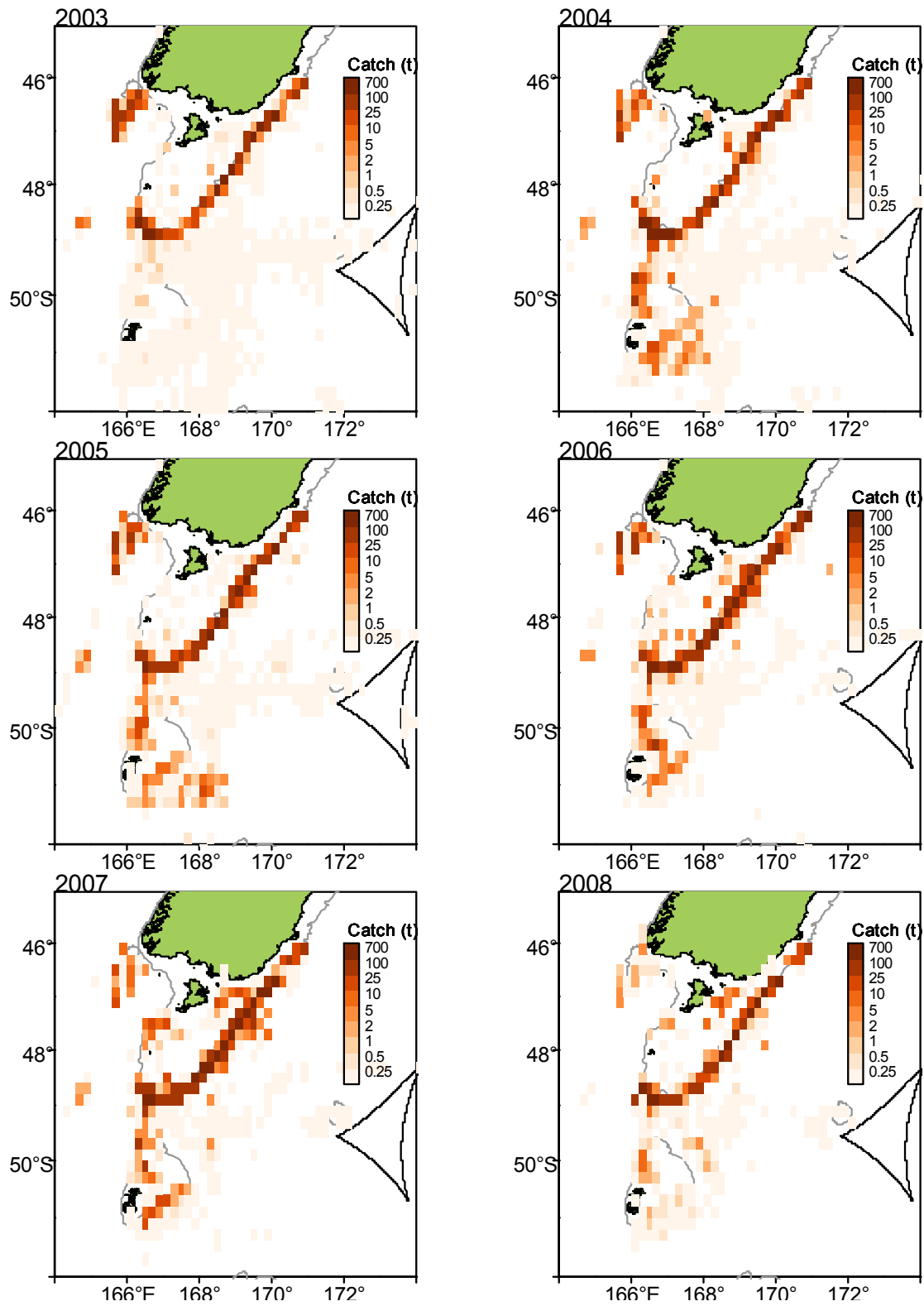
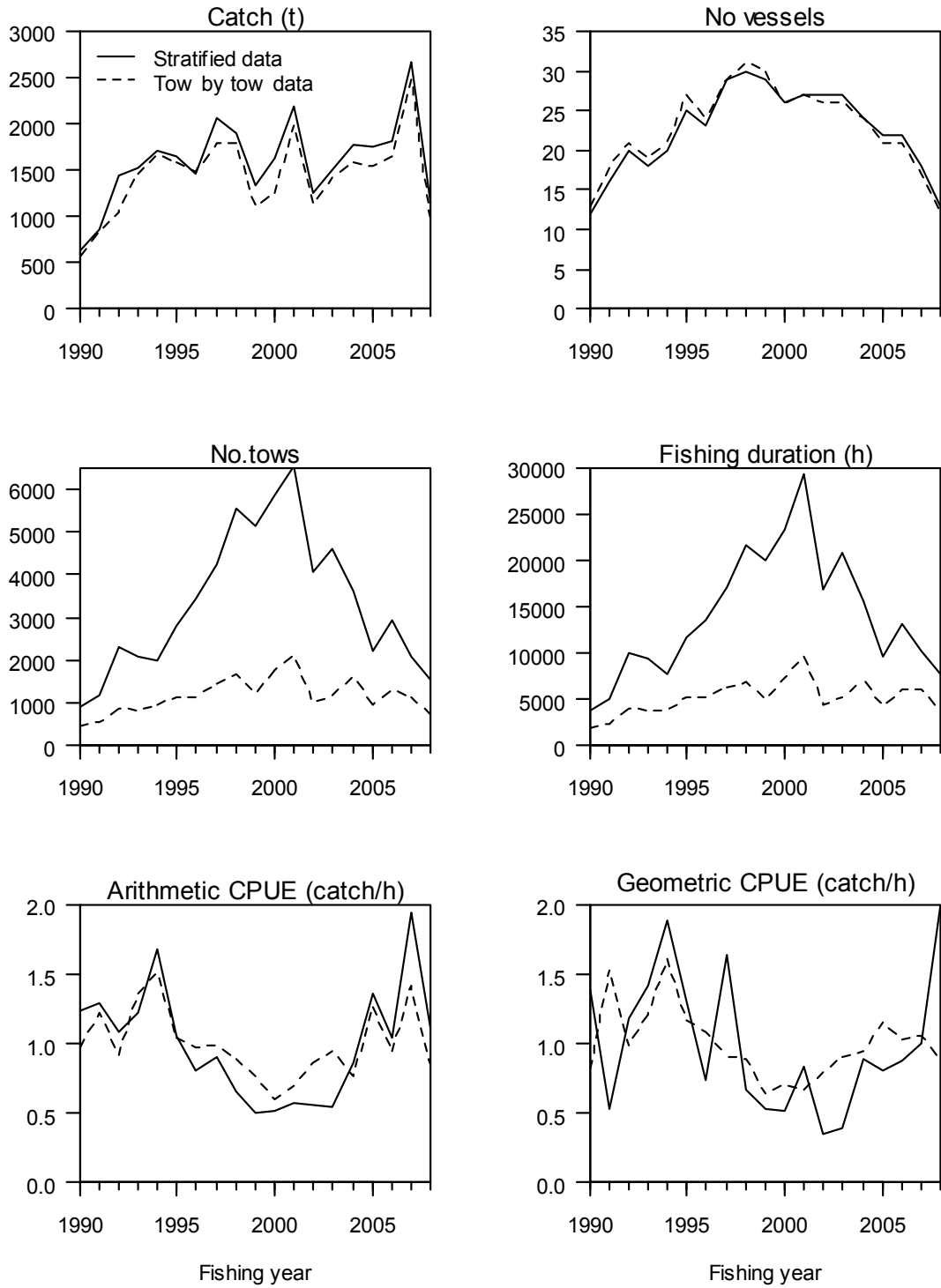
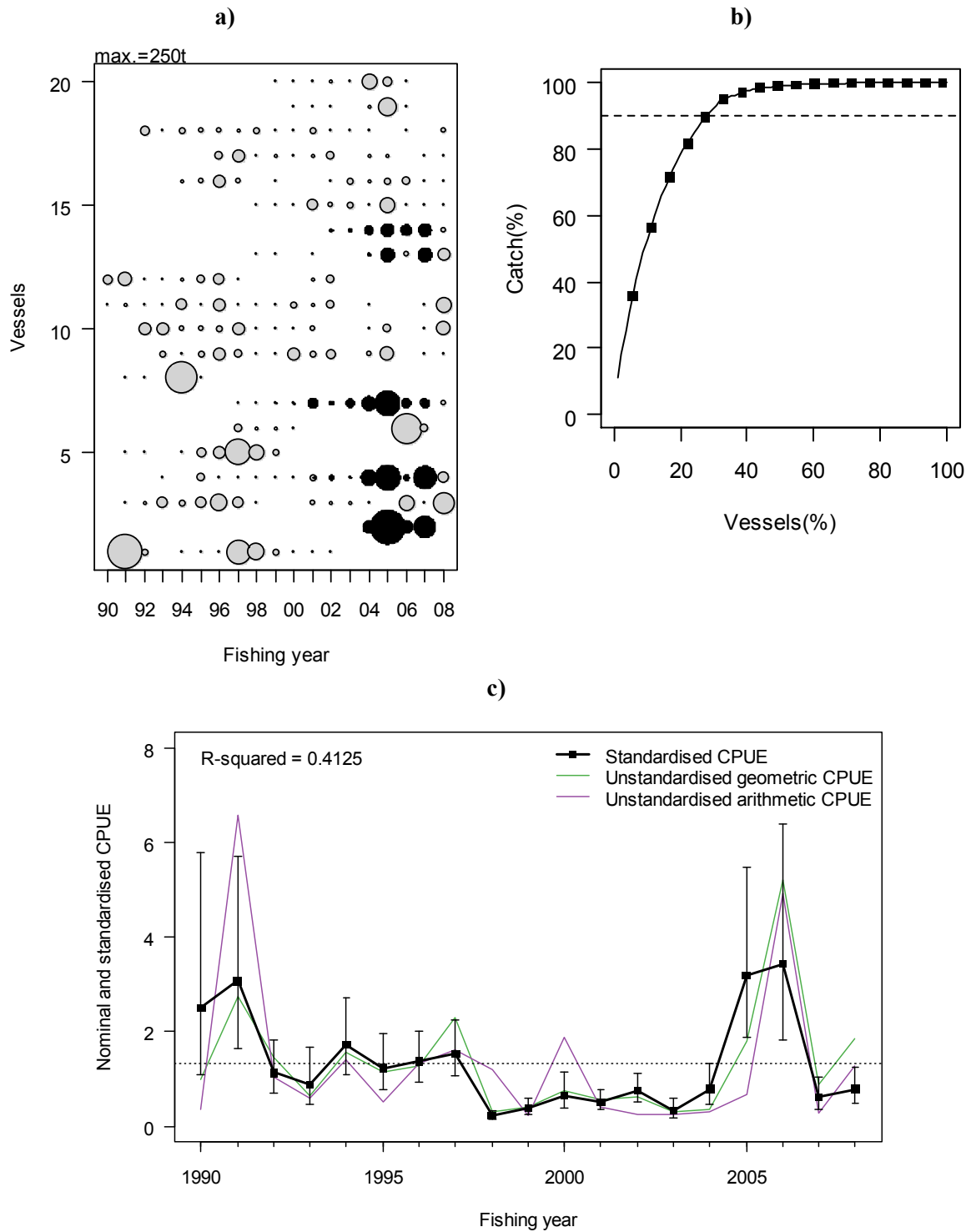


Figure 60: Distribution of SWA catch within the SOUTHLAND region aggregated into 0.2 degree spatial blocks for fishing years 2003–2007.



**Figure 61: Comparison of merged (trip-level) and unmerged (tow-level) datasets used in EAST COAST SOUTH ISLAND CPUE analyses for core vessels only (Models 1 and 2).**



**Figure 62: CHATHAM RISE CPUE Model 1 (stratified dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric, and standardised CPUE indices for SWA 1990–2008.**

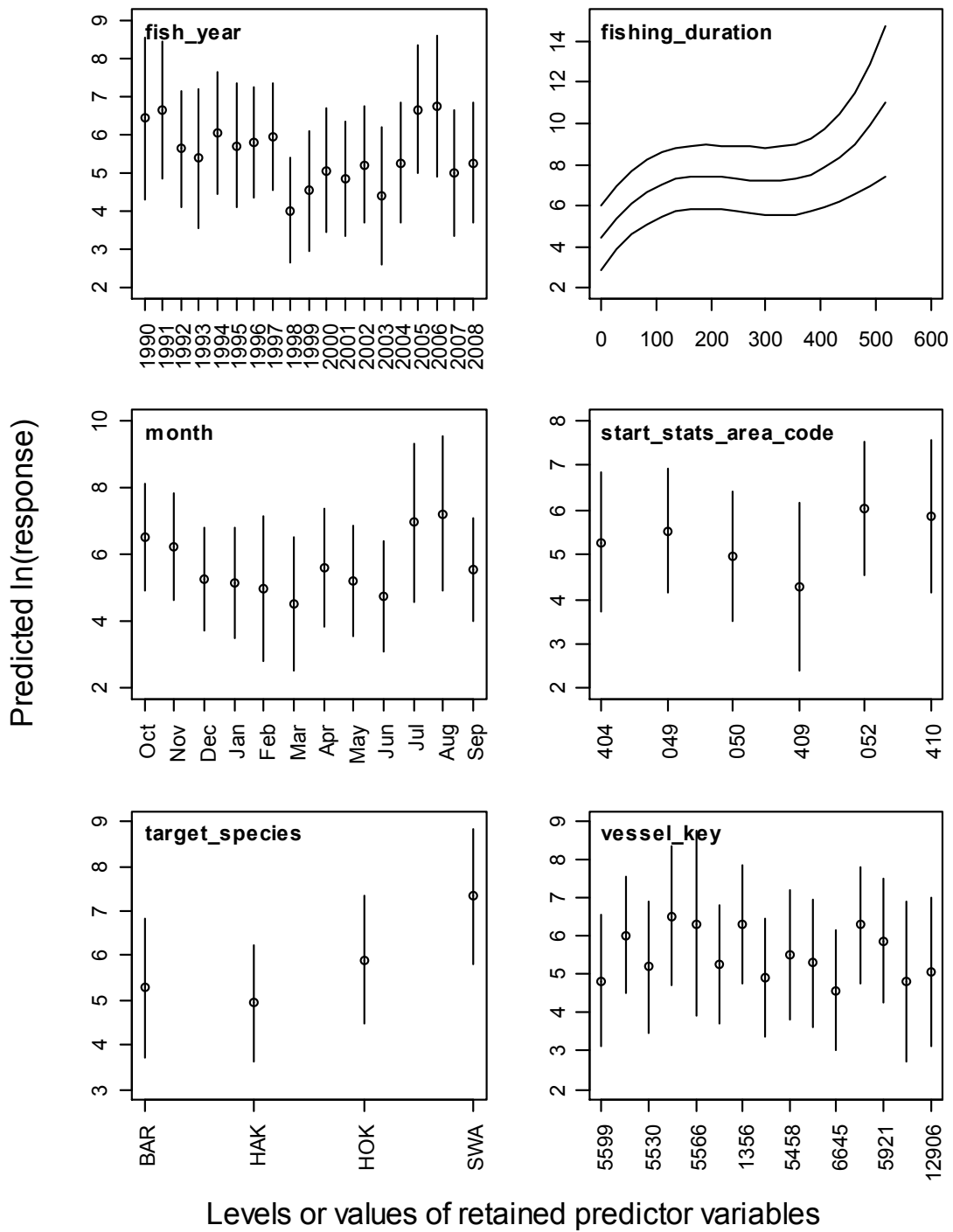
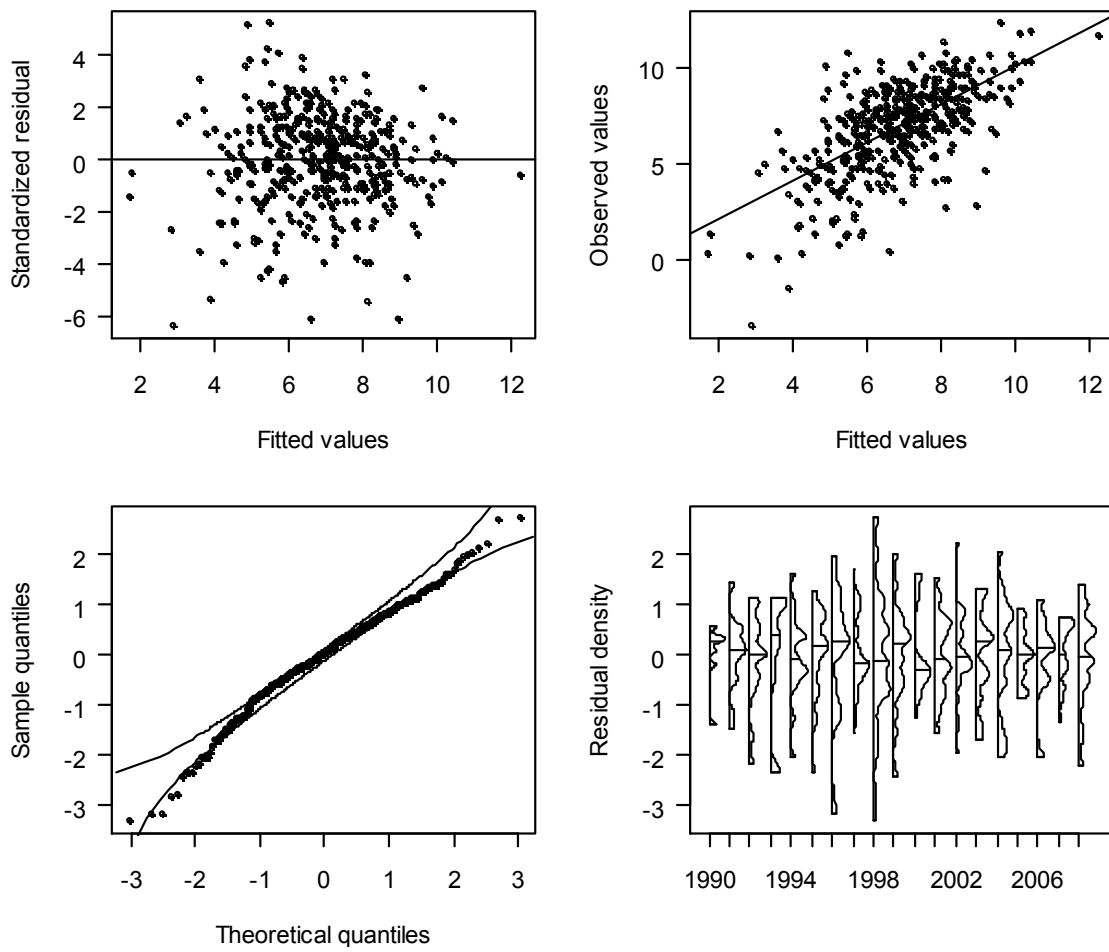
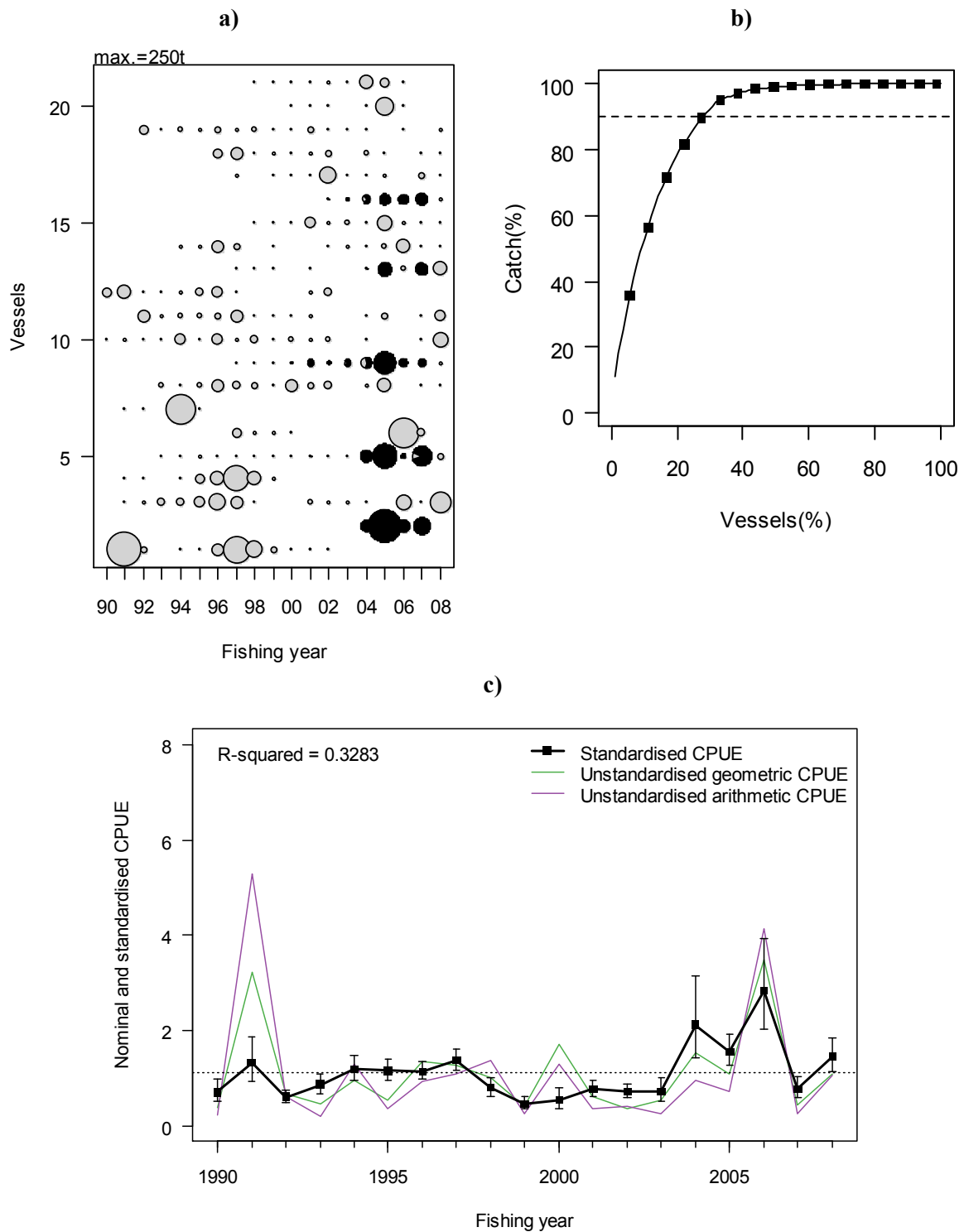


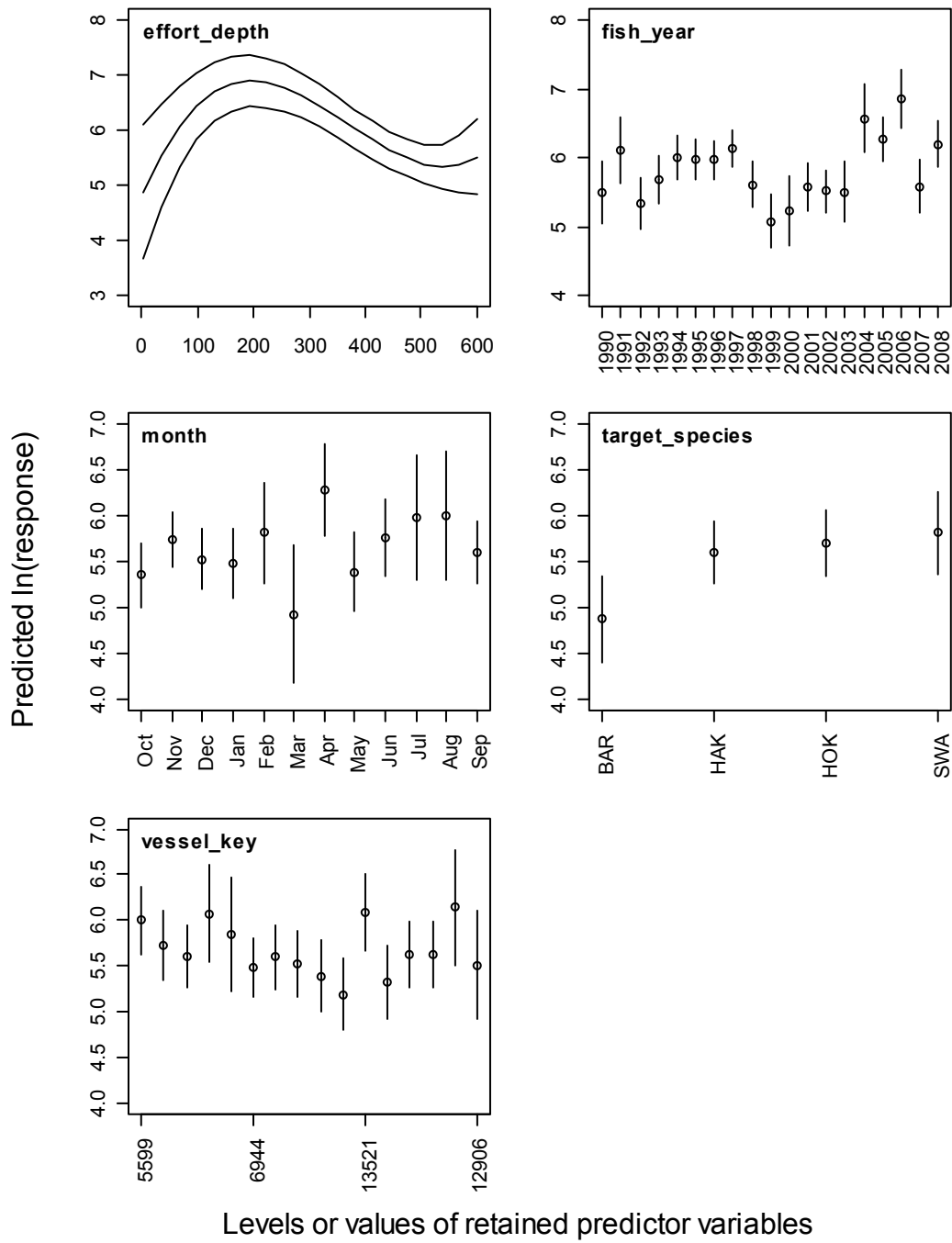
Figure 63: CHATHAM RISE CPUE model 1 (stratified dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.



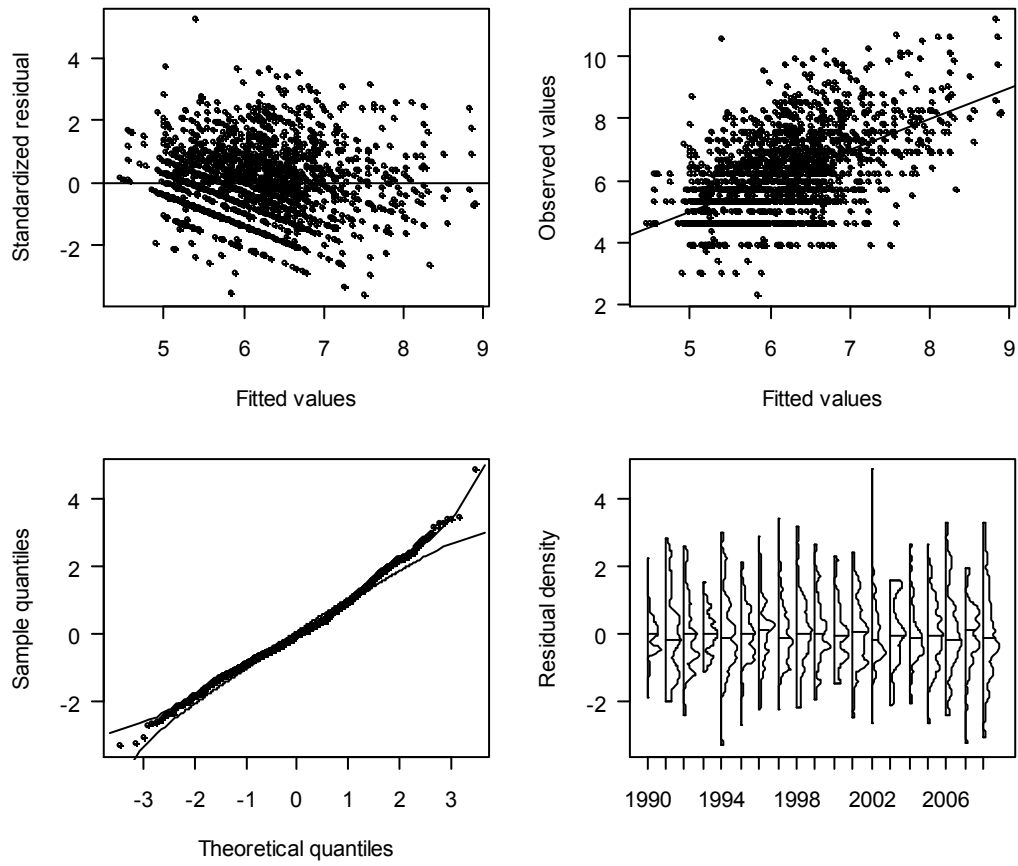
**Figure 64: CHATHAM RISE CPUE model 1 (tow-level dataset). Residual diagnostic plots describing the fit of the GLM CPUE model**



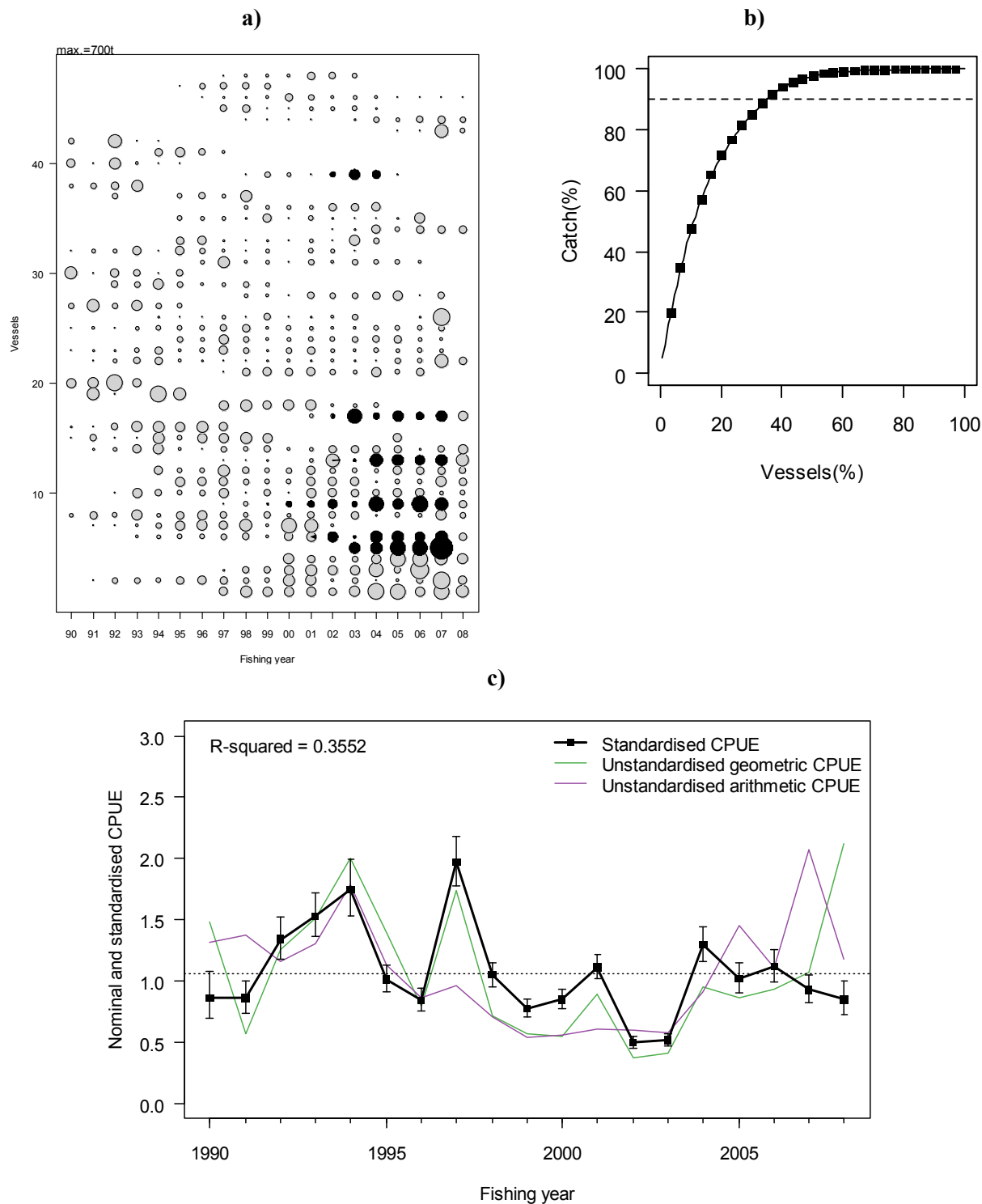
**Figure 65: CHATHAM RISE CPUE Model 2 (tow-level dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric, and standardised CPUE indices for SWA 1990–2008.**



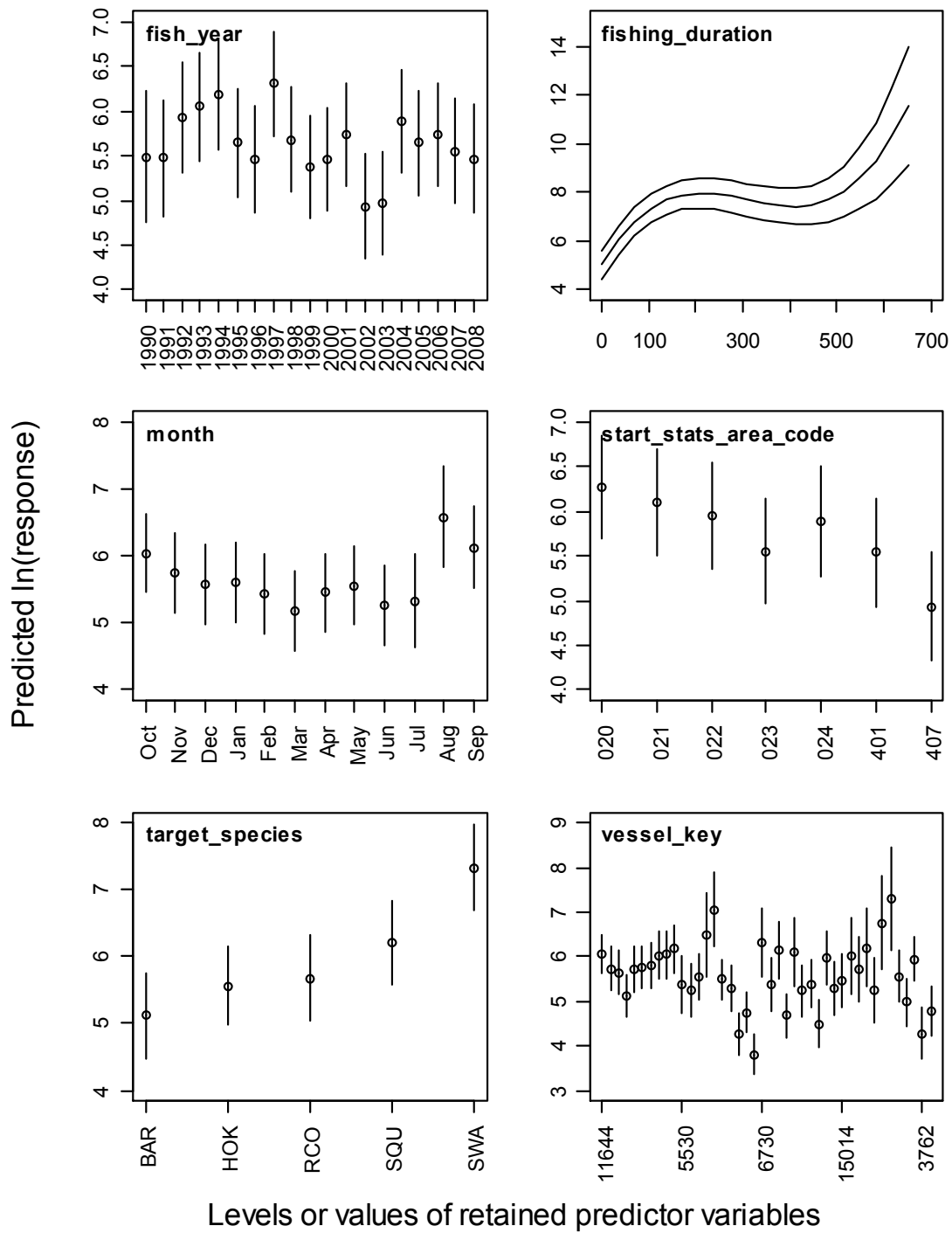
**Figure 66: CHATHAM RISE CPUE model 2 (tow-level dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.**



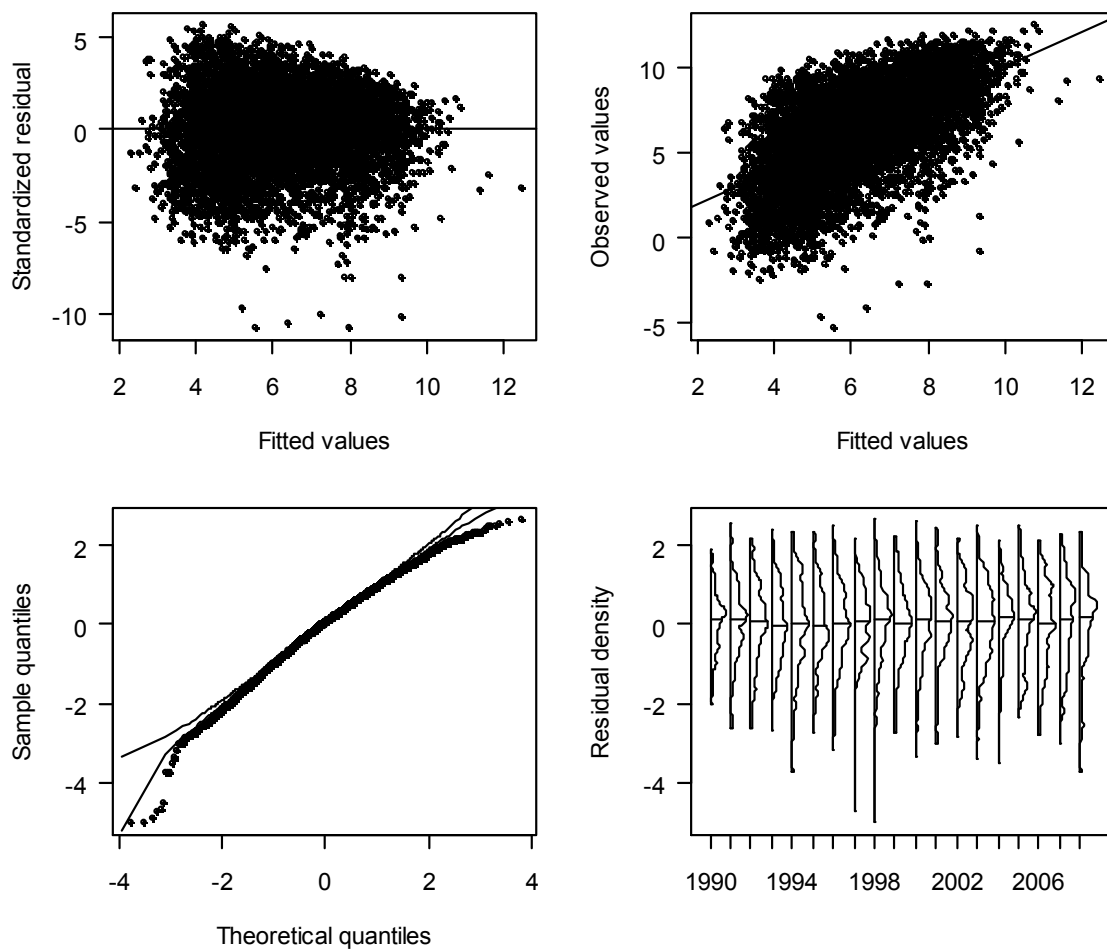
**Figure 67:** CHATHAM RISE CPUE Model 2 (tow-level dataset). Residual diagnostic plots describing the fit of the GLM CPUE model.



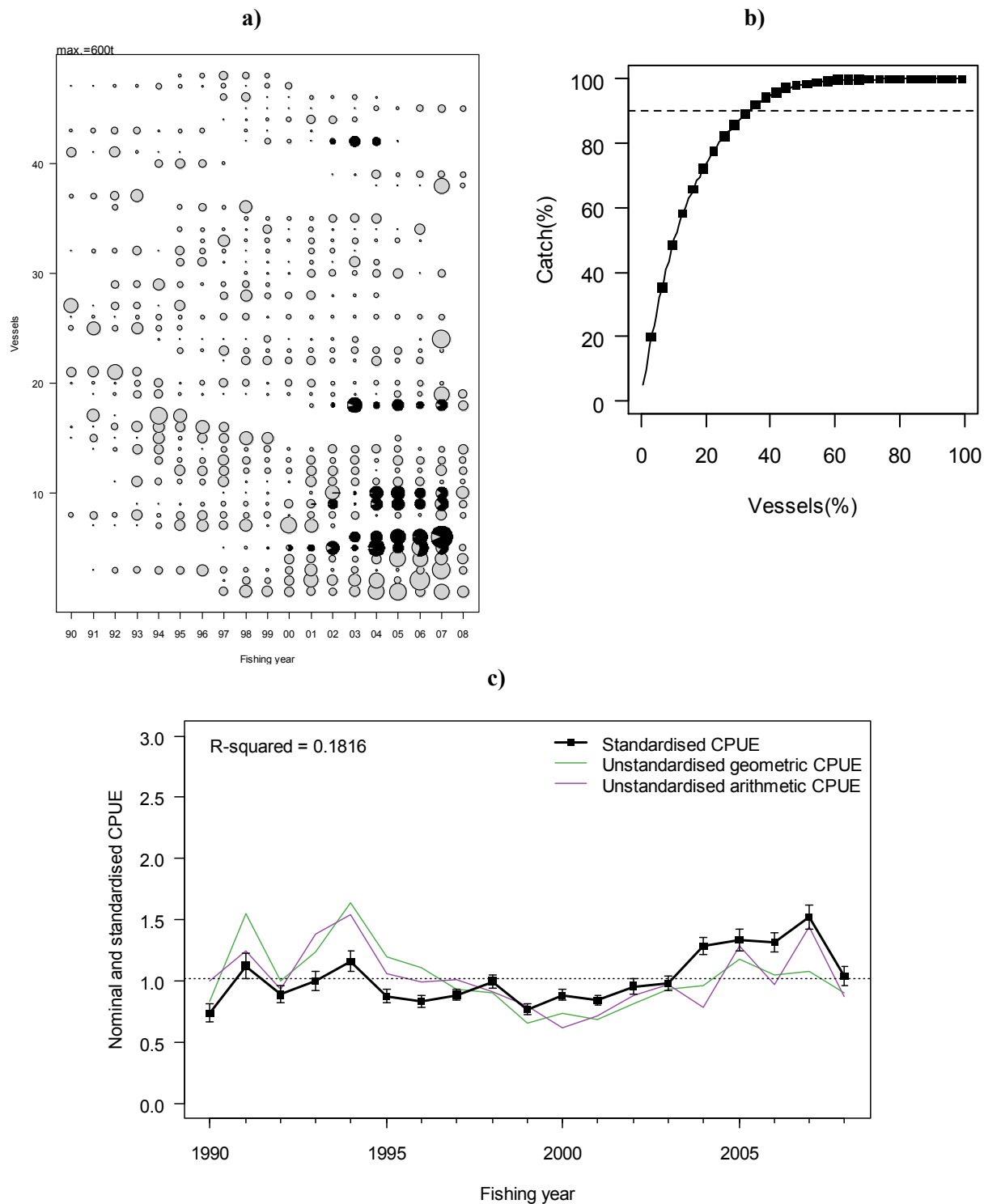
**Figure 68: EAST COAST SOUTH ISLAND CPUE Model 1 (stratified dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric and standardised CPUE indices for SWA 1990–2008.**



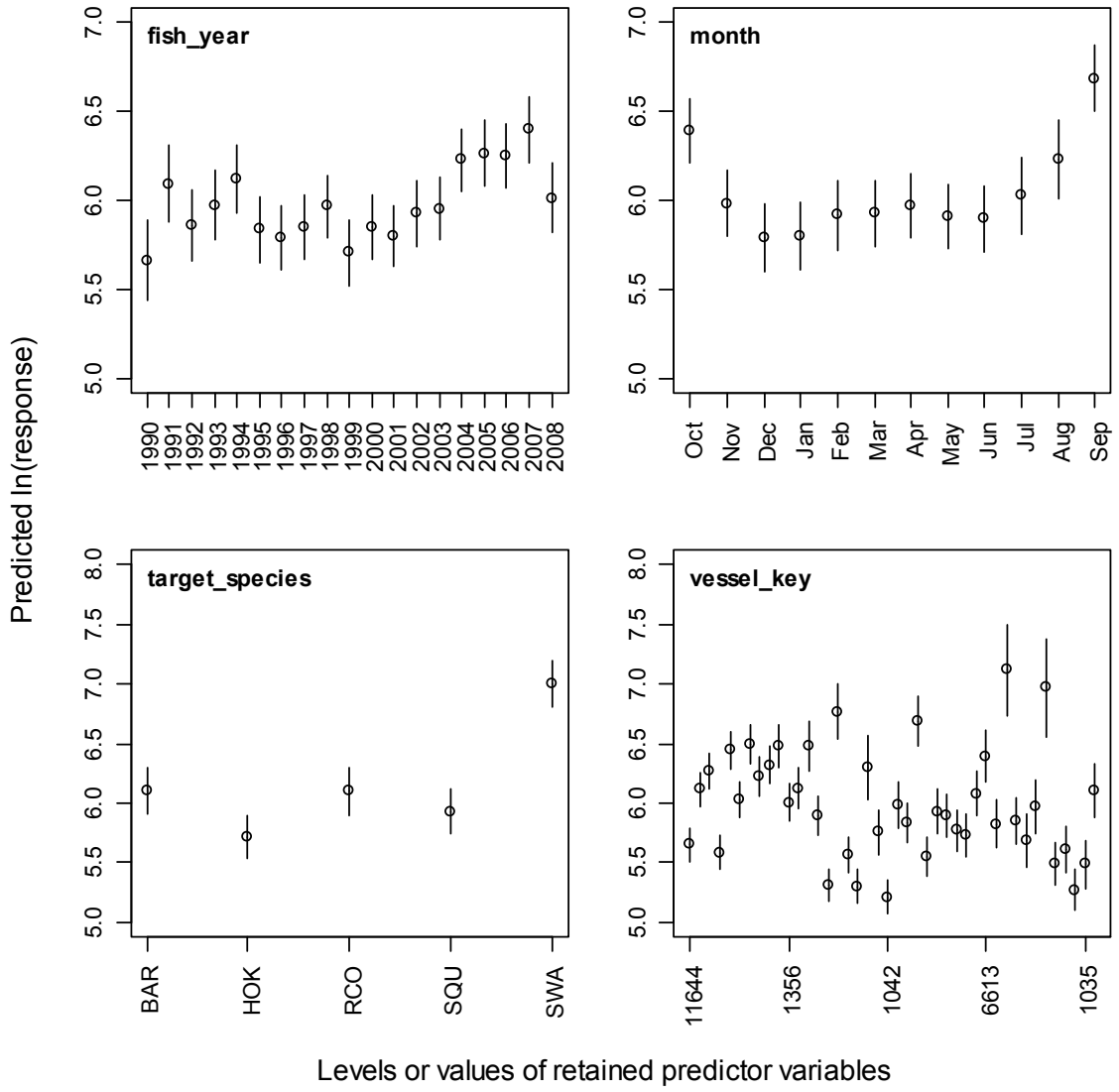
**Figure 69:** EAST COAST SOUTH ISLAND CPUE Model 1 (stratified dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.



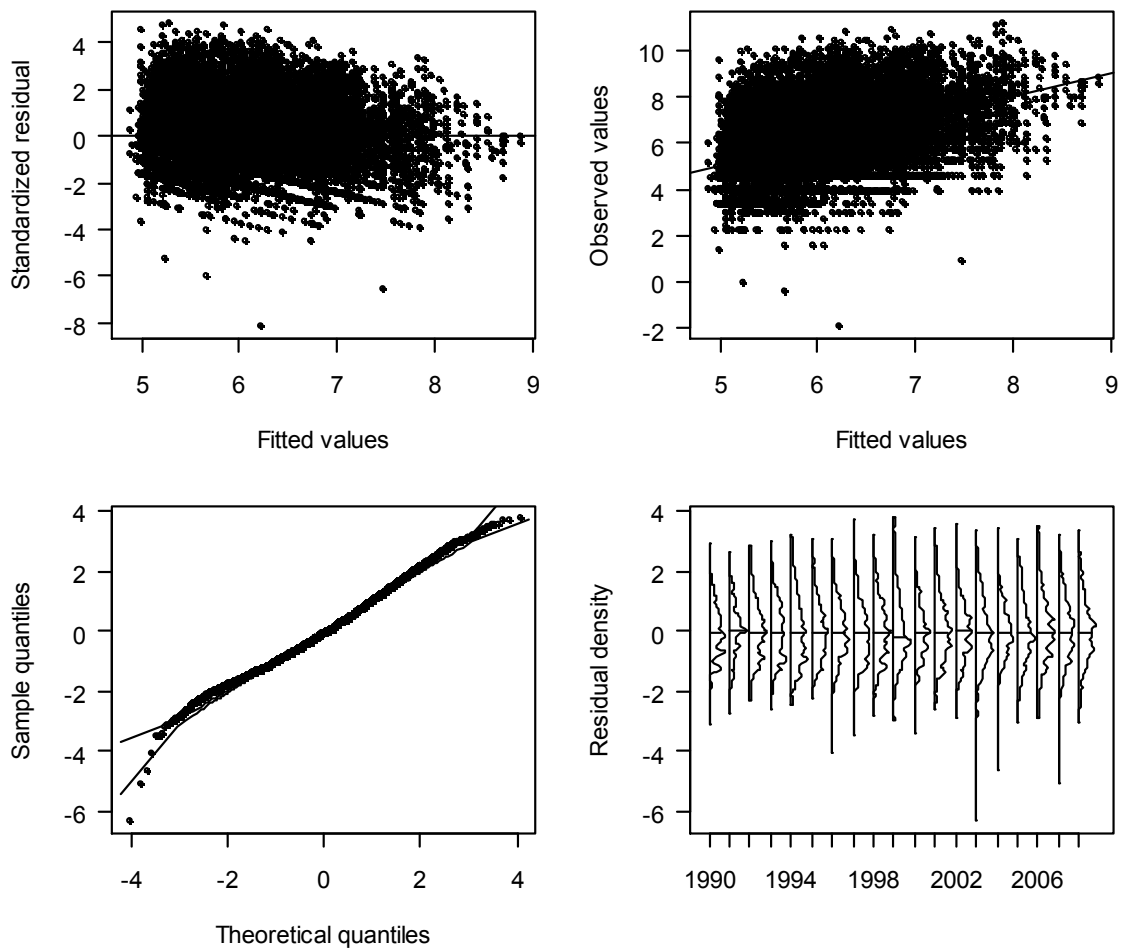
**Figure 70: EAST COAST SOUTH ISLAND CPUE Model 1 (stratified dataset). Residual diagnostic plots describing the fit of the GLM CPUE model**



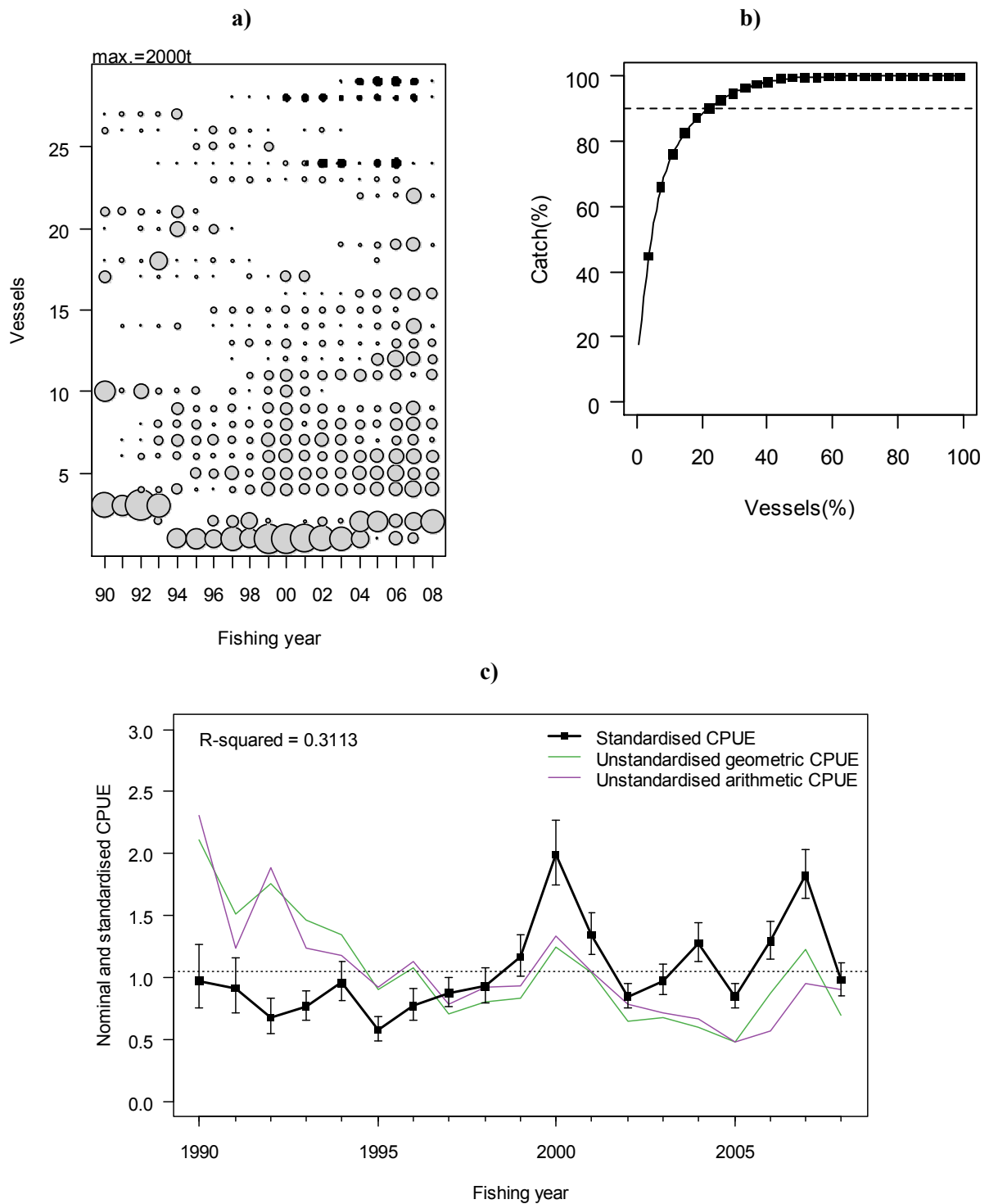
**Figure 71: EAST COAST SOUTH ISLAND CPUE Model 2 (tow-level dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric, and standardised CPUE indices for SWA 1990–2008.**



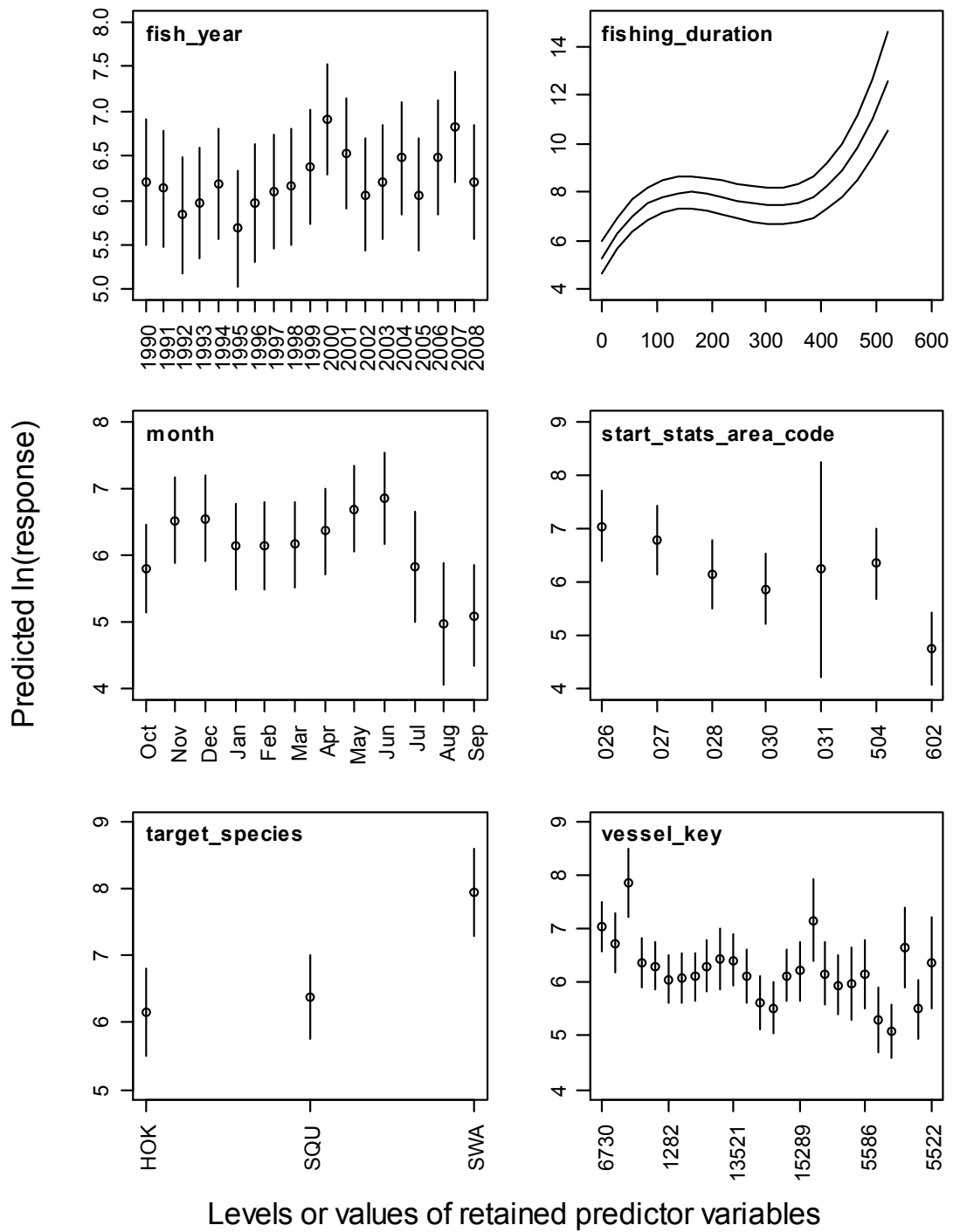
**Figure 72: EAST COAST SOUTH ISLAND CPUE Model 2 (tow-level dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.**



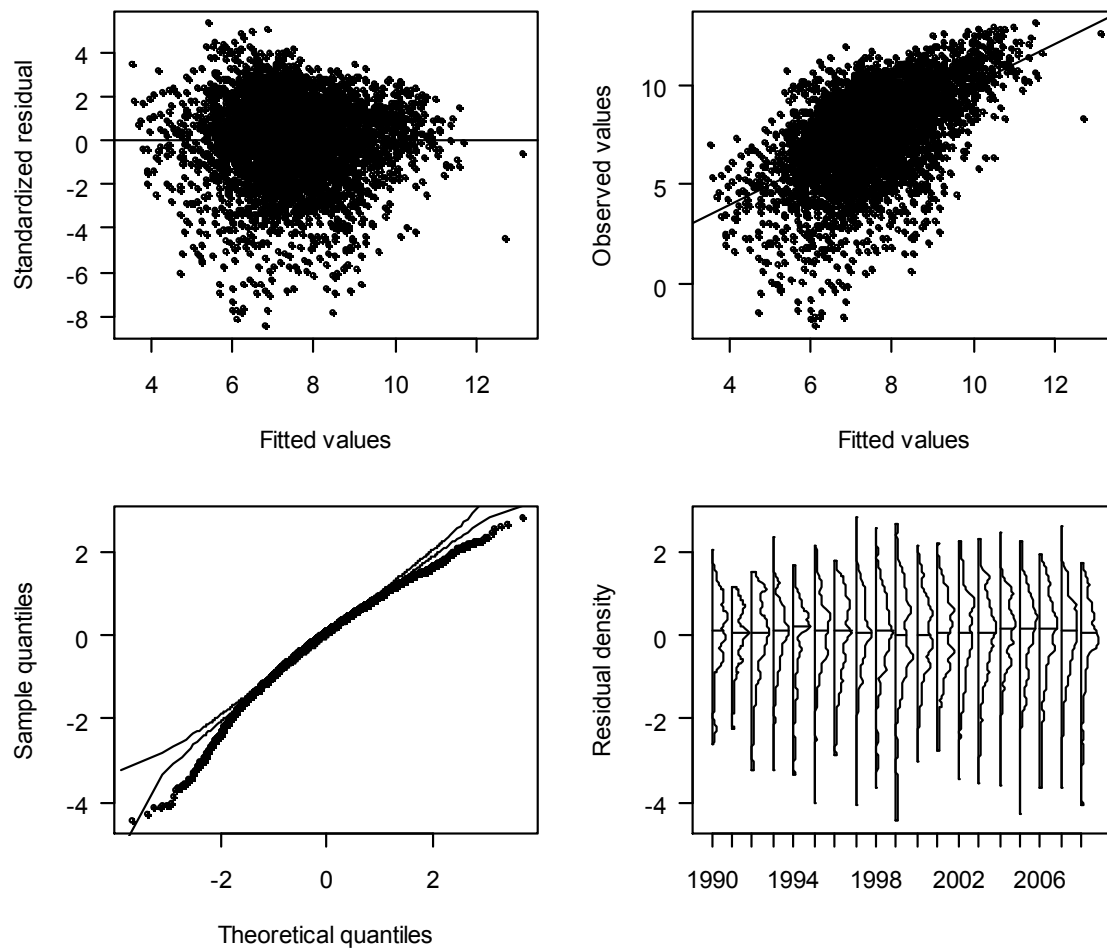
**Figure 73: EAST COAST SOUTH ISLAND CPUE Model 2 (tow-level dataset). Residual diagnostic plots describing the fit of the GLM CPUE model.**



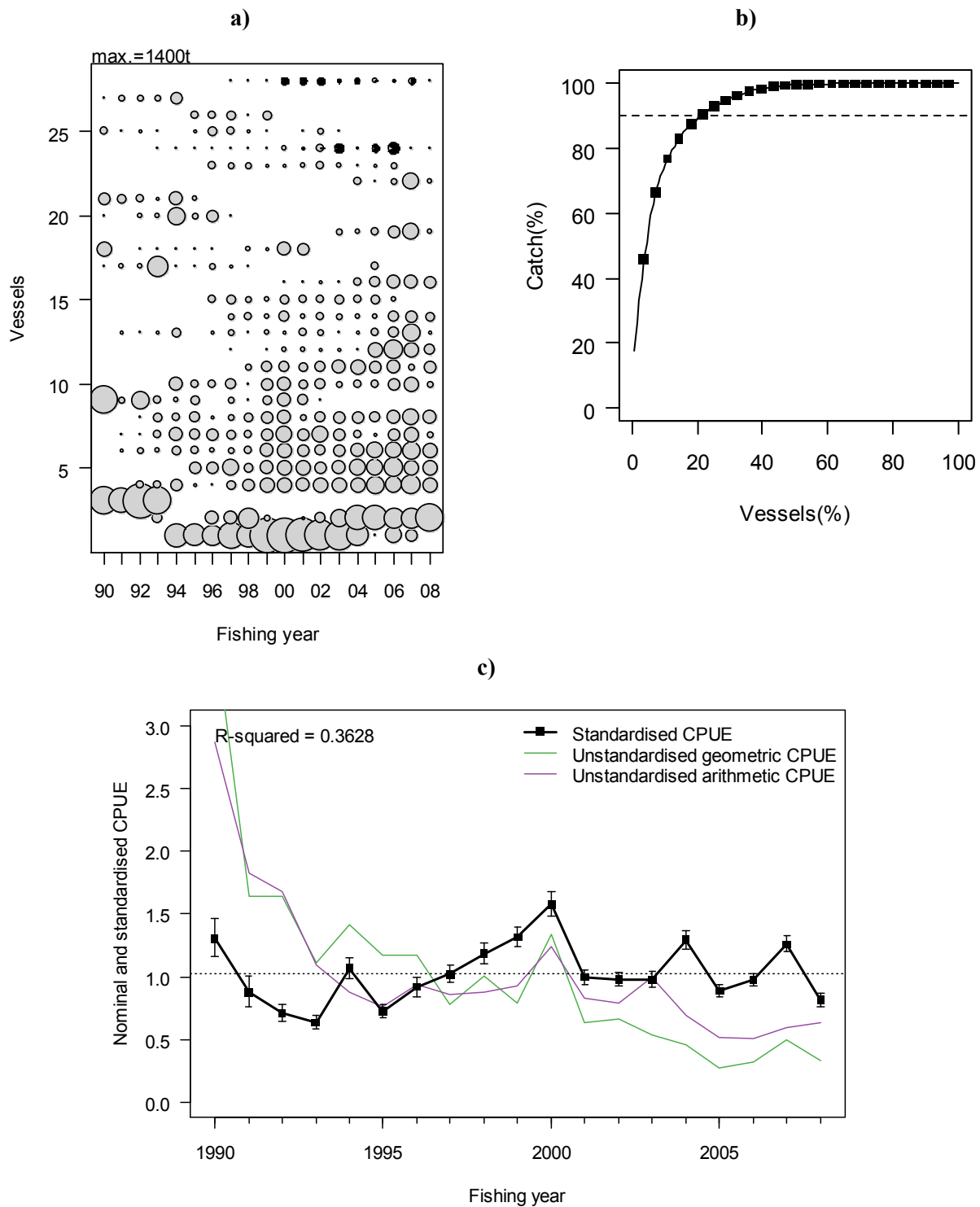
**Figure 74: SOUTHLAND CPUE Model 1 (stratified dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric, and standardised CPUE indices for SWA 1990–2008.**



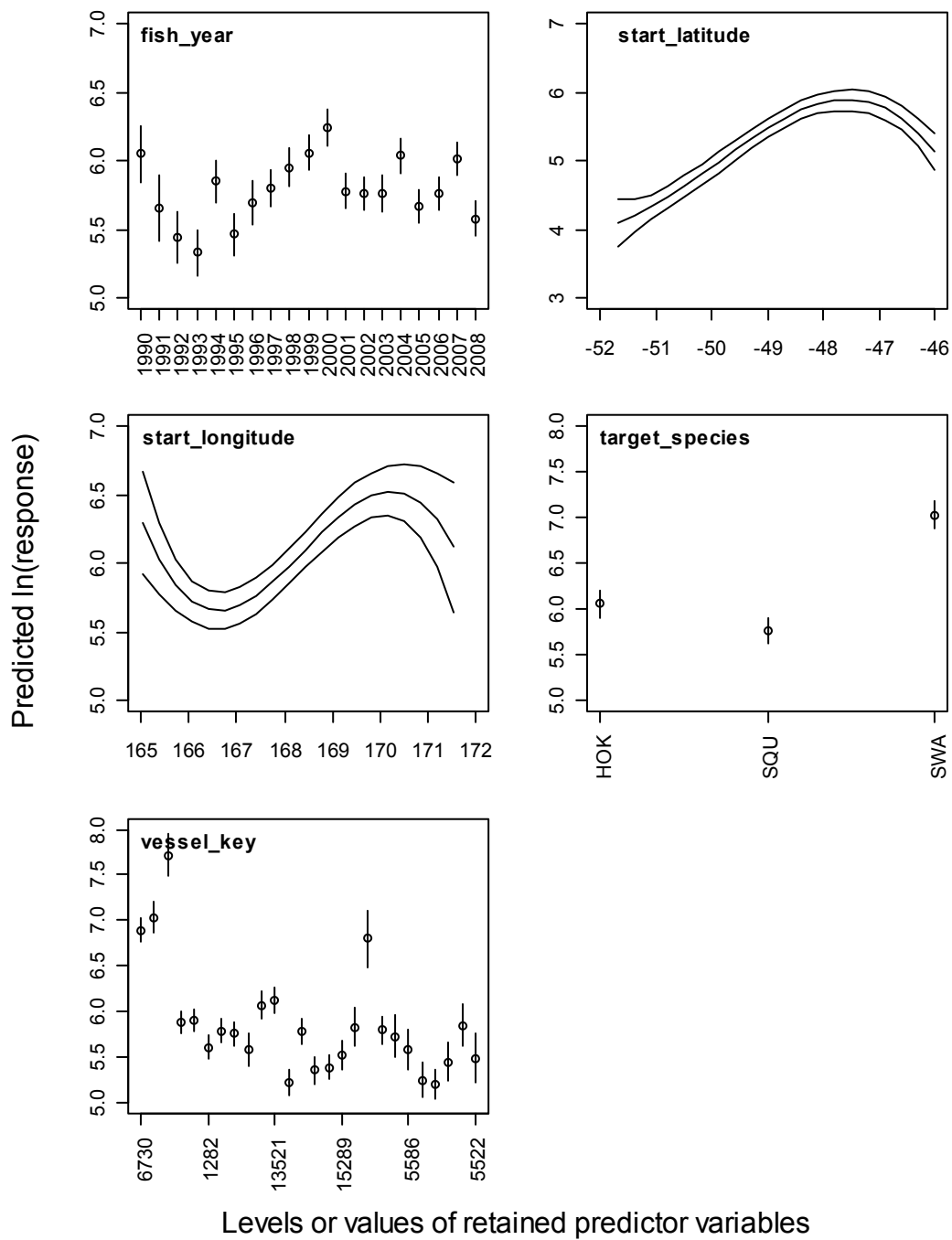
**Figure 75: SOUTHLAND CPUE Model 1 (stratified dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.**



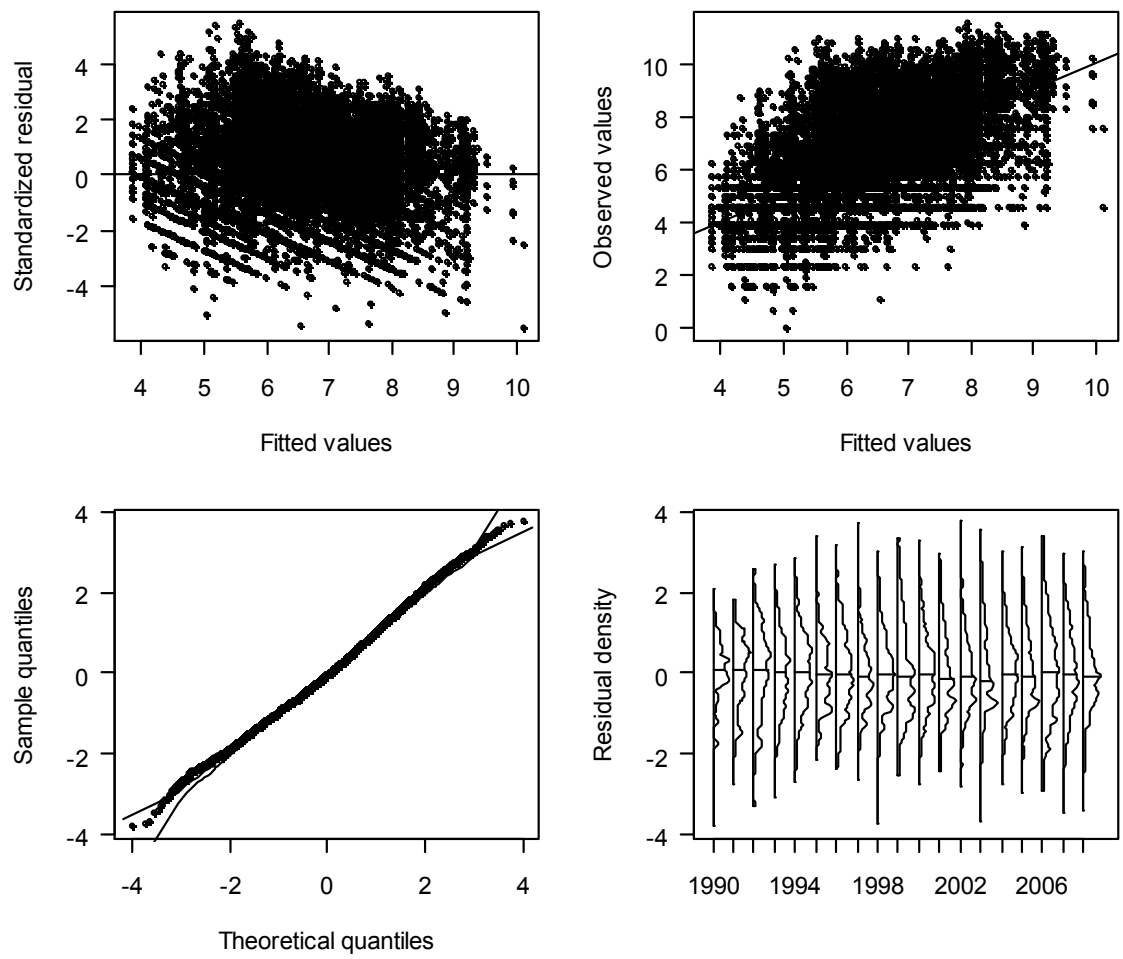
**Figure 76: SOUTHLAND CPUE Model 1 (stratified dataset). Residual diagnostic plots describing the fit of the GLM CPUE model**



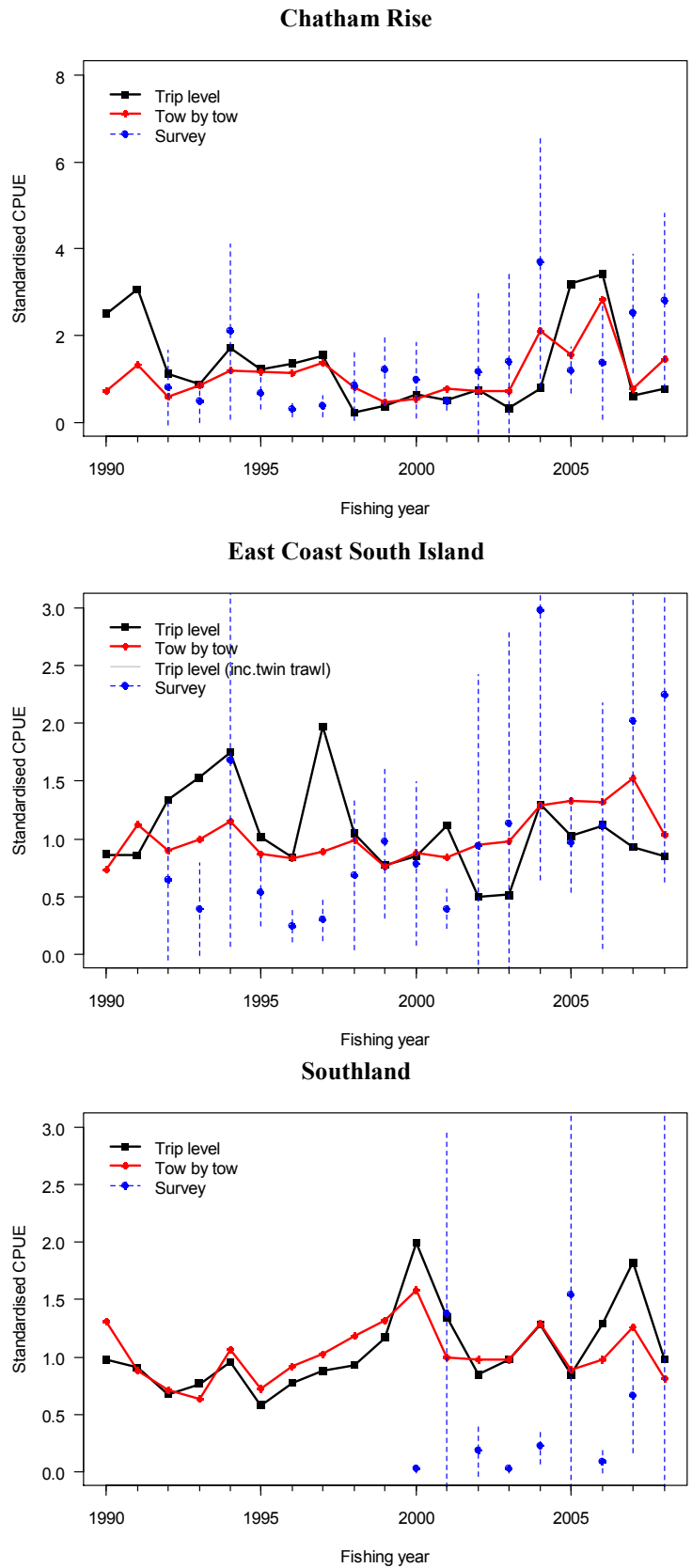
**Figure 77: SOUTHLAND CPUE Model 2 (tow-level dataset): a) scaled annual catch by vessel. Black shaded portions of symbols indicate the proportion of catch using twin trawl gear. b) Cumulative proportion of SWA catch ranked by vessel. c) arithmetic, geometric, and standardised CPUE indices for SWA 1990–2008.**



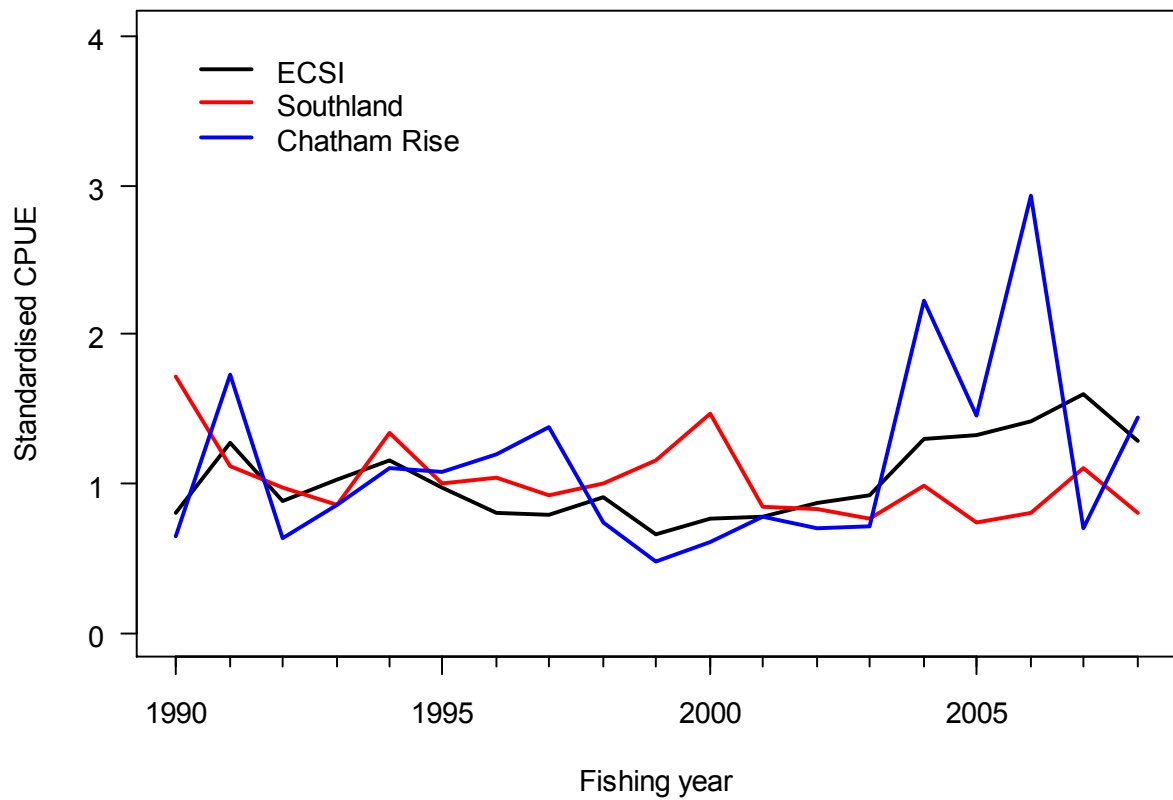
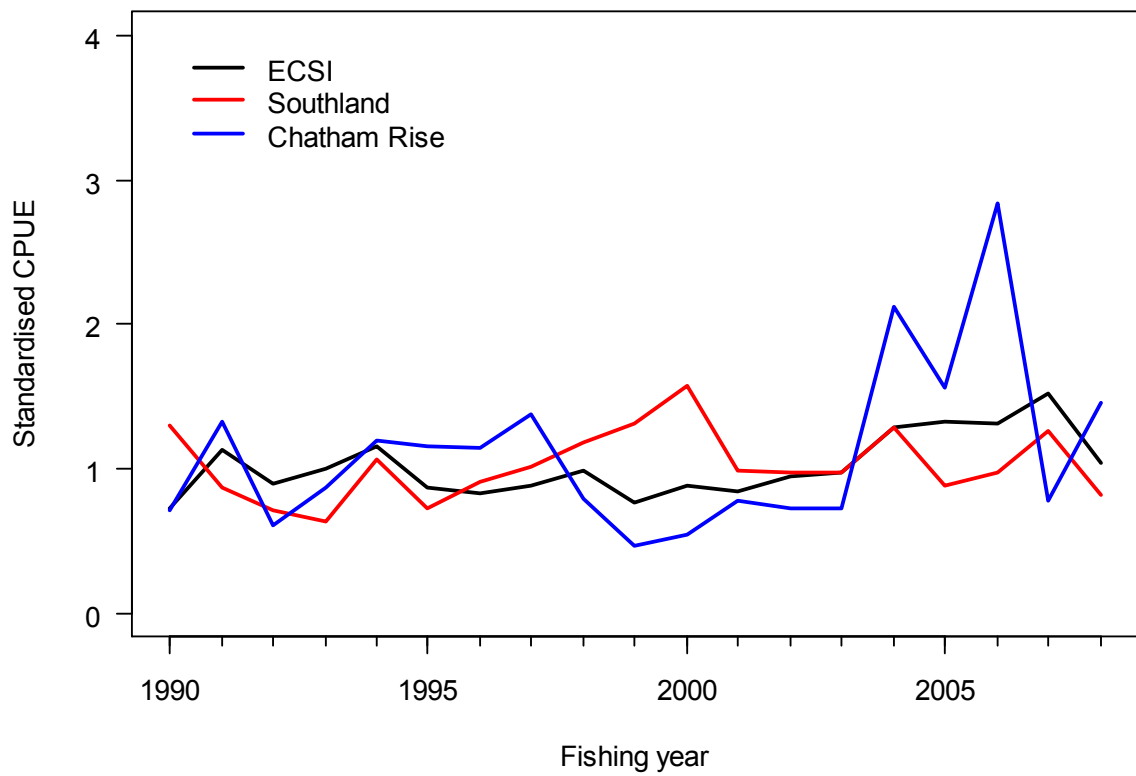
**Figure 78: SOUTHLAND CPUE Model 2 (tow-stratified dataset). Predictor variables retained in the GLM analysis and their distributions by factor levels.**



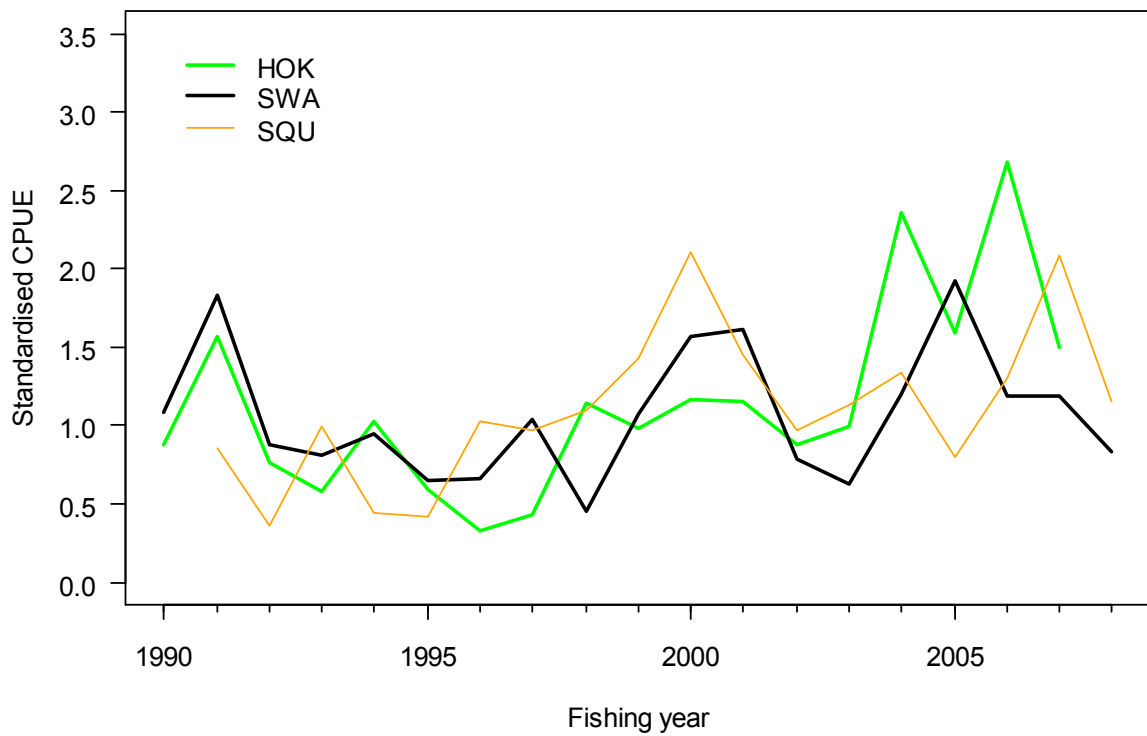
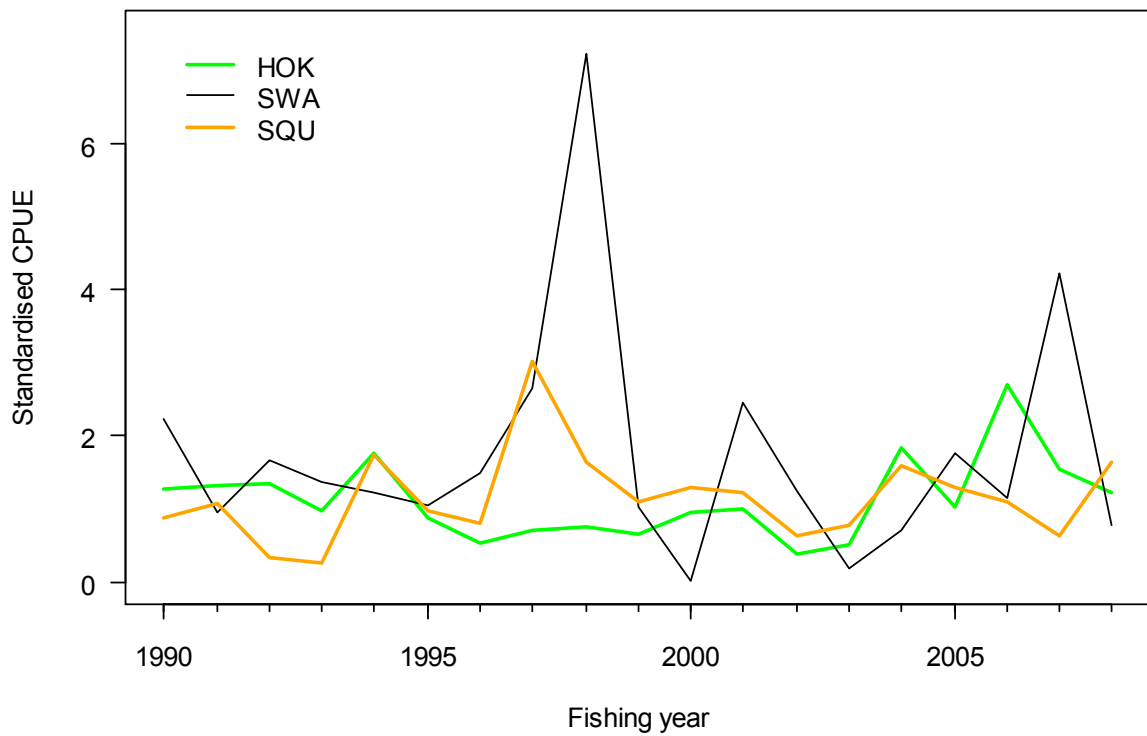
**Figure 79: SOUTHLAND CPUE Model 2 (tow-level dataset). Residual diagnostic plots describing the fit of the GLM CPUE model.**



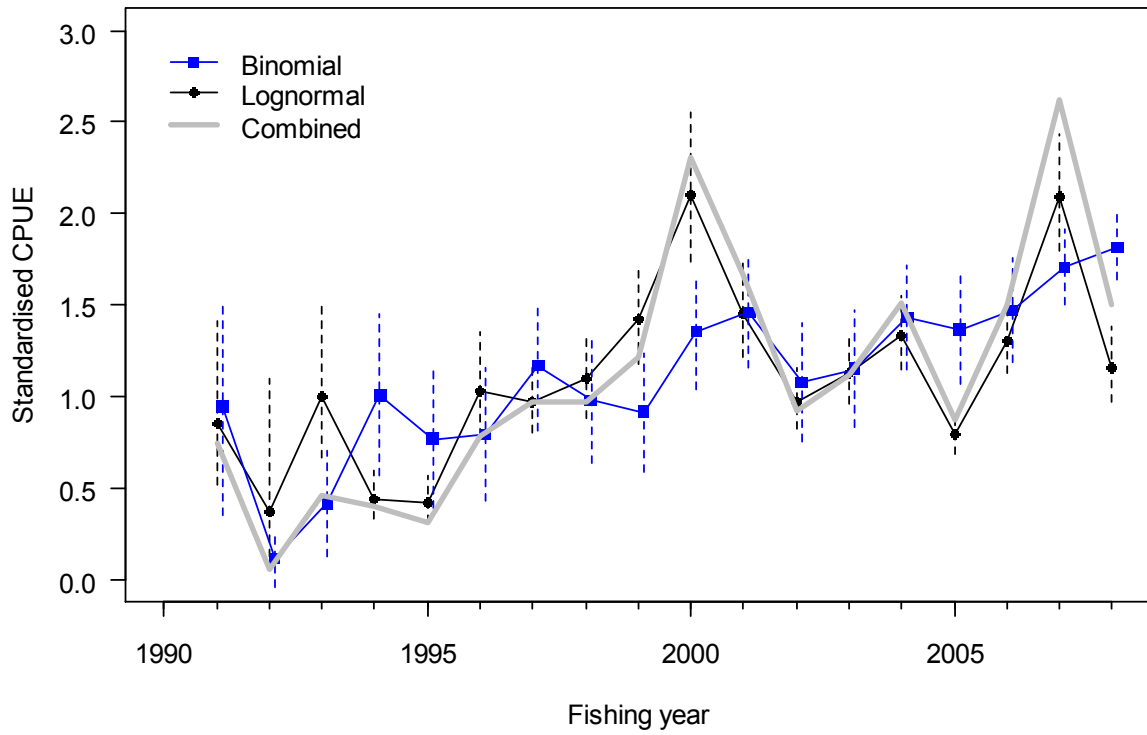
**Figure 80: Overlay of Canonical CPUE indices, standardised from Models 1, 2 and 3 (for ECSI only) along with biomass estimates and confidence intervals from the bottom trawl survey from Chatham Rise [upper and middle panels], and Sub-Antarctic [lower panel].**



**Figure 81:** Overlay of CPUE trends for the three areas from [upper panel] Model 2 (tow-level dataset, major target species offered) and [lower panel] Model 8 (tow-level dataset, target species removed). Note Chatham Rise Model 2 did not retain target species, so CPUE series is identical.

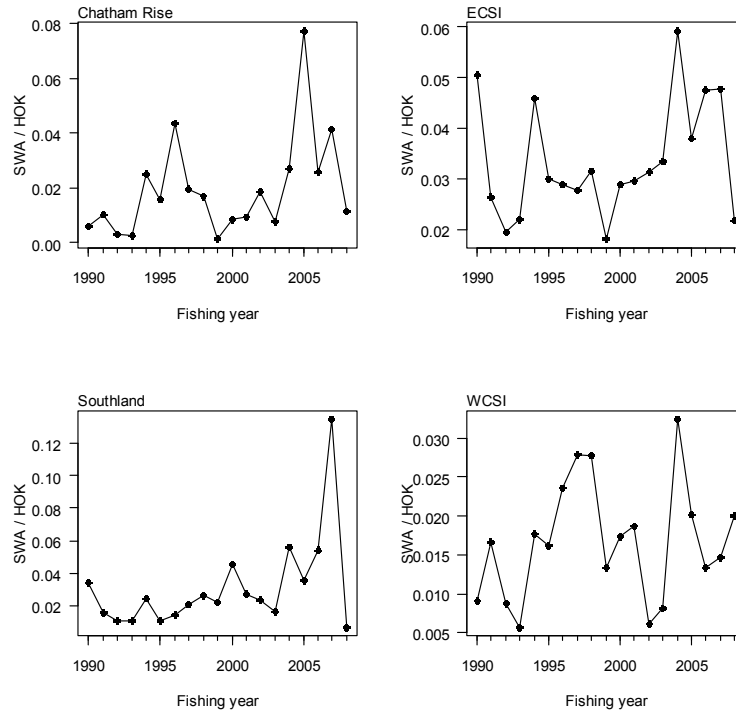


**Figure 82: Overlay of CPUE trends by the three main target species for [upper panel] ECSI and [lower panel] Southland. This combines CPUE trends from Models 4, 5, and 6. Note The proportion of catch for the ECSI area SWA target is very low from 1997 to 2004 (see Table A15).**

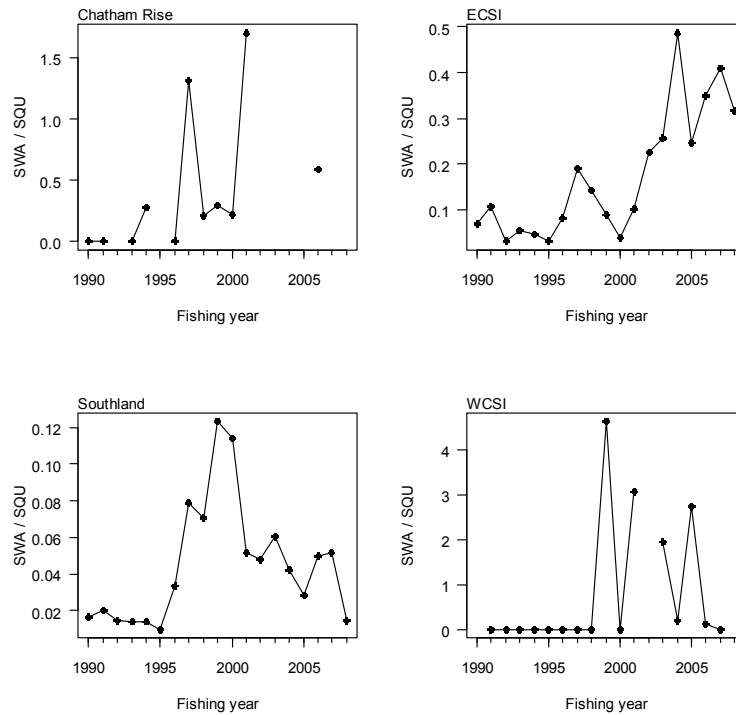


**Figure 83: Overlay plot of the effect of including a binomial model of the proportion of tows with zero catch on the lognormal CPUE estimated from Model 6 (target SQU fishery in Southland). The combined CPUE index is the result for Model 9.**

A



B



**Figure 84:** Plots by area of the SWA bycatch rate in units of kg SWA per kg target species for a) HOK, and b) SQU. Only tows targeting either HOK or SQU are included based on merged and re-stratified data. Note, tows catching no SWA are not included if the trip did not land any SWA. Bias due to this effect should be minor.

## APPENDIX A

**Table A1: Details of data corrections by imputation and invalid record removal during the grooming process for each QMA.**

### SWA 1

Imputations made	Records	Before	After	Difference	percentage		
Invalid start date	337277	417	159	258	0.08		
Invalid primary method	335601	373	156	217	0.06		
Invalid target species	335445	178	0	178	0.05		
Invalid stat area	335445	3883	0	3883	1.16		
Invalid latitude or longitude	305738	2895	345	2550	0.83		
Invalid effort depth (TCPER)	327709	1417	32	1385	0.42		
Invalid bottom depth (TCEPR)	327709	3679	624	3055	0.93		
Transpose bottom-effort depth	327709	16326	0	16326	4.98		
Invalid BT effort number	179450	391	1	390	0.22		
Invalid BT effort width	179450	7261	111	7150	3.98		
Invalid BT effort height	179450	6482	29	6453	3.60		
Invalid BT effort speed for TCPER	164136	260	0	260	0.16		
Invalid BT fishing duration	179450	1026	64	962	0.54		
Invalid MW effort number for TCPER	140891	132	0	132	0.09		
Invalid MW effort width for TCPER	140891	3565	4	3561	2.53		
Invalid MW effort height for TCPER	140891	422	0	422	0.30		
Invalid MW effort speed for TCPER	140891	447	0	447	0.32		
Invalid MW fishing duration for TCPER	140891	1184	11	1173	0.83		
Other misc	4933	280	164	116	2.35		
		Effort			Landings		
Records removed	Records	Trips	Catch	Records	Trips	Catch	
Original extract	338258	12958	52145	21242	13076	46106	
Missing vessel key	338257	12957	52145	21241	13075	46106	
Unmatched trip number	338257	12957	52145	21060	12957	45627	
Duplicate form number	337277	12891	52120	20983	12891	45598	
Invalid start date	335601	12855	51866	20911	12855	45439	
Invalid primary method	335445	12848	51862	20903	12848	45436	
Invalid target	335445	12848	51862	20903	12848	45436	
Invalid stats area	327709	12687	50442	20582	12687	44536	
Re-stratify by stat area, trip, target, method	50346	12687	50442	20582	12687	44536	
Remove interim landing codes	49673	12524	49333	19008	12524	37981	

**Table A1: Continued.****SWA3**

Imputations made	Records	Before	After	Difference	percentage			
Invalid start date	359362	349	131	218	0.06			
Invalid primary method	357508	220	84	136	0.04			
Invalid target species	357424	125	0	125	0.03			
Invalid stat area	357424	3313	0	3313	0.93			
Invalid latitude or longitude	334028	3678	286	3392	1.02			
Invalid effort depth (TCPER)	351167	312	0	312	0.09			
Invalid bottom depth (TCEPR)	351167	1521	509	1012	0.29			
Transpose bottom-effort depth	351167	14617	0	14617	4.16			
Invalid BT effort number	282420	172	0	172	0.06			
Invalid BT effort width	282420	12112	104	12008	4.25			
Invalid BT effort height	282420	8126	162	7964	2.82			
Invalid BT effort speed for TCPER	275621	1826	41	1785	0.65			
Invalid BT fishing duration	282420	2822	44	2778	0.98			
Invalid MW effort number for TCPER	58403	60	0	60	0.10			
Invalid MW effort width for TCPER	58403	1326	1	1325	2.27			
Invalid MW effort height for TCPER	58403	625	0	625	1.07			
Invalid MW effort speed for TCPER	58403	253	1	252	0.43			
Invalid MW fishing duration for TCPER	58403	443	1	442	0.76			
Other misc	23845	1640	68	1572	6.59			
Original extract	360439	14827	111899			26362	14939	69179
Missing vessel key	360439	14827	111899			26362	14939	69179
Unmatched trip number	360439	14827	111899			26195	14827	68800
Duplicate form number	359362	14681	111769			26018	14681	68743
Invalid start date	357508	14655	111477			25940	14655	68525
Invalid primary method	357424	14654	111475			25938	14654	68523
Invalid target	357424	14654	111475			25938	14654	68523
Invalid stats area	351167	14554	109674			25602	14554	67467
Re-stratify by stat area, trip, target, method	52614	14554	109674			25602	14554	67467
Remove interim landing codes	52103	14475	109244			24101	14475	61189

**Table A1: Continued.****SWA4**

Imputations made	Records	Before	After	Difference	percentage			
Invalid start date	430371	316	148	168	0.04			
Invalid primary method	428865	285	167	118	0.03			
Invalid target species	428698	63	0	63	0.01			
Invalid stat area	428698	2981	0	2981	0.70			
Invalid latitude or longitude	419876	4241	273	3968	0.95			
Invalid effort depth (TCPER)	420962	362	0	362	0.09			
Invalid bottom depth (TCEPR)	420962	2026	661	1365	0.32			
Transpose bottom-effort depth	420962	18870		18870	4.48			
Invalid BT effort number	313703	95	0	95	0.03			
Invalid BT effort width	313703	7183	50	7133	2.27			
Invalid BT effort height	313703	20965	137	20828	6.64			
Invalid BT effort speed for TCPER	313217	388	4	384	0.12			
Invalid BT fishing duration	313703	2068	100	1968	0.63			
Invalid MW effort number for TCPER	106655	55	0	55	0.05			
Invalid MW effort width for TCPER	106655	2030	55	1975	1.85			
Invalid MW effort height for TCPER	106655	207	0	207	0.19			
Invalid MW effort speed for TCPER	106655	247	2	245	0.23			
Invalid MW fishing duration for TCPER	106655	959	6	953	0.89			
Other misc	1515	89	89	0	0.00			
Original extract	430640	4995	121107			17515	5026	82087
Missing vessel key	430640	4995	121107			17515	5026	82087
Unmatched trip number	430640	4995	121107			17431	4995	81515
Duplicate form number	430371	4991	120983			17417	4991	81458
Invalid start date	428865	4977	120715			17360	4977	81411
Invalid primary method	428698	4973	120712			17354	4973	81407
Invalid target	428698	4973	120712			17354	4973	81407
Invalid stats area	420962	4881	118814			16995	4881	80541
Re-stratify by stat area, trip, target, method	40252	4881	118814			16995	4881	80541
Remove interim landing codes	39689	4794	118288			15252	4794	76335

**Table A2: Total catch by vessel nationality from groomed and merged data for fishing years 1990 – 2008.**

Fish year	Korea	NZ	Japan	Ukraine	Malta	Vanuatu	Panama	Belize	Russia	Unknown	Other	Total
1990	249	1178	4693	19	0	0	0	0	477	7	0	6623
1991	414	754	4558	36	0	27	0	0	306	0	13	6108
1992	671	947	4547	125	0	13	0	0	352	8	10	6673
1993	1686	1193	3072	254	8	2	0	5	492	0	22	6734
1994	3081	1524	1840	347	13	69	0	72	1107	6	103	8164
1995	2495	1340	1175	261	43	182	0	299	884	50	162	6890
1996	3453	2158	214	535	13	162	0	531	1275	98	157	8595
1997	4211	3000	89	1673	62	194	46	206	1858	278	508	12124
1998	2460	3401	2	1008	171	787	195	231	1923	45	411	10634
1999	2851	2140	0	545	121	452	102	325	1790	39	118	8484
2000	3095	3454	0	908	138	325	239	103	1936	0	186	10384
2001	3672	3202	0	572	288	376	305	0	2168	0	166	10748
2002	2924	2383	0	669	628	176	163	0	1651	0	126	8719
2003	3022	2353	0	613	525	275	209	0	1431	0	130	8557
2004	2555	3899	0	584	1236	198	367	0	1576	0	117	10533
2005	3515	4327	0	105	448	17	162	0	893	0	0	9468
2006	4208	3516	0	380	318	240	535	0	1173	26	0	10398
2007	7202	3779	0	324	495	233	0	0	1412	470	0	13915
2008	4216	2220	0	334	204	205	0	0	913	0	0	8093
Total	55979	46768	20189	9292	4710	3934	2324	1771	23618	1027	2232	171843

**Table A3: Proportion of catch reported each month from the Chatham Rise area for fishing years 1990–2008.**

Fish_year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.00	0.16	0.42	0.07	0.05	0.01	0.03	0.23	0.01	0.03	0.00	0.00	35
1991	0.00	0.03	0.14	0.79	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	308
1992	0.00	0.14	0.53	0.04	0.11	0.00	0.14	0.01	0.01	0.00	0.00	0.02	102
1993	0.12	0.01	0.02	0.08	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.16	253
1994	0.00	0.08	0.00	0.03	0.01	0.00	0.01	0.01	0.64	0.00	0.00	0.21	292
1995	0.16	0.16	0.01	0.36	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.15	275
1996	0.07	0.06	0.05	0.02	0.00	0.00	0.00	0.63	0.16	0.00	0.00	0.00	633
1997	0.02	0.50	0.16	0.00	0.00	0.00	0.01	0.17	0.06	0.07	0.00	0.00	486
1998	0.08	0.48	0.12	0.02	0.00	0.00	0.01	0.04	0.09	0.07	0.00	0.08	219
1999	0.05	0.11	0.02	0.06	0.02	0.07	0.52	0.02	0.00	0.00	0.00	0.12	124
2000	0.07	0.02	0.40	0.24	0.03	0.06	0.14	0.03	0.01	0.00	0.00	0.00	302
2001	0.06	0.11	0.22	0.12	0.01	0.15	0.27	0.00	0.00	0.00	0.00	0.05	385
2002	0.06	0.12	0.19	0.13	0.16	0.01	0.02	0.12	0.00	0.01	0.03	0.16	389
2003	0.08	0.11	0.17	0.09	0.09	0.12	0.30	0.02	0.00	0.01	0.00	0.02	496
2004	0.03	0.16	0.36	0.10	0.09	0.03	0.10	0.05	0.03	0.05	0.00	0.02	359
2005	0.06	0.24	0.11	0.20	0.03	0.03	0.01	0.20	0.03	0.00	0.05	0.05	898
2006	0.09	0.19	0.05	0.13	0.03	0.07	0.01	0.01	0.43	0.00	0.01	0.01	546
2007	0.02	0.10	0.13	0.34	0.06	0.04	0.06	0.06	0.03	0.06	0.00	0.08	391
2008	0.03	0.12	0.08	0.11	0.03	0.01	0.03	0.17	0.00	0.03	0.26	0.12	539
Total	0.06	0.16	0.14	0.16	0.04	0.04	0.07	0.13	0.11	0.02	0.03	0.06	7 032

**Table A4: Proportion of catch reported for each statistical area from the Chatham Rise area for fishing years 1990–2008.**

Fish_year	49	50	51	52	403	404	409	410	412	Other	Total
1990	0.35	0.07	0.00	0.05	0.00	0.50	0.00	0.00	0.00	0.03	35
1991	0.14	0.08	0.00	0.01	0.02	0.01	0.00	0.74	0.00	0.00	308
1992	0.20	0.25	0.00	0.01	0.00	0.40	0.01	0.11	0.00	0.01	102
1993	0.06	0.00	0.00	0.00	0.00	0.31	0.00	0.62	0.00	0.00	253
1994	0.05	0.03	0.00	0.02	0.00	0.26	0.01	0.62	0.00	0.00	292
1995	0.06	0.09	0.00	0.34	0.02	0.44	0.01	0.01	0.00	0.03	275
1996	0.48	0.01	0.00	0.26	0.01	0.12	0.00	0.08	0.03	0.01	633
1997	0.15	0.06	0.00	0.16	0.00	0.54	0.02	0.08	0.00	0.00	486
1998	0.04	0.05	0.01	0.20	0.02	0.31	0.01	0.37	0.00	0.00	219
1999	0.55	0.01	0.09	0.02	0.01	0.20	0.03	0.09	0.00	0.00	124
2000	0.54	0.07	0.06	0.19	0.07	0.05	0.01	0.01	0.00	0.00	302
2001	0.25	0.16	0.03	0.35	0.01	0.14	0.04	0.03	0.00	0.00	385
2002	0.14	0.10	0.03	0.12	0.00	0.21	0.03	0.37	0.00	0.00	389
2003	0.47	0.10	0.14	0.17	0.02	0.08	0.00	0.02	0.00	0.00	496
2004	0.23	0.12	0.11	0.14	0.03	0.04	0.24	0.10	0.00	0.00	359
2005	0.08	0.05	0.07	0.27	0.02	0.13	0.04	0.34	0.00	0.00	898
2006	0.22	0.11	0.05	0.45	0.01	0.05	0.03	0.08	0.00	0.00	546
2007	0.07	0.05	0.04	0.07	0.07	0.13	0.31	0.26	0.00	0.00	391
2008	0.27	0.13	0.00	0.08	0.03	0.36	0.06	0.06	0.00	0.00	539
Total	0.22	0.08	0.04	0.19	0.02	0.19	0.05	0.21	0.00	0.00	7 032

**Table A5: Proportion of catch reported by gear type from the Chatham Rise area for fishing years 1990–2008.**

Fish_year	BLL	BT	MW	SN	Other	Total
1990	0.00	1.00	0.00	0.00	0.00	35
1991	0.00	1.00	0.00	0.00	0.00	308
1992	0.00	0.98	0.02	0.00	0.00	102
1993	0.00	0.93	0.07	0.00	0.00	253
1994	0.00	0.99	0.01	0.00	0.00	292
1995	0.00	0.91	0.09	0.00	0.00	275
1996	0.00	0.68	0.32	0.00	0.00	633
1997	0.00	0.99	0.01	0.00	0.00	486
1998	0.00	1.00	0.00	0.00	0.00	219
1999	0.00	0.46	0.54	0.00	0.00	124
2000	0.00	0.40	0.60	0.00	0.00	302
2001	0.00	0.79	0.21	0.00	0.00	385
2002	0.00	1.00	0.00	0.00	0.00	389
2003	0.00	0.58	0.42	0.00	0.00	496
2004	0.00	0.83	0.17	0.00	0.00	359
2005	0.00	0.98	0.02	0.00	0.00	898
2006	0.00	0.93	0.07	0.00	0.00	546
2007	0.00	1.00	0.00	0.00	0.00	391
2008	0.00	0.99	0.01	0.00	0.00	539
Total	0.00	0.87	0.13	0.00	0.00	7 032

**Table A6: Proportion of catch reported by target species from the Chatham Rise area for fishing years 1990–2008.**

Fish_year	BAR	HAK	HOK	JMA	LIN	SQU	STA	SWA	TAR	Other	Total
1990	0.07	0.50	0.09	0.00	0.00	0.00	0.00	0.27	0.00	0.06	35
1991	0.03	0.01	0.07	0.00	0.00	0.00	0.00	0.86	0.00	0.02	308
1992	0.14	0.35	0.10	0.00	0.00	0.00	0.00	0.25	0.00	0.16	102
1993	0.00	0.31	0.03	0.00	0.00	0.00	0.00	0.60	0.00	0.05	253
1994	0.07	0.17	0.25	0.00	0.00	0.02	0.00	0.49	0.00	0.00	292
1995	0.04	0.35	0.54	0.00	0.00	0.00	0.00	0.06	0.00	0.01	275
1996	0.21	0.11	0.16	0.02	0.00	0.00	0.00	0.45	0.00	0.05	633
1997	0.08	0.51	0.16	0.01	0.00	0.17	0.00	0.07	0.00	0.00	486
1998	0.11	0.15	0.56	0.03	0.00	0.07	0.04	0.05	0.00	0.00	219
1999	0.51	0.09	0.20	0.00	0.05	0.02	0.00	0.03	0.00	0.10	124
2000	0.30	0.06	0.23	0.26	0.01	0.03	0.06	0.00	0.00	0.05	302
2001	0.16	0.09	0.19	0.08	0.02	0.24	0.00	0.09	0.11	0.03	385
2002	0.07	0.12	0.19	0.12	0.07	0.00	0.18	0.18	0.03	0.04	389
2003	0.36	0.06	0.09	0.10	0.02	0.02	0.02	0.05	0.12	0.15	496
2004	0.17	0.05	0.49	0.00	0.00	0.00	0.01	0.04	0.15	0.09	359
2005	0.01	0.14	0.40	0.00	0.01	0.00	0.08	0.25	0.07	0.05	898
2006	0.09	0.02	0.11	0.01	0.10	0.02	0.00	0.42	0.15	0.08	546
2007	0.01	0.05	0.61	0.00	0.12	0.00	0.00	0.13	0.03	0.05	391
2008	0.05	0.12	0.16	0.02	0.33	0.00	0.00	0.23	0.08	0.01	539
Total	0.12	0.14	0.25	0.03	0.05	0.03	0.03	0.24	0.05	0.05	7 032

**East Coast South Island**

**Table A7: Proportion of catch reported each month from the east coast South Island area for fishing years 1990–2008.**

Fish_year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.01	0.07	0.05	0.00	0.02	0.05	0.11	0.21	0.06	0.01	0.06	0.36	1 215
1991	0.34	0.11	0.04	0.04	0.00	0.01	0.02	0.10	0.17	0.01	0.08	0.08	1 571
1992	0.09	0.03	0.05	0.08	0.04	0.07	0.14	0.21	0.03	0.04	0.04	0.18	2 343
1993	0.05	0.02	0.03	0.12	0.09	0.29	0.07	0.09	0.03	0.01	0.11	0.09	2 635
1994	0.20	0.10	0.14	0.12	0.04	0.09	0.06	0.09	0.08	0.00	0.04	0.04	2 328
1995	0.23	0.09	0.06	0.10	0.03	0.03	0.02	0.07	0.06	0.00	0.10	0.21	2 284
1996	0.13	0.02	0.06	0.04	0.03	0.07	0.12	0.21	0.05	0.00	0.03	0.25	2 425
1997	0.11	0.09	0.04	0.05	0.03	0.10	0.12	0.15	0.02	0.04	0.00	0.24	3 532
1998	0.14	0.05	0.02	0.05	0.10	0.06	0.13	0.15	0.06	0.00	0.00	0.24	3 343
1999	0.18	0.13	0.06	0.04	0.09	0.08	0.14	0.12	0.01	0.01	0.03	0.11	2 028
2000	0.15	0.07	0.06	0.10	0.07	0.10	0.12	0.19	0.02	0.00	0.00	0.11	2 473
2001	0.13	0.04	0.05	0.02	0.06	0.17	0.11	0.10	0.04	0.02	0.00	0.26	3 031
2002	0.19	0.05	0.03	0.02	0.02	0.04	0.18	0.09	0.00	0.00	0.00	0.37	2 244
2003	0.19	0.04	0.03	0.05	0.06	0.04	0.11	0.13	0.04	0.00	0.03	0.31	2 830
2004	0.15	0.01	0.08	0.04	0.02	0.05	0.17	0.09	0.07	0.10	0.04	0.18	3 287
2005	0.05	0.01	0.03	0.06	0.06	0.02	0.28	0.17	0.07	0.01	0.06	0.19	3 413
2006	0.07	0.03	0.03	0.08	0.03	0.08	0.28	0.25	0.09	0.02	0.00	0.03	3 595
2007	0.14	0.12	0.02	0.06	0.05	0.04	0.22	0.18	0.10	0.00	0.01	0.04	5 465
2008	0.09	0.02	0.06	0.07	0.02	0.01	0.25	0.14	0.06	0.08	0.03	0.17	2 689
Total	0.13	0.06	0.05	0.06	0.05	0.07	0.15	0.15	0.06	0.02	0.03	0.17	52 732

**Table A8: Proportion of catch reported for each statistical area from the East Coast South Island area for fishing years 1990–2008.**

Fish_year	16	18	20	21	22	23	24	401	407	Other	Total
1990	0.00	0.00	0.27	0.14	0.40	0.12	0.01	0.06	0.00	0.00	1 215
1991	0.00	0.01	0.18	0.09	0.45	0.03	0.01	0.18	0.05	0.01	1 571
1992	0.00	0.01	0.26	0.07	0.27	0.12	0.04	0.18	0.04	0.00	2 343
1993	0.01	0.01	0.16	0.25	0.14	0.03	0.03	0.30	0.05	0.02	2 635
1994	0.01	0.05	0.18	0.12	0.41	0.05	0.06	0.07	0.05	0.00	2 328
1995	0.02	0.04	0.23	0.17	0.22	0.04	0.05	0.18	0.02	0.02	2 284
1996	0.03	0.11	0.25	0.26	0.19	0.03	0.02	0.07	0.01	0.02	2 425
1997	0.03	0.06	0.32	0.18	0.27	0.03	0.04	0.04	0.00	0.02	3 532
1998	0.02	0.05	0.42	0.15	0.20	0.04	0.03	0.05	0.01	0.03	3 343
1999	0.02	0.03	0.41	0.13	0.19	0.04	0.04	0.09	0.01	0.04	2 028
2000	0.02	0.08	0.41	0.09	0.20	0.09	0.02	0.05	0.03	0.02	2 473
2001	0.01	0.02	0.36	0.12	0.22	0.15	0.01	0.04	0.06	0.02	3 031
2002	0.01	0.01	0.51	0.23	0.11	0.04	0.00	0.03	0.01	0.04	2 244
2003	0.01	0.02	0.46	0.10	0.22	0.04	0.02	0.10	0.01	0.03	2 830
2004	0.02	0.02	0.40	0.08	0.24	0.10	0.01	0.06	0.02	0.05	3 287
2005	0.02	0.01	0.29	0.05	0.48	0.05	0.02	0.03	0.02	0.03	3 413
2006	0.01	0.02	0.21	0.05	0.43	0.13	0.00	0.02	0.04	0.07	3 595
2007	0.02	0.00	0.23	0.02	0.52	0.10	0.00	0.02	0.04	0.05	5 465
2008	0.02	0.01	0.27	0.06	0.40	0.09	0.00	0.04	0.06	0.04	2 689
Total	0.02	0.03	0.31	0.12	0.30	0.07	0.02	0.08	0.03	0.03	52 732

**Table A9: Proportion of catch reported by gear type from the East Coast South Island area for fishing years 1990–2008.**

Fish_year	BLL	BPT	BT	CP	DL	DS	MW	RLP	SN	Other	Total
1990	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 215
1991	0.00	0.00	0.98	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1 571
1992	0.00	0.00	0.99	0.00	0.00	0.00	0.01	0.00	0.00	0.00	2 343
1993	0.00	0.00	0.90	0.00	0.00	0.00	0.10	0.00	0.00	0.00	2 635
1994	0.00	0.00	0.94	0.00	0.00	0.00	0.05	0.00	0.01	0.00	2 328
1995	0.00	0.00	0.92	0.00	0.00	0.00	0.07	0.00	0.01	0.00	2 284
1996	0.00	0.00	0.90	0.00	0.00	0.00	0.09	0.00	0.01	0.00	2 425
1997	0.00	0.00	0.90	0.00	0.00	0.00	0.10	0.00	0.00	0.00	3 532
1998	0.00	0.00	0.85	0.00	0.00	0.00	0.15	0.00	0.00	0.00	3 343
1999	0.00	0.00	0.89	0.00	0.00	0.00	0.11	0.00	0.00	0.00	2 028
2000	0.00	0.00	0.94	0.00	0.00	0.00	0.06	0.00	0.00	0.00	2 473
2001	0.00	0.00	0.97	0.00	0.00	0.00	0.03	0.00	0.00	0.00	3 031
2002	0.00	0.00	0.97	0.00	0.00	0.00	0.03	0.00	0.00	0.00	2 244
2003	0.00	0.00	0.94	0.00	0.00	0.00	0.06	0.00	0.00	0.00	2 830
2004	0.00	0.00	0.95	0.00	0.00	0.00	0.05	0.00	0.00	0.00	3 287
2005	0.00	0.00	0.91	0.00	0.00	0.00	0.09	0.00	0.00	0.00	3 413
2006	0.00	0.00	0.91	0.00	0.00	0.00	0.09	0.00	0.00	0.00	3 595
2007	0.00	0.00	0.95	0.00	0.00	0.00	0.05	0.00	0.00	0.00	5 465
2008	0.00	0.00	0.89	0.00	0.00	0.00	0.11	0.00	0.00	0.00	2 689
Total	0.00	0.00	0.93	0.00	0.00	0.00	0.07	0.00	0.00	0.00	52 732

**Table A10: Proportion of catch reported by target species from the East Coast South Island area for fishing years 1990–2008.**

Fish_year	BAR	HOK	JMA	LIN	RCO	SCI	SPE	SQU	SWA	Other	Total
1990	0.05	0.42	0.00	0.02	0.01	0.00	0.00	0.09	0.40	0.01	1 215
1991	0.11	0.39	0.02	0.04	0.02	0.00	0.00	0.06	0.35	0.01	1 571
1992	0.12	0.45	0.00	0.04	0.02	0.01	0.00	0.09	0.26	0.01	2 343
1993	0.10	0.32	0.05	0.01	0.06	0.01	0.00	0.06	0.38	0.03	2 635
1994	0.15	0.37	0.01	0.01	0.08	0.02	0.00	0.25	0.10	0.02	2 328
1995	0.06	0.42	0.02	0.01	0.05	0.02	0.00	0.10	0.28	0.05	2 284
1996	0.03	0.54	0.01	0.01	0.03	0.02	0.00	0.12	0.22	0.03	2 425
1997	0.09	0.50	0.03	0.00	0.06	0.01	0.00	0.22	0.07	0.03	3 532
1998	0.05	0.64	0.02	0.00	0.10	0.01	0.00	0.12	0.06	0.02	3 343
1999	0.04	0.62	0.00	0.01	0.08	0.01	0.00	0.15	0.08	0.01	2 028
2000	0.02	0.73	0.00	0.00	0.06	0.01	0.00	0.16	0.00	0.01	2 473
2001	0.04	0.60	0.00	0.00	0.02	0.01	0.00	0.26	0.06	0.01	3 031
2002	0.02	0.61	0.01	0.01	0.04	0.01	0.00	0.23	0.06	0.01	2 244
2003	0.02	0.58	0.02	0.00	0.04	0.03	0.02	0.21	0.06	0.01	2 830
2004	0.01	0.78	0.00	0.00	0.06	0.00	0.01	0.13	0.01	0.01	3 287
2005	0.01	0.46	0.00	0.00	0.03	0.00	0.00	0.35	0.13	0.02	3 413
2006	0.01	0.53	0.05	0.00	0.01	0.00	0.00	0.21	0.18	0.01	3 595
2007	0.05	0.35	0.02	0.01	0.01	0.00	0.06	0.27	0.22	0.02	5 465
2008	0.12	0.39	0.02	0.01	0.01	0.00	0.00	0.15	0.27	0.03	2 689
Total	0.05	0.51	0.02	0.01	0.04	0.01	0.01	0.18	0.15	0.02	52 732

**Southland**

**Table A11: Proportion of catch reported each month from the Southland area for fishing years 1990–2008.**

Fish_year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	0.09	0.01	0.10	0.15	0.03	0.20	0.17	0.12	0.09	0.00	0.03	0.00	3 663
1991	0.01	0.04	0.19	0.10	0.11	0.05	0.06	0.18	0.19	0.03	0.00	0.04	2 491
1992	0.02	0.05	0.17	0.01	0.03	0.29	0.15	0.15	0.09	0.00	0.03	0.01	3 073
1993	0.02	0.00	0.15	0.07	0.09	0.13	0.21	0.18	0.09	0.02	0.02	0.00	2 783
1994	0.04	0.20	0.30	0.09	0.02	0.03	0.09	0.11	0.10	0.01	0.00	0.02	3 055
1995	0.02	0.18	0.07	0.14	0.07	0.08	0.13	0.17	0.11	0.00	0.01	0.01	2 111
1996	0.05	0.07	0.09	0.06	0.11	0.05	0.17	0.24	0.14	0.00	0.00	0.01	2 991
1997	0.02	0.02	0.10	0.16	0.13	0.19	0.08	0.10	0.18	0.00	0.00	0.01	4 810
1998	0.03	0.01	0.14	0.09	0.09	0.07	0.13	0.27	0.06	0.01	0.01	0.09	3 855
1999	0.03	0.02	0.08	0.11	0.14	0.39	0.13	0.03	0.01	0.01	0.00	0.04	4 440
2000	0.02	0.06	0.15	0.12	0.26	0.16	0.11	0.05	0.03	0.00	0.00	0.04	5 405
2001	0.11	0.03	0.10	0.13	0.07	0.12	0.16	0.17	0.06	0.00	0.00	0.05	4 454
2002	0.04	0.05	0.07	0.17	0.07	0.16	0.14	0.14	0.07	0.00	0.00	0.10	4 989
2003	0.03	0.02	0.04	0.20	0.07	0.29	0.20	0.08	0.05	0.00	0.00	0.02	4 210
2004	0.02	0.02	0.04	0.26	0.05	0.25	0.19	0.11	0.03	0.00	0.01	0.03	5 566
2005	0.01	0.08	0.14	0.08	0.05	0.08	0.33	0.14	0.05	0.03	0.00	0.00	3 848
2006	0.05	0.19	0.04	0.06	0.05	0.14	0.17	0.27	0.02	0.00	0.00	0.00	5 348
2007	0.04	0.08	0.27	0.23	0.07	0.09	0.17	0.02	0.01	0.01	0.00	0.00	6 073
2008	0.03	0.02	0.18	0.11	0.02	0.09	0.47	0.04	0.03	0.00	0.00	0.01	3 222
Total	0.04	0.06	0.12	0.13	0.08	0.16	0.17	0.13	0.07	0.01	0.01	0.03	76 389

**Table A12: Proportion of catch reported for each statistical area from the Southland area for fishing years 1990–2008.**

Fish_year	25	26	27	28	29	30	31	504	602	Other	Total
1990	0.00	0.27	0.31	0.28	0.01	0.01	0.00	0.09	0.03	0.00	3 663
1991	0.00	0.10	0.30	0.20	0.07	0.11	0.00	0.18	0.04	0.01	2 491
1992	0.00	0.29	0.20	0.36	0.00	0.06	0.00	0.05	0.02	0.00	3 073
1993	0.00	0.22	0.21	0.32	0.02	0.11	0.00	0.07	0.04	0.00	2 783
1994	0.00	0.22	0.31	0.28	0.00	0.03	0.00	0.11	0.03	0.01	3 055
1995	0.01	0.24	0.20	0.36	0.01	0.08	0.00	0.10	0.00	0.00	2 111
1996	0.08	0.19	0.29	0.30	0.00	0.05	0.00	0.07	0.01	0.00	2 991
1997	0.03	0.15	0.16	0.42	0.01	0.04	0.00	0.19	0.01	0.00	4 810
1998	0.02	0.15	0.15	0.25	0.02	0.25	0.03	0.11	0.01	0.00	3 855
1999	0.00	0.20	0.09	0.55	0.00	0.12	0.01	0.02	0.00	0.00	4 440
2000	0.00	0.28	0.17	0.33	0.00	0.12	0.00	0.06	0.04	0.00	5 405
2001	0.00	0.22	0.13	0.35	0.02	0.22	0.02	0.04	0.00	0.00	4 454
2002	0.00	0.13	0.11	0.42	0.02	0.18	0.05	0.07	0.01	0.01	4 989
2003	0.00	0.13	0.19	0.45	0.00	0.08	0.01	0.12	0.02	0.00	4 210
2004	0.00	0.14	0.12	0.49	0.00	0.04	0.02	0.10	0.07	0.00	5 566
2005	0.00	0.23	0.27	0.25	0.00	0.07	0.00	0.11	0.05	0.02	3 848
2006	0.00	0.21	0.28	0.23	0.00	0.07	0.00	0.15	0.06	0.00	5 348
2007	0.00	0.19	0.28	0.31	0.01	0.01	0.00	0.16	0.03	0.00	6 073
2008	0.00	0.22	0.28	0.38	0.00	0.01	0.00	0.09	0.02	0.00	3 222
Total	0.01	0.20	0.21	0.35	0.01	0.09	0.01	0.10	0.03	0.00	76 389

**Table A13: Proportion of catch reported by gear type from the Southland area for fishing years 1990–2008.**

Fish_year	BLL	BT	DL	MW	SN	Other	Total
1990	0.00	0.97	0.00	0.03	0.00	0.00	3 663
1991	0.00	0.94	0.00	0.06	0.00	0.00	2 491
1992	0.00	0.97	0.00	0.03	0.00	0.00	3 073
1993	0.00	0.97	0.00	0.03	0.00	0.00	2 783
1994	0.00	0.95	0.00	0.05	0.00	0.00	3 055
1995	0.00	0.93	0.00	0.07	0.00	0.00	2 111
1996	0.00	0.85	0.00	0.15	0.00	0.00	2 991
1997	0.00	0.66	0.00	0.34	0.00	0.00	4 810
1998	0.00	0.68	0.00	0.32	0.00	0.00	3 855
1999	0.00	0.81	0.00	0.19	0.00	0.00	4 440
2000	0.00	0.86	0.00	0.14	0.00	0.00	5 405
2001	0.00	0.86	0.00	0.14	0.00	0.00	4 454
2002	0.00	0.74	0.00	0.26	0.00	0.00	4 989
2003	0.00	0.76	0.00	0.24	0.00	0.00	4 210
2004	0.00	0.71	0.00	0.29	0.00	0.00	5 566
2005	0.00	0.95	0.00	0.05	0.00	0.00	3 848
2006	0.00	0.92	0.00	0.08	0.00	0.00	5 348
2007	0.00	0.84	0.00	0.16	0.00	0.00	6 073
2008	0.00	0.95	0.00	0.05	0.00	0.00	3 222
Total	0.00	0.84	0.00	0.16	0.00	0.00	76 389

**Table A14: Proportion of catch reported by target species from the Southland area for fishing years 1990–2008.**

Fish_year	BAR	HAK	HOK	JMA	LIN	RCO	SQU	SWA	WWA	Other	Total
1990	0.04	0.00	0.11	0.00	0.02	0.00	0.08	0.72	0.02	0.01	3 663
1991	0.12	0.00	0.14	0.03	0.04	0.00	0.17	0.50	0.00	0.00	2 491
1992	0.02	0.00	0.10	0.00	0.02	0.01	0.09	0.73	0.00	0.02	3 073
1993	0.04	0.00	0.08	0.00	0.02	0.01	0.12	0.72	0.00	0.00	2 783
1994	0.04	0.00	0.07	0.01	0.04	0.01	0.17	0.64	0.00	0.01	3 055
1995	0.02	0.01	0.08	0.01	0.00	0.01	0.20	0.68	0.00	0.00	2 111
1996	0.07	0.00	0.07	0.05	0.00	0.04	0.22	0.53	0.00	0.02	2 991
1997	0.06	0.00	0.07	0.03	0.00	0.01	0.54	0.29	0.00	0.00	4 810
1998	0.04	0.00	0.19	0.08	0.01	0.01	0.38	0.30	0.00	0.00	3 855
1999	0.01	0.01	0.12	0.06	0.01	0.00	0.50	0.28	0.01	0.00	4 440
2000	0.05	0.00	0.31	0.03	0.01	0.00	0.26	0.33	0.01	0.00	5 405
2001	0.01	0.01	0.24	0.01	0.00	0.00	0.29	0.39	0.05	0.00	4 454
2002	0.01	0.00	0.21	0.02	0.00	0.00	0.44	0.30	0.01	0.01	4 989
2003	0.01	0.00	0.10	0.01	0.00	0.01	0.52	0.29	0.06	0.00	4 210
2004	0.01	0.00	0.13	0.00	0.00	0.00	0.59	0.21	0.05	0.00	5 566
2005	0.00	0.01	0.10	0.00	0.02	0.01	0.48	0.35	0.03	0.01	3 848
2006	0.01	0.00	0.06	0.00	0.02	0.00	0.54	0.29	0.07	0.01	5 348
2007	0.01	0.01	0.12	0.00	0.02	0.00	0.53	0.30	0.01	0.01	6 073
2008	0.01	0.00	0.02	0.00	0.02	0.00	0.24	0.70	0.01	0.00	3 222
Total	0.03	0.00	0.13	0.02	0.01	0.01	0.37	0.41	0.02	0.01	76 389

**Table A15: CPUE estimated values and c.v.s by year and area for Model's 1–8.**

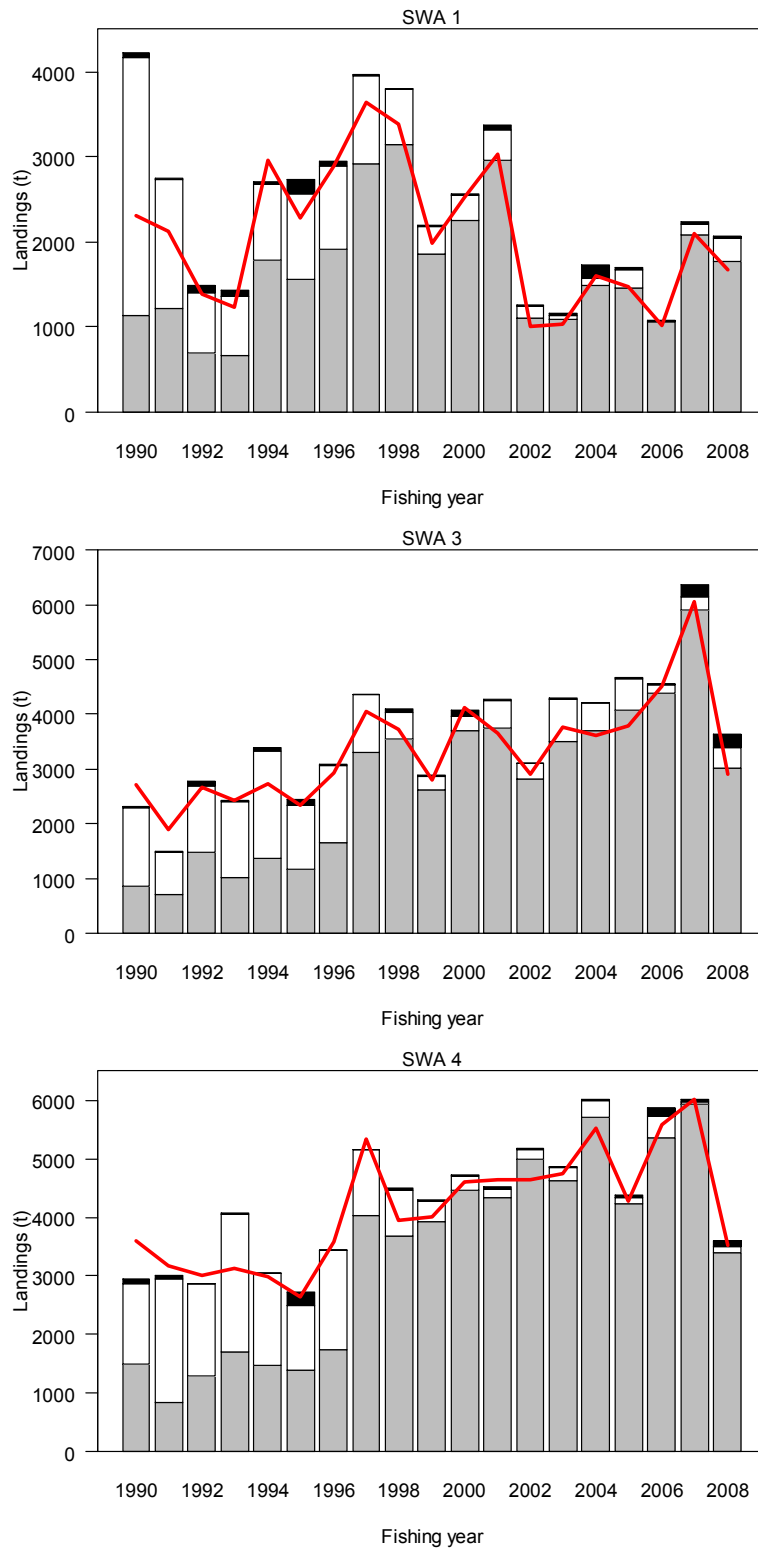
ECSI Year	1		2		3		4		5		6		7		8	
	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.
1990	0.86	0.11	0.73	0.05	0.80	0.11	1.27	0.22	2.22	0.39	0.87	0.38			0.80	0.05
1991	0.86	0.08	1.12	0.05	0.80	0.08	1.32	0.21	0.95	0.30	1.08	0.41			1.27	0.05
1992	1.34	0.06	0.89	0.04	1.23	0.06	1.35	0.14	1.65	0.27	0.34	0.20			0.88	0.04
1993	1.53	0.06	1.00	0.04	1.34	0.06	0.97	0.16	1.37	0.20	0.25	0.24			1.03	0.04
1994	1.75	0.07	1.16	0.04	1.56	0.06	1.77	0.19	1.23	0.23	1.74	0.13			1.16	0.04
1995	1.01	0.06	0.87	0.03	0.98	0.05	0.86	0.12	1.04	0.17	0.98	0.12			0.98	0.03
1996	0.84	0.05	0.83	0.03	0.77	0.05	0.52	0.10	1.49	0.19	0.80	0.13			0.80	0.03
1997	1.97	0.05	0.88	0.03	1.62	0.05	0.70	0.09	2.64	0.36	3.02	0.12			0.80	0.03
1998	1.05	0.05	0.99	0.03	0.92	0.04	0.74	0.08	7.21	0.66	1.64	0.13			0.92	0.03
1999	0.77	0.05	0.76	0.03	0.71	0.05	0.65	0.08	1.03	0.32	1.09	0.11			0.66	0.03
2000	0.85	0.05	0.88	0.03	0.85	0.05	0.95	0.07	0.00	1.28	1.30	0.10			0.77	0.03
2001	1.11	0.04	0.84	0.02	1.00	0.04	0.99	0.07	2.45	0.45	1.22	0.09			0.78	0.02
2002	0.50	0.05	0.95	0.03	0.49	0.05	0.38	0.09	1.24	0.35	0.62	0.10			0.87	0.03
2003	0.51	0.05	0.98	0.03	0.52	0.05	0.51	0.08	0.20	0.35	0.77	0.10			0.93	0.03
2004	1.29	0.05	1.29	0.03	1.47	0.05	1.82	0.09	0.71	0.70	1.58	0.12			1.30	0.03
2005	1.02	0.06	1.33	0.03	1.05	0.05	1.03	0.13	1.76	0.43	1.29	0.10			1.33	0.03
2006	1.12	0.06	1.32	0.03	1.41	0.05	2.69	0.11	1.15	0.23	1.10	0.11			1.41	0.03
2007	0.93	0.06	1.52	0.03	1.32	0.05	1.54	0.13	4.22	0.24	0.63	0.10			1.60	0.03
2008	0.85	0.08	1.04	0.04	1.19	0.07	1.21	0.13	0.77	0.19	1.63	0.24			1.29	0.04

**Table A15: Continued**

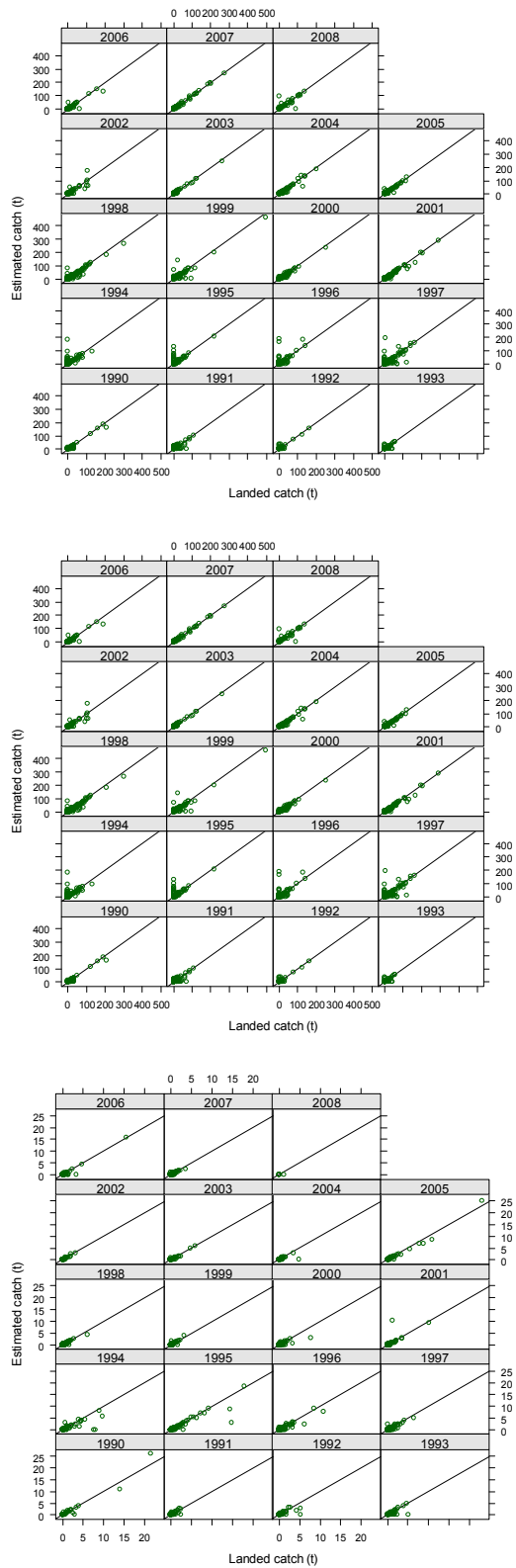
<b>Southland</b>		1		2		3		4		5		6		7		8	
Year	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	
1990	0.97	0.13	1.30	0.06			0.88	0.25	0.88	0.25	1.08	0.24			1.72	0.06	
1991	0.91	0.12	0.88	0.07			1.57	0.30	1.57	0.30	1.83	0.24			1.11	0.07	
1992	0.67	0.10	0.71	0.05			0.76	0.20	0.76	0.20	0.88	0.16			0.97	0.05	
1993	0.77	0.08	0.64	0.04			0.58	0.17	0.58	0.17	0.81	0.13			0.86	0.04	
1994	0.95	0.08	1.07	0.04			1.03	0.21	1.03	0.21	0.95	0.14			1.34	0.04	
1995	0.58	0.08	0.73	0.04			0.59	0.25	0.59	0.25	0.65	0.13			1.00	0.04	
1996	0.77	0.08	0.92	0.04			0.33	0.21	0.33	0.21	0.66	0.16			1.04	0.04	
1997	0.87	0.07	1.02	0.03			0.43	0.15	0.43	0.15	1.04	0.18			0.92	0.03	
1998	0.93	0.08	1.18	0.04			1.14	0.13	1.14	0.13	0.46	0.19			1.01	0.04	
1999	1.17	0.07	1.32	0.03			0.98	0.14	0.98	0.14	1.08	0.20			1.16	0.03	
2000	1.99	0.06	1.58	0.03			1.17	0.10	1.17	0.10	1.57	0.18			1.47	0.03	
2001	1.34	0.06	0.99	0.03			1.15	0.11	1.15	0.11	1.62	0.16			0.85	0.03	
2002	0.85	0.06	0.98	0.03			0.88	0.13	0.88	0.13	0.79	0.14			0.83	0.03	
2003	0.97	0.06	0.98	0.03			0.99	0.13	0.99	0.13	0.63	0.18			0.77	0.03	
2004	1.28	0.06	1.29	0.03			2.36	0.20	2.36	0.20	1.20	0.25			0.99	0.03	
2005	0.85	0.06	0.89	0.03			1.59	0.24	1.59	0.24	1.93	0.17			0.74	0.03	
2006	1.29	0.06	0.98	0.02			2.68	0.23	2.68	0.23	1.19	0.15			0.81	0.02	
2007	1.82	0.05	1.26	0.03			1.50	0.13	1.50	0.13	1.19	0.14			1.10	0.03	
2008	0.98	0.07	0.81	0.03							0.84	0.15			0.81	0.03	

**Table A15: Continued**

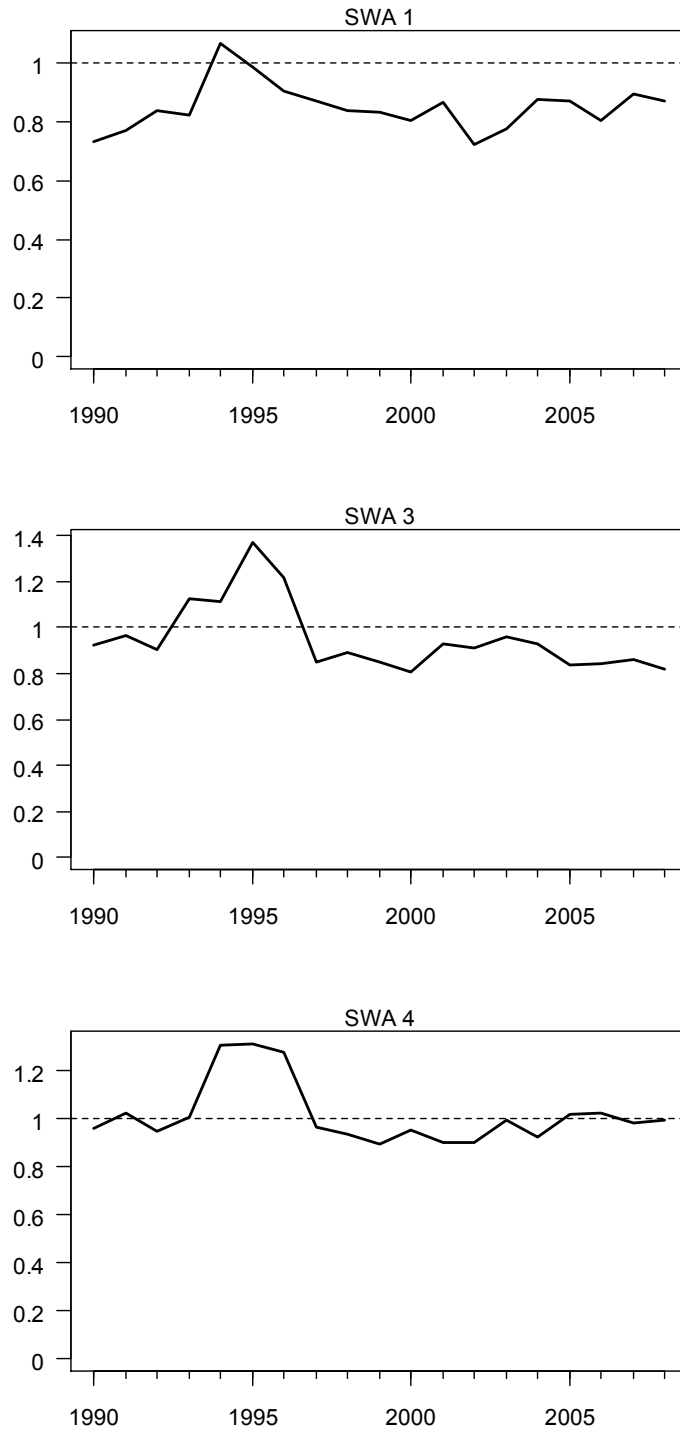
<b>Chatham Rise</b>		<u>1</u>		<u>2</u>		<u>3</u>		<u>4</u>		<u>5</u>		<u>6</u>		<u>7</u>		<u>8</u>	
Year	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	CPUE	c.v.	
1990	2.51	0.44	0.72	0.17									0.76	0.11	0.65	0.17	
1991	3.07	0.32	1.33	0.17									1.03	0.08	1.73	0.17	
1992	1.13	0.24	0.61	0.12									1.37	0.07	0.64	0.11	
1993	0.88	0.33	0.87	0.12									1.40	0.06	0.86	0.12	
1994	1.72	0.23	1.20	0.11									1.63	0.07	1.11	0.10	
1995	1.23	0.24	1.16	0.10									0.80	0.06	1.08	0.10	
1996	1.37	0.19	1.15	0.08									0.74	0.05	1.20	0.08	
1997	1.54	0.19	1.37	0.08									1.36	0.05	1.38	0.08	
1998	0.23	0.19	0.80	0.12									0.63	0.05	0.74	0.12	
1999	0.38	0.22	0.47	0.13									0.64	0.05	0.48	0.13	
2000	0.65	0.29	0.55	0.20									0.71	0.05	0.61	0.19	
2001	0.52	0.21	0.78	0.11									1.02	0.04	0.77	0.11	
2002	0.75	0.20	0.73	0.09									0.48	0.05	0.71	0.09	
2003	0.33	0.30	0.72	0.17									0.48	0.05	0.72	0.17	
2004	0.79	0.26	2.12	0.20									1.28	0.06	2.22	0.20	
2005	3.19	0.27	1.56	0.10									1.01	0.06	1.46	0.10	
2006	3.42	0.32	2.84	0.17									1.10	0.06	2.92	0.16	
2007	0.62	0.27	0.78	0.14									0.73	0.06	0.70	0.14	
2008	0.78	0.24	1.45	0.12									0.69	0.08	1.45	0.12	



**Figure A1: Annual retained landings (grey bar), interim landings (white bar, interim landings include “T” destination code as defined by Starr (2007), and landings removed in the grooming procedure from 1989–90 to 2007–08 fishing years for SWA 1, 2 and 3.**



**Figure A2: Estimated catch vs. retained landings (interim landing events include “T” destination code as defined by Starr (2007) by trip from 1989–90 to 2007–08 fishing year for SWA 1 (left panel), SWA 3 (middle panel), and SWA 4 (right panel) in the groomed and unmerged dataset.**



**Figure A3: Annual reporting rate, defined as the annual estimated catch as a proportion of retained landings (interim landing events include “T” destination code as defined by Starr (2007) from 1989–90 to 2007–08 for SWA 1, 3, and 4 in the groomed and merged datasets.**