



# Fisheries New Zealand

Tini a Tangaroa

## Characterisation and CPUE standardisation of scampi in SCI 4A

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## EXECUTIVE SUMMARY

**Tuck, I.D. (2020). Characterisation and CPUE standardisation of scampi in SCI 4A.**

*New Zealand Fisheries Assessment Report 2020/04. 48 p.*

A fishery description and characterisation for SCI 4A was undertaken, using catch and effort data from the TCEPR system, observer records and Chatham Rise middle depths trawl survey data. No scampi specific surveys are available for this area. Catches have historically been intermittent in this fishery, but increased rapidly after 2010, and have fluctuated around the TACC since 2014. Catches have predominantly been taken from a distinct area to the north of the Chatham Islands, with fishing in another area to the west for a short period during the mid 2000s.

Standardised CPUE indices follow trends observed in raw CPUE data, suggesting that abundance roughly trebled between the early 1990s and the early 2000s, declined to slightly below early 1990s levels by 2008, but subsequently increased. These trends largely follow those observed by scampi catches from the Chatham Rise middle depths trawl survey.

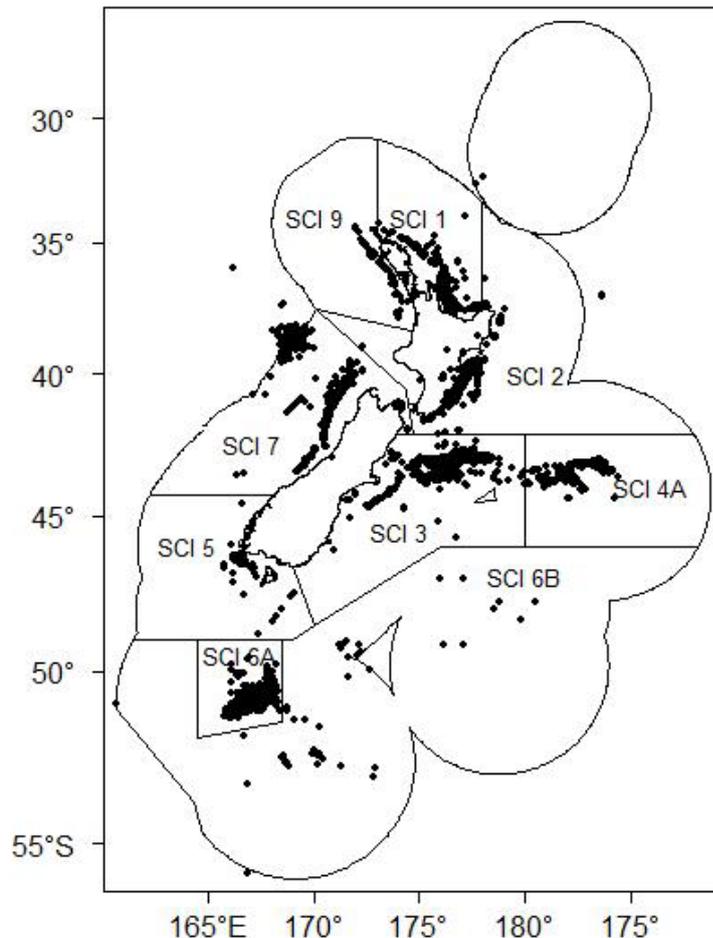
Observer data have been used to estimate female size at maturity. Annual patterns in mean size from observer data are not matched by length data from the Chatham Rise middle depths trawl survey.

## 1. INTRODUCTION

The scampi fishery is based on the species *Metanephrops challengeri*, which is widely distributed around New Zealand (Figure 1). National scampi landings in 2017/18 were 1019 t (limit 1312 t). The landings for scampi in SCI 4A were 111 t (TACC 120 t) in 2017/18, and have averaged 121 t over the period 2014/15 to 2017/18. The other major fisheries are SCI 1 (TACC 120 t), SCI 2 (TACC 153 t), SCI 3 (TACC 408 t), and SCI 6A (TACC 306 t). Scampi are taken by light trawl gear, which catches the scampi that have emerged from burrows in the seabed. The main fisheries are in waters 300 – 500 m deep, although the range is slightly deeper in the SCI 6A region (350 – 550 m). The spatial distribution of scampi fisheries and management areas are shown in Figure 1.

Scampi occupy burrows in muddy substrates, and are only available to trawl fisheries when emerged on the seabed (Bell et al. 2006). Scampi emergence (examined through catch rates, both of European and New Zealand species) has been shown to vary seasonally in relation to moult and reproductive cycles, and over shorter time scales in relation to diel and tidal cycles (Aguzzi et al. 2003; Bell et al. 2006; Tuck et al. 2015c). Uncertainty over trawl catchability associated with these emergence patterns has led to the development of survey approaches based on visual counts of scampi burrows rather than animals (Froglia et al. 1997; Tuck et al. 1997; Cryer et al. 2003a; Smith et al. 2003), although these approaches still face uncertainties over burrow occupancy and population size composition (ICES 2007; Sardà & Aguzzi 2012). Photographic surveying has been used extensively to estimate the abundance of the European scampi and has been carried out in New Zealand since 1998. Photographic and trawl surveys have been conducted in SCI 1 (Cryer et al. 2003b; Tuck et al. 2013; Tuck et al. 2016), SCI 2 (Tuck et al. 2006; Tuck et al. 2013; Tuck et al. 2016), SCI 3 (Cryer et al. 2003c; Tuck et al. 2011; Tuck et al. 2015a; Tuck et al. 2018) and SCI 6A (Tuck et al. 2009a; Tuck et al. 2009b; Tuck et al. 2015b; Tuck et al. 2017). SCI 4A has only been consistently fished in recent years, and has not been the focus of a targeted scampi survey.

Fishery characterisations and development of CPUE indices are part of the regular cycle of scampi assessments undertaken within Fisheries New Zealand research projects for SCI 1, SCI 2, SCI 3 and SCI 6A (Tuck 2016a; Tuck 2016b; Tuck 2017), but the SCI 4A fishery has not been examined in detail since the 2007/08 fishing year (Tuck 2009).



**Figure 1: Spatial distribution of the scampi fishery since 1988–89 (ungroomed data) and current scampi management areas. Each dot shows the mid-point of one or more tows recorded on TCEPR with scampi as the target species.**

**OVERALL OBJECTIVE:** To characterise and develop CPUE indices for scampi (*Metanephrops challengerii*) in SCI 4A.

**OBJECTIVES:**

1. To complete a descriptive analysis of scampi in SCI 4A up to and including the 2017–18 fishing year.
2. To develop and complete relevant CPUE indices.

**2. FISHERY DESCRIPTION**

Scampi fishers have consistently reported catches on the Trawl Catch, Effort, and Processing Returns (TCEPR) form since its introduction in 1989–90, providing a very valuable record of catch and effort on a tow by tow basis.

Data were extracted from the Fisheries New Zealand TCEPR database (rep log 12091), requesting all fishing events (from all areas) where scampi (SCI) was the nominated target species, or was reported in the catch from that trip. This extract was used both for this project, and Fisheries New Zealand research project SCI2018-01 - Characterisation and length-based assessment model for scampi (*Metanephrops challengerii*) in the Bay of Plenty (SCI 1) and Hawke Bay–Wairarapa (SCI 2).

This extract included 364 284 fishing events, 25 644 of which were conducted within the SCI 4A management area. Just under 25% of these events targeted scampi (the majority of the remainder targeting hoki, hake, ling, orange roughy and barracouta) but the 6392 scampi targeted events accounted for over 99.5% of estimated scampi catches in SCI 4A, and so only scampi targeting events were considered further. Errors in TCEPR records are reducing in frequency, but do occur, and the raw records were groomed in the following manner, as per previous scampi characterisations (Tuck 2017). For each record, the reported data were used to estimate the fishing duration of the trawl shot, the distance between the start and finish locations, and the mid point between the start and finish locations. There were no scampi targeted events with zero hours tow duration recorded but some scampi catch. All tows with a tow distance greater than 50 km were reset to the median of the mid point of tows on the same day, adjacent days, or the trip, depending on available data (60 events, spread throughout the years of the fishery). Once edited, these events were included in the allocation of catch data to area and time step analysis, but not included in the CPUE analysis. Where a vessel only reported start position (rather than start and finish position) for a tow (5 events), this was used instead of the mid point. The data for exploration of patterns in the SCI 4A fishery comprised 6332 events. This dataset represents over 98.9% of estimated scampi catches by the scampi target fishery, or 98.6% of estimated scampi catches within SCI 4A. Vessels have been allocated a letter code to maintain confidentiality.

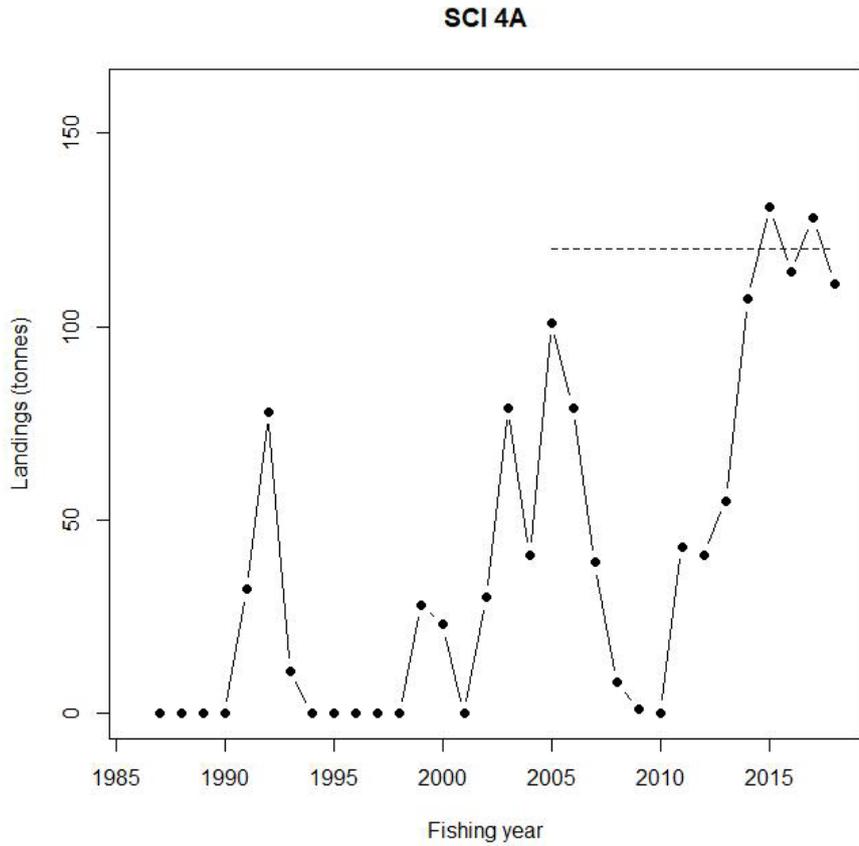
## 2.1 Management and fishing history

The spatial distribution of the targeted scampi fishery within SCI 4A is focussed in an area on the eastern end of the Chatham Rise, east of 180° W (Figure 1). Prior to introduction into the QMS, the management area boundary between the Mernoo Bank (western Chatham Rise) and the remainder of the Chatham Rise (QMA 3 and QMA 4) fisheries was reviewed on the basis of information on average catch rates, trends in CPUE, average size, sex ratio, bathymetry, and by-catch amount and composition (Cryer 2000), resulting in changes being introduced on 1 October 2004. The fishery parameters examined were generally similar between QMA 3 and 4W but less similar for QMA 4E, and hence the former two areas were combined into SCI 3, with QMA 4E becoming SCI 4A. The current analysis has been conducted on the basis of the SCI 4A region.

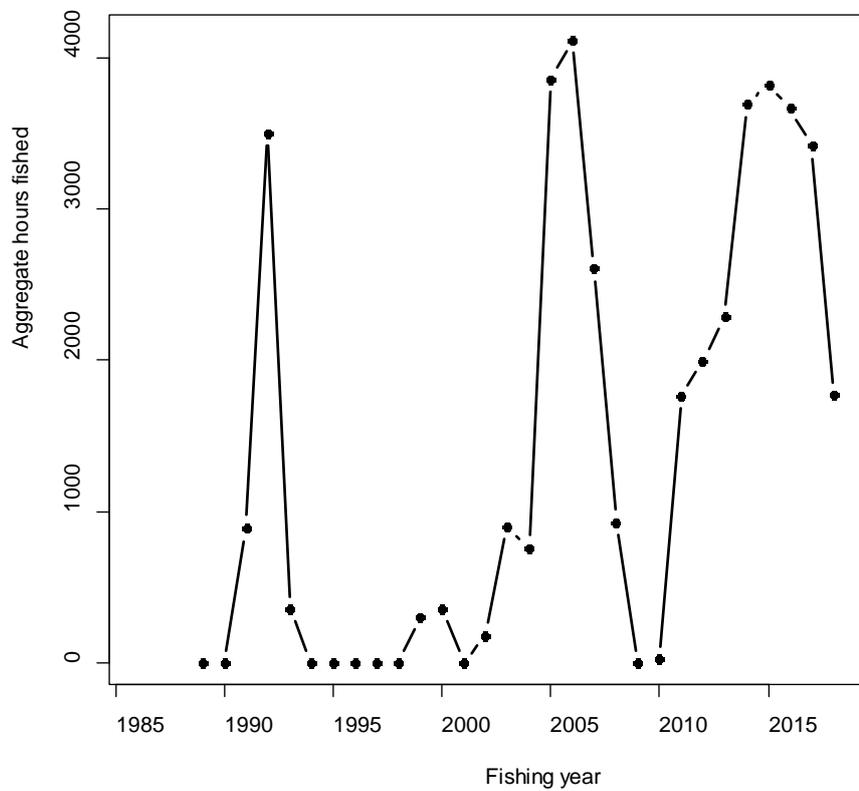
Scampi landings and effort from SCI 4A (Table 1, Figure 2, Figure 3) show that the fishery was quite intermittent throughout the 1990s and early 2000s, with no fishing occurring in a number of years; presumably when the scampi targeting fleet maintained sufficient catches across the other grounds and did not need to visit SCI 4A. After 2010 catches showed a consistent increase to the TACC, and they have been maintained at or about that level since 2014. As with other scampi fisheries, scampi catches are taken predominantly by scampi targeting vessels (99.7% across the history of this fishery), but scampi catches have also been reported by vessels targeting ling, bluenose, hoki, gemfish, sea perch and school shark.

**Table 1: Reported commercial landings (tonnes) from the 1989–90 to 2017–18 fishing years for SCI 4A, and catch (kg) estimated from TCEPR (all vessels and scampi target fishery).**

	Landings (MHR)	Total catch (TCEPR)	Target catch (TCEPR)	% SCI target
1989–90	0		0	
1990–91	32	31 985	31 985	100.0%
1991–92	78	73 022	73 022	100.0%
1992–93	11	10 960	10 960	100.0%
1993–94	0		0	
1994–95	0	370	370	100.0%
1995–96	0		0	
1996–97	0		0	
1997–98	0	802	802	100.0%
1998–99	28	25 409	25 409	100.0%
1999–00	23	21 888	23 913	91.5%
2000–01	0		313	0.0%
2001–02	30	25 977	26 157	99.3%
2002–03	79	66 255	66 255	100.0%
2003–04	41	33 949	33 949	100.0%
2004–05	101	85 058	85 058	100.0%
2005–06	79	66 560	66 560	100.0%
2006–07	39	32 552	32 552	100.0%
2007–08	8	6 479	6 479	100.0%
2008–09	1		0	
2009–10	< 1	80	80	100.0%
2010–11	43	39 855	39 969	99.7%
2011–12	41	37 125	37 133	100.0%
2012–13	55	51 990	52 006	100.0%
2013–14	107	96 801	96 961	99.8%
2014–15	131	121 416	121 434	100.0%
2015–16	114	97 747.5	97 747.5	100.0%
2016–17	129	116 660	116 828	99.9%
2017–18	111	72 014	72 029	100.0%

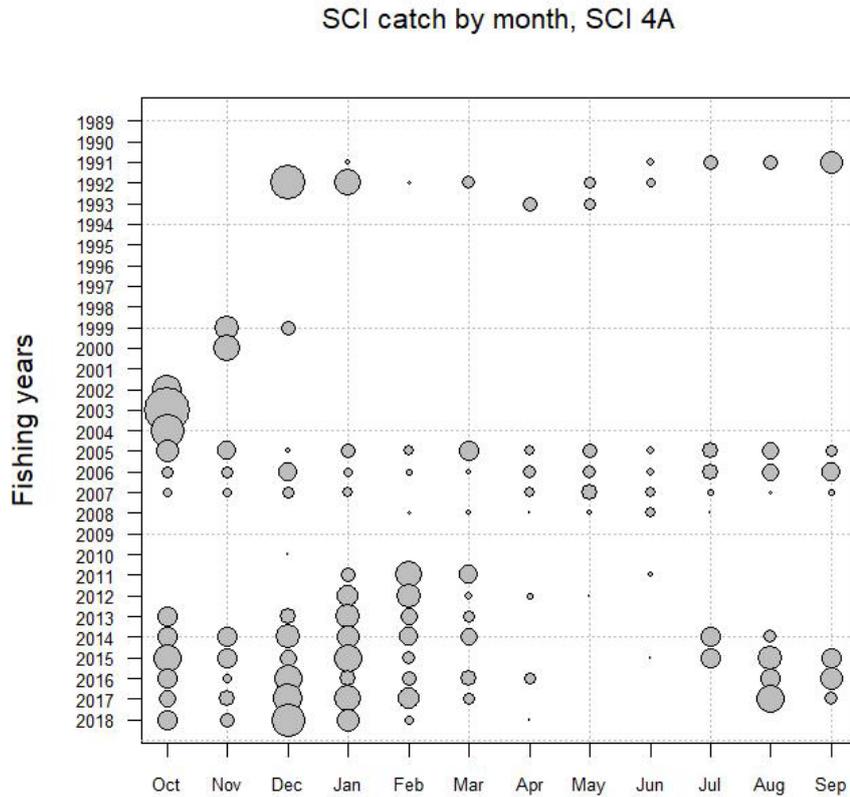


**Figure 2: Time series of scampi landings from SCI 4A by fishing year (MHR data). The dashed line indicates the 120 t TACC that was introduced on 1 October 2004.**



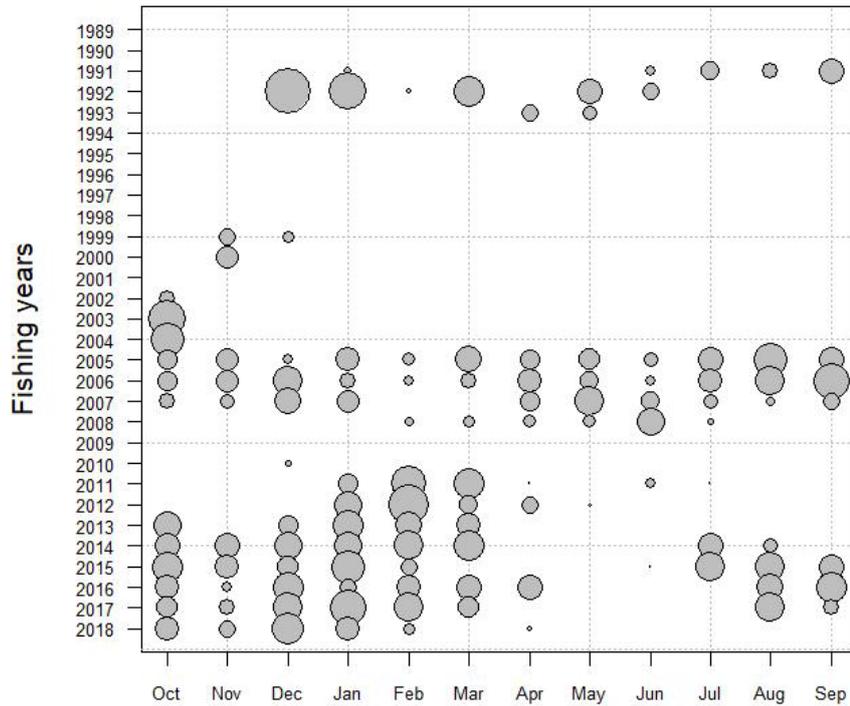
**Figure 3: Time series of scampi targeted effort (aggregate hours fished) from SCI 4A by fishing year.**

Monthly patterns of catch and effort are presented in Figure 4 and Figure 5 respectively. Effort and catch show a similar pattern. At the start of the fishery (1991–92 and 1992–93) targeted scampi fishing occurred throughout most of the year, with very little further fishing occurring until 2001–02 to 2003–04, when the fishery was managed with competitive catch limits, incentivising fishing at the start of the fishing year. In the early years following scampi’s introduction to the QMS, (on 1 October 2004) fishing once again occurred throughout the year, with more consistent catches subsequently taken between July and March since 2010, with minimal activity between April and June.



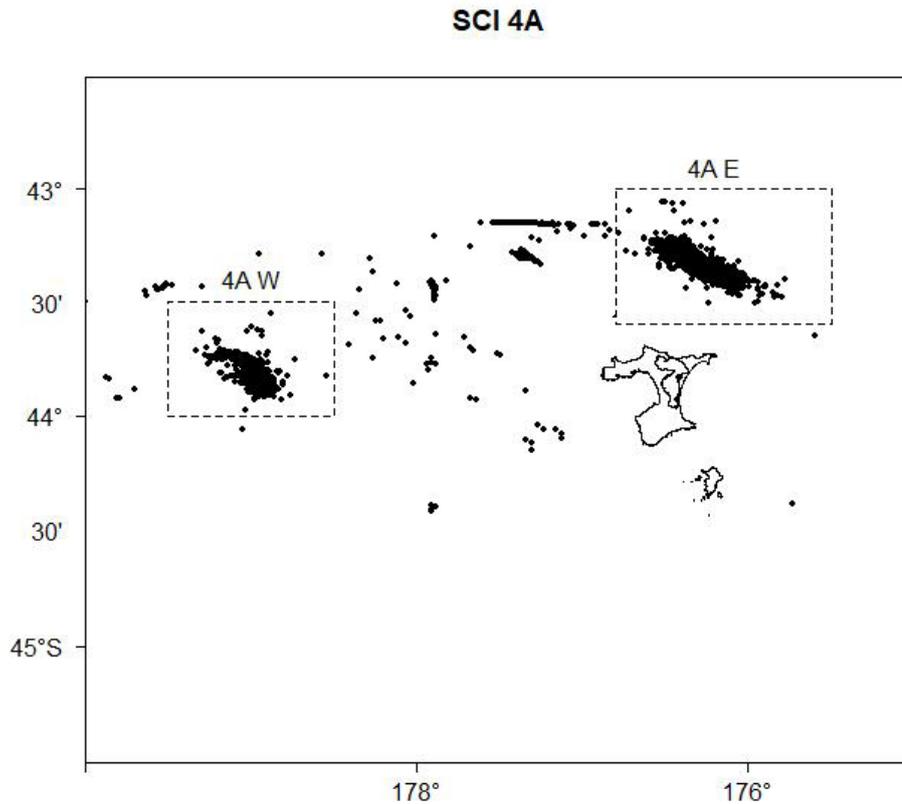
**Figure 4: Monthly pattern of scampi catches in the scampi targeted fishery by fishing year for SCI 4A.**

### Effort by month, SCI 4A



**Figure 5: Monthly pattern of fishing effort in the scampi targeted fishery by fishing year for SCI 4A.**

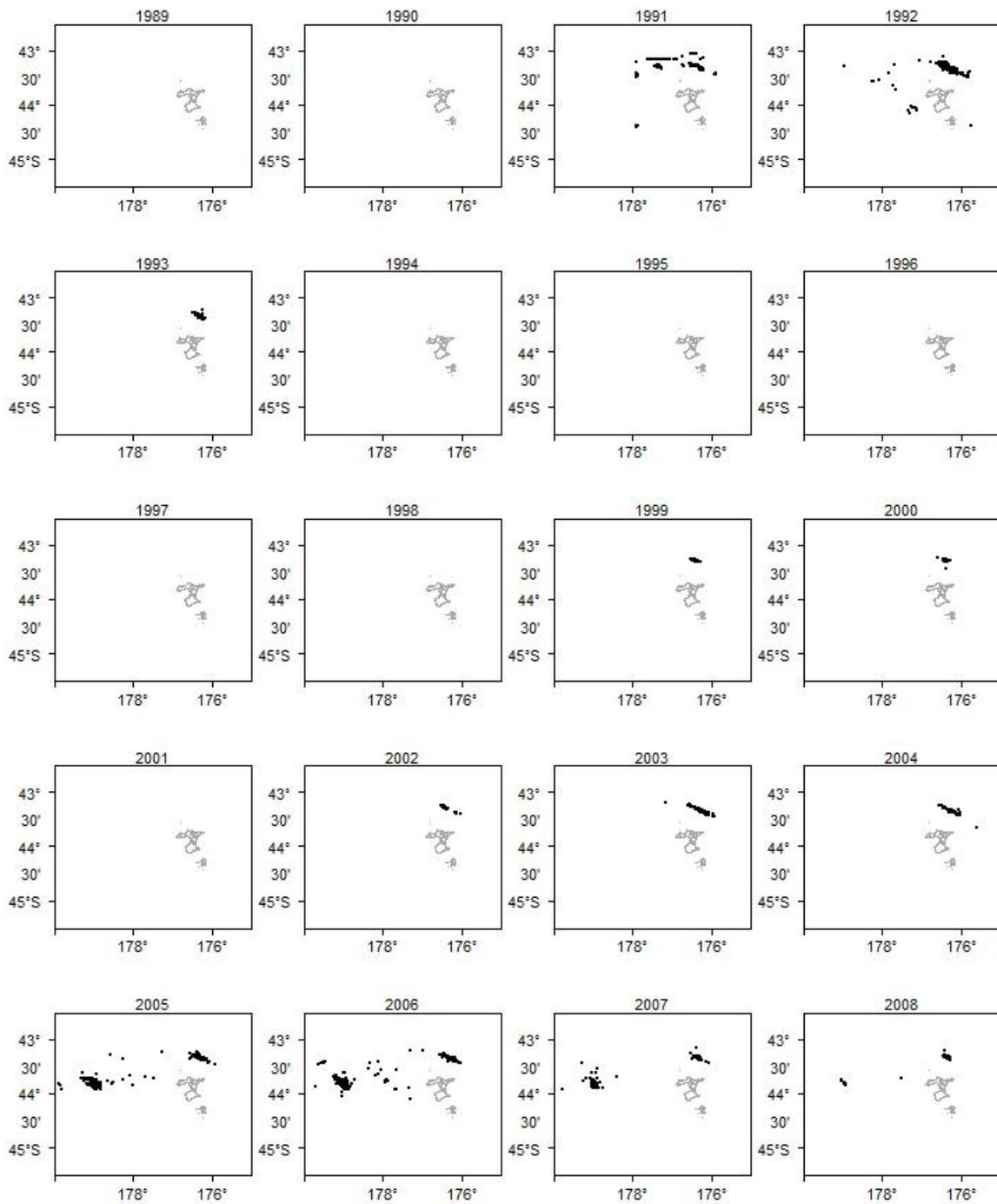
Fishing events targeting scampi (1990–91 to 2017–18) have been distributed across the SCI 4A area between 43° – 44° S and 180° W and 175° 30' E, mainly focussing on two distinct patches (to the north, and to the west of the Chatham Islands; Figure 6). These two areas identified in Figure 6 are referred to here as 4A E and 4A W, to the north and west of the Chatham Islands respectively. The annual distribution of fishing activity within SCI 4A since 1989 is presented in Figure 7 and Figure 8.



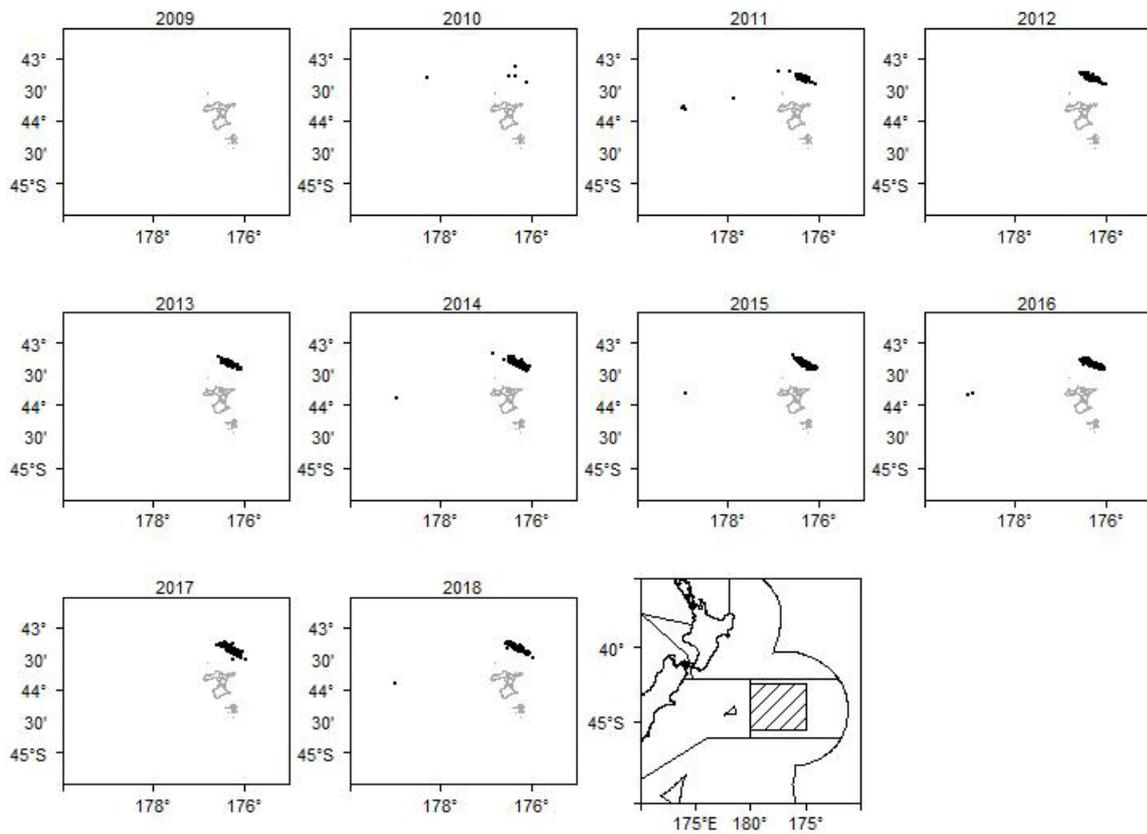
**Figure 6: Spatial distribution of fishing events targeting scampi within SCI 4A, 1990–91 to 2018–18. Each dot shows the mid-point of one or more tows recorded on TCEPR. The two regions delimited by dashed lines are described in the text.**

Scampi targeted fishing activity was initially widespread, becoming focussed on area 4A E by 1992–93 (Figure 7). No scampi targeted activity then took place for a number of years, but 4A E remained the sole focus when scampi were targeted, until 2004–05. Between 2004–05 and 2007–08 scampi targeted activity took place both in 4A E and 4A W, along with occasional tows elsewhere, but after this almost all activity has again been focussed in the 4A E region. During the 2004–05 to 2007–08 period when both 4A E and 4A W were targeted, vessels FF, Q, R and S fished in both areas, while vessels DD and V did not fish in 4A E (Figure 9).

A time series of catches by subarea (4A E, 4A W and elsewhere, defined as Other) within SCI 4A is presented in Figure 10. Substantial scampi catches have only been taken from outside the two defined subareas in 1990–91. In the three years the 4A W area was fished, scampi catches matched or exceeded those from 4A E, but over the history of the fishery 4A E has dominated.



**Figure 7: Spatial distribution of the SCI 4A scampi trawl fishery from 1989–90 to 2007–08. Each dot represents the mid point of one or more tows reported on TCEPR. The general area covered by the plots is indicated within Figure 8.**



**Figure 8: Spatial distribution of the SCI 4A scampi trawl fishery from 2008–09 to 2017–18. Each dot represents the mid point of one or more tows reported on TCEPR. The general area covered by the plots is indicated by the shaded box in the bottom right plot.**

Tows by vessel by subarea, SCI 4

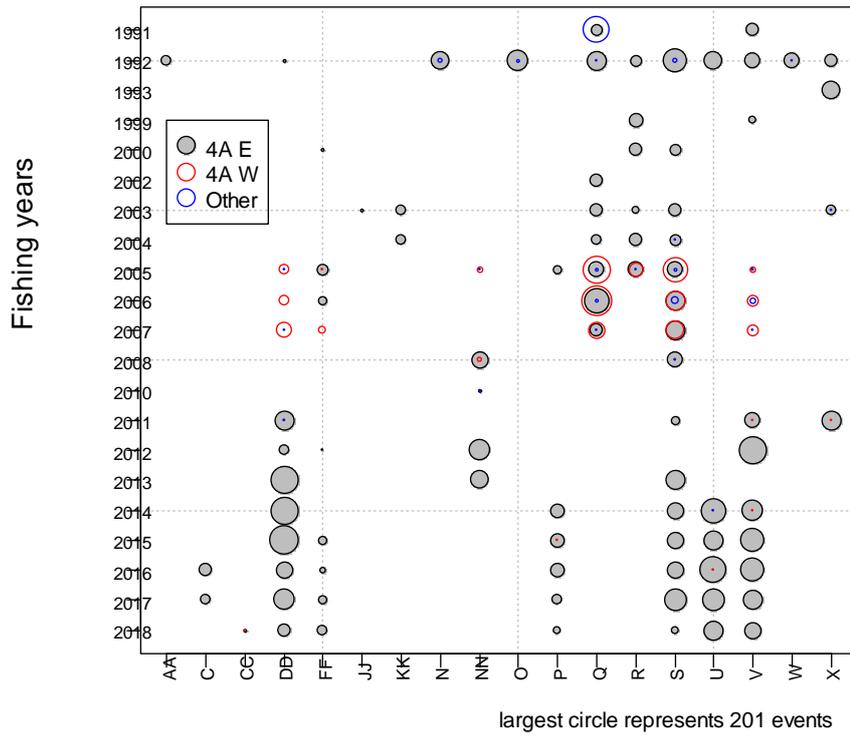


Figure 9: Fishing activity (number of tows) by vessel and sub area within SCI 4A.

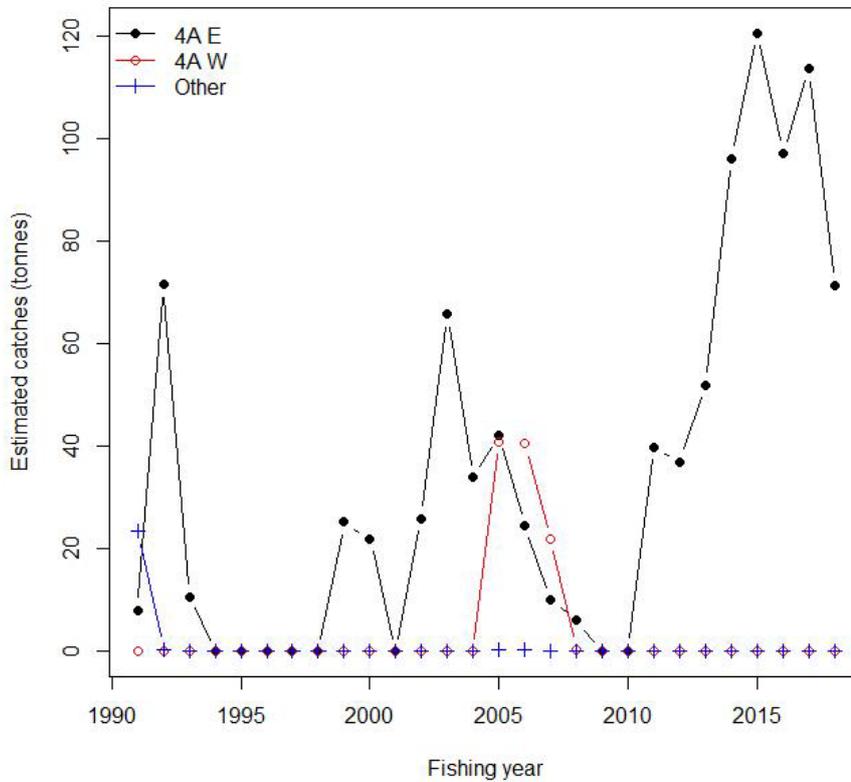
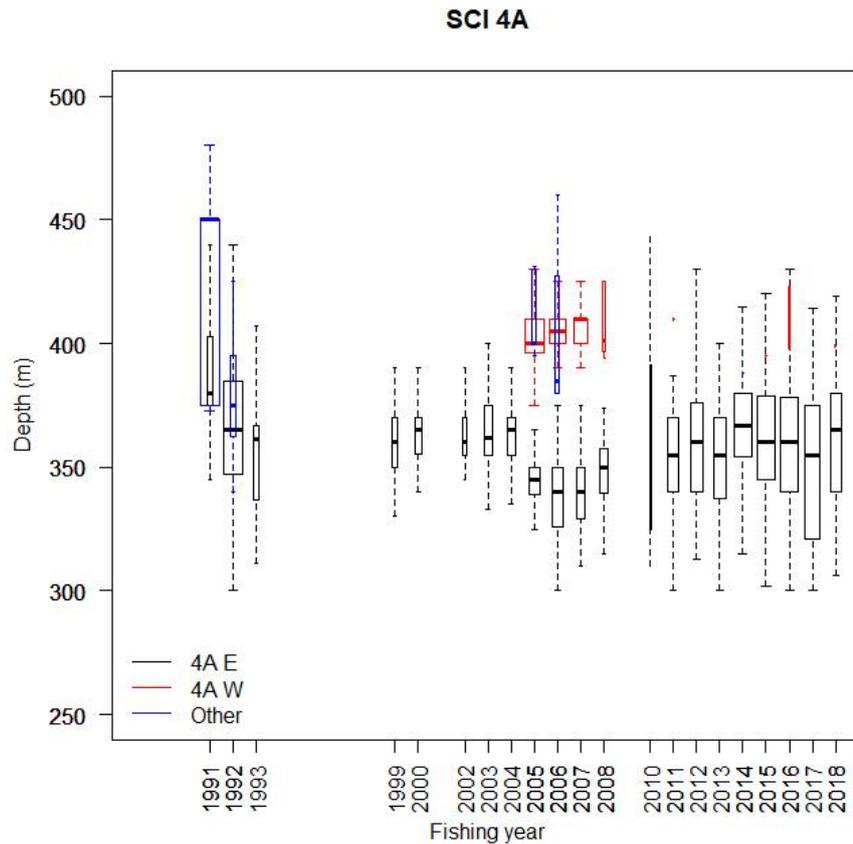


Figure 10: Time series of scampi landings from SCI 4A by subarea of the fishery (4A E, 4A W and Other (Figure 6)) and fishing year (MHR data).

All the scampi targeted fishing activity within SCI 4A has been within the depth range normally observed for scampi in other areas (300 – 550 m). Within SCI 4A, median annual depth of scampi targeted fishing has ranged from about 340 m to 380 m within the 4A E subarea, but appears to have been deeper within 4A W (about 400 m) in the years this area was fished (Figure 11).



**Figure 11: Boxplot of depth of scampi targeted fishing events by year and subarea within SCI 4A. Box widths are proportional to the square root of the number of observations.**

## 2.2 Size composition, sex ratio and maturity

Ministry Observers have collected scampi length frequency data from scampi targeted fishing on commercial vessels in SCI 4A since 1991–92. The numbers of tows for which length data are available are presented by fishing year and month in Table 2. Length samples for SCI 4A are available from 259 separate events (13 trips), representing 4 % of scampi targeted activity. Given the relatively low level of scampi fishing activity in the region, an observer participating in a single voyage may represent a significant proportion of the activity, and on an annual basis observer coverage has been as high as 38%. Reflecting the patterns in the fishery, the observer samples are mostly from the 4A E subarea (Table 2, Figure 12).

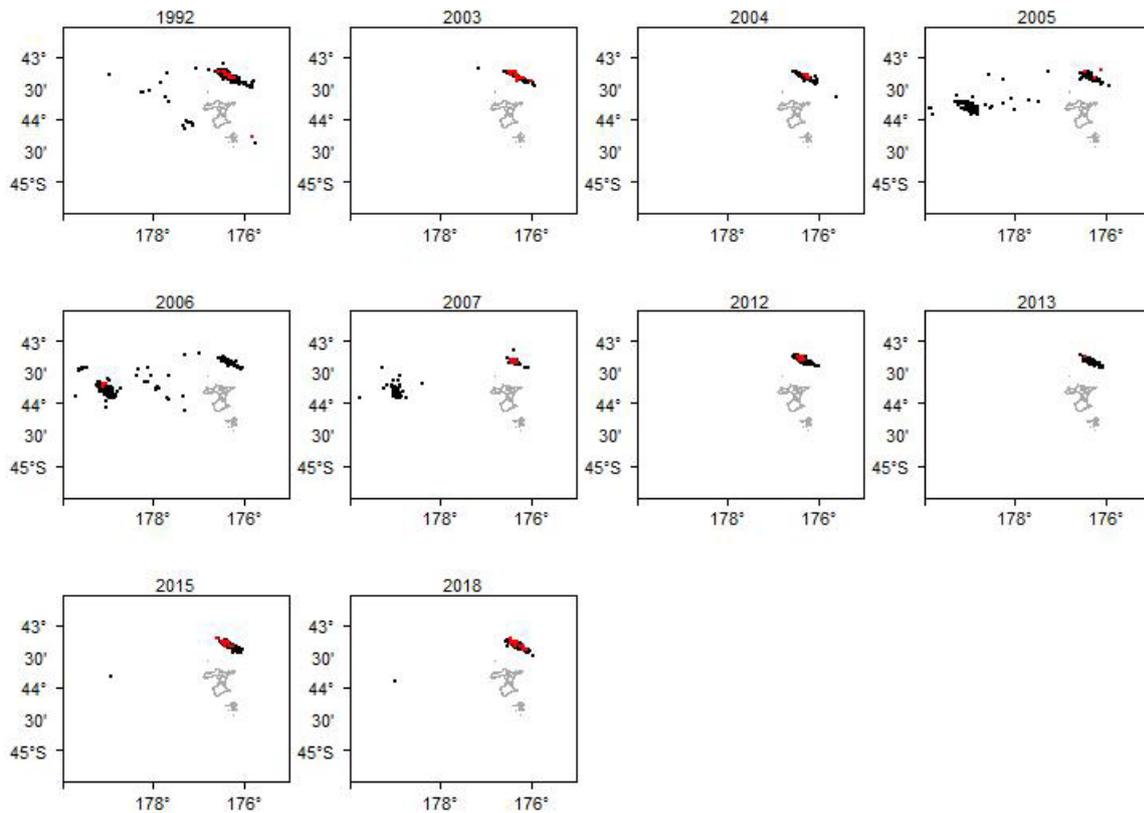
The development of length based stock assessment models for scampi in other fisheries has shown that determination of appropriate time steps for the model is important when fitting to length and sex ratio data in particular (Tuck 2016b; Tuck 2016a; Tuck 2017). Scampi inhabit burrows and are not available to trawling when within a burrow. Catchability varies between the sexes on a seasonal basis in relation to moulting and reproductive behaviour, resulting in seasonal changes in the sex ratio of catches. These patterns have been inferred from observer data, as survey data does not provide information throughout the year.

In SCI 3 (the western end of the Chatham Rise), catches tend to be male dominated from July to December, and female dominated from January to June. The observer data from SCI 4A (Figure 13) do not show this pattern, and given the low level of sampling and poor coverage through the year, no consistent pattern can be detected. There are insufficient data to determine if there have been any spatial differences in sex ratio within SCI 4A.

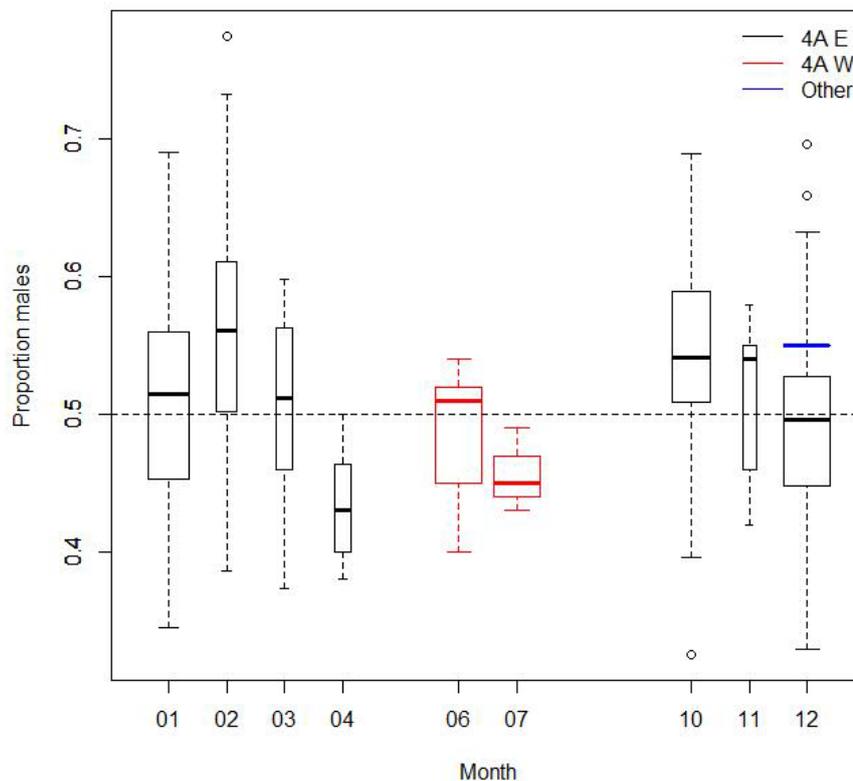
**Table 2: Number of commercial fishing events for which length distributions are available for SCI 4A, by month and fishing year. Total annual commercial scampi targeted events, annual number of events sampled, and annual number of scampi measured also provided. Most samples are from the 4A E subarea, with others indicated. Years not listed represent years where no scampi targeted activity was recorded in SCI 4A.**

Fishing year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total events	Sampled events	Scampi measured
1991													218	0	
1992	6											20, 1 <sup>‡</sup>	680	27	3 366
1993													74	0	
1999													59	0	
2000													68	0	
2002													38	0	
2003										22			149	22	3 123
2004										24			119	24	3 742
2005												4	618	4	628
2006						5 <sup>†</sup>	5 <sup>†</sup>						613	10	1 000
2007										9	7		380	16	1 600
2008													127	0	
2010													5	0	
2011													249	0	
2012			10	10									285	20	2 865
2013												3	321	3	169
2014													521	0	
2015	19	15											529	34	4 955
2016													516	0	
2017													474	0	
2018	37											56	244	93	8 140

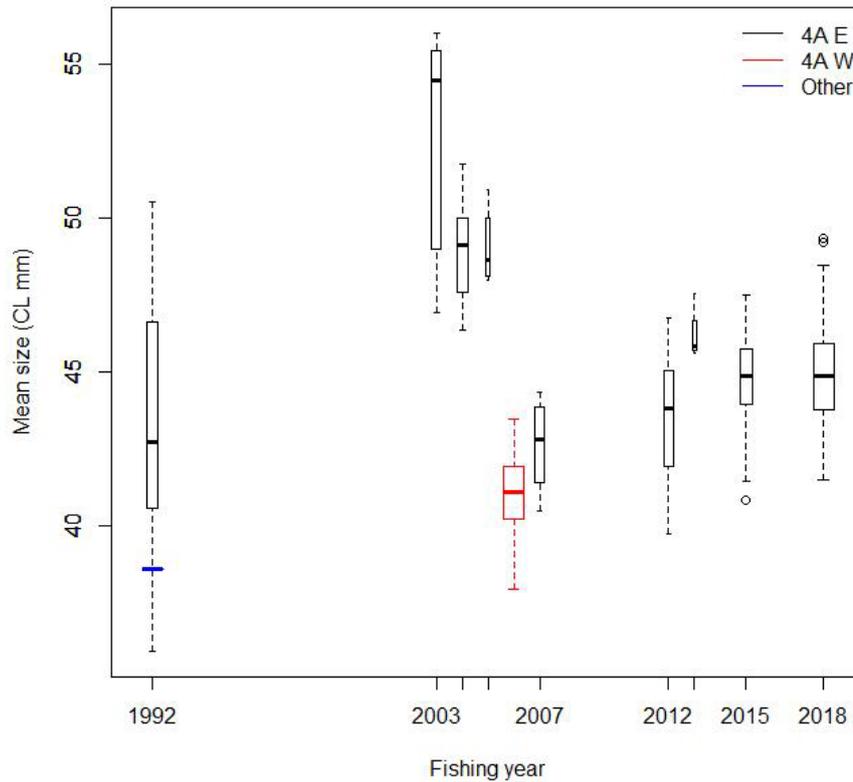
<sup>†</sup> - samples from subarea SCI 4A W; <sup>‡</sup> - samples from subarea SCI 4A Other.



**Figure 12: Location of scampi targeted fishing activity (black dots) and observer samples (red dots) in the years observer data are available.**



**Figure 13: Boxplot of the proportion male scampi from observer samples by month and subarea within SCI 4A. Box widths are proportional to the square root of the number of observations.**



**Figure 14: Boxplot of mean size of scampi from observer samples by year and subarea within SCI 4A. Box widths are proportional to the square root of the number of observations.**

Mean size from the observer sampling suggests that significantly larger scampi were caught in 2003 to 2005, compared to other sampled years (Figure 14). Minimal trawl gear parameter data are available for these (or other) trips, but the vessels sampled during this period (vessel FF, Q and S) were all regular scampi vessels (Figure 9). All three of these vessels were also sampled in other years. Samples in these years were from the 4A E area (Figure 12), and the months sampled in these years were also sampled in other years. While only 4 events were sampled in 2005, over 20 events were sampled in 2003 and 2004, with over 100 scampi per sample on average. Scaled length frequencies for each of the 13 trips are presented in Appendix 1.

Scampi length frequencies were not recorded on the earliest middle depths surveys but have been routinely recorded since 1997. Numbers of animals caught and measured have varied considerably over the series, and it is unclear how representative length frequencies from this series are likely to be. Scaled numbers at length for the SCI 4A region are provided in Appendix 2. Survey length frequency data do not show the higher mean size observed in the observer data between 2003 and 2005.

Ministry observers also record the presence of eggs on the pleopods of female scampi, and stage them for development on the basis of colour (Ministry of Fisheries 2002), adapted from Fenaughty (1989) (Table 3).

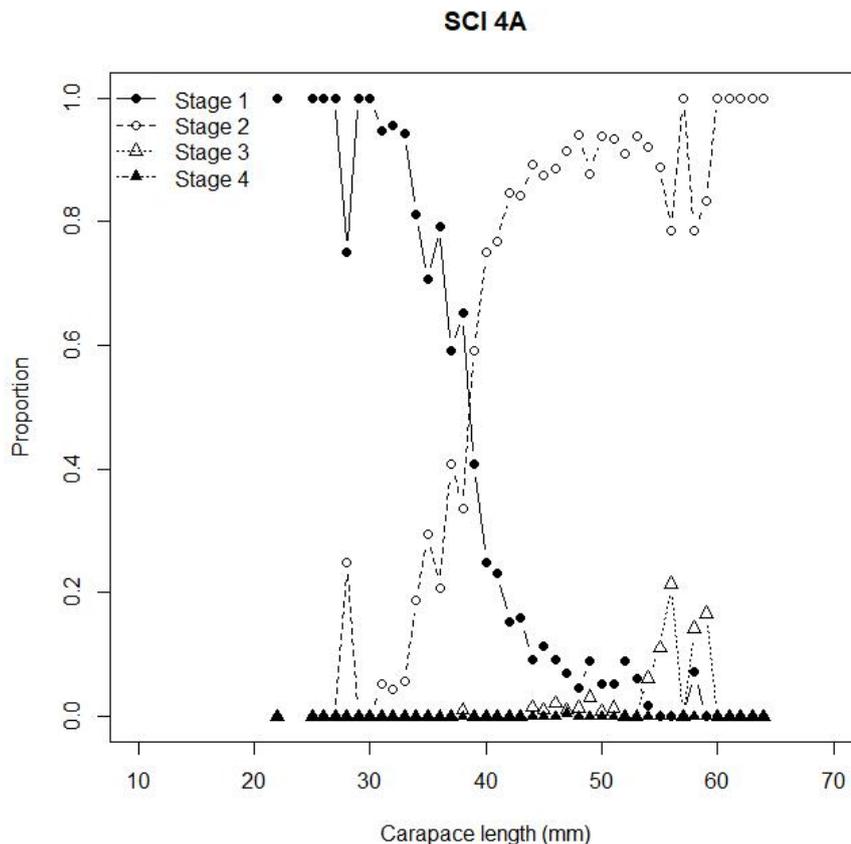
**Table 3: Scampi egg developmental stages (Ministry of Fisheries 2002), adapted from Fenaughty (1989).**

Stage	Description
1	No eggs attached
2	Eggs carried are sky blue to pale green in colour – no orange or red
3	Eggs carried are blue or pale green with orange or red spots and blotches
4	Eggs carried are rose coloured with varying amounts of orange, but no trace of blue

While external eggs are a clear indication of maturity when observed, the seasonal nature of the scampi reproductive cycle means that mature females do not carry eggs all year round, and at these times maturity cannot be confirmed without observing the developing ovary. Examination of scampi ovaries is not possible without damaging the animal, and so is not conducted by observers. There is evidence (IDT & Alaric McCarthy, unpublished observations) that smaller scampi spawn their eggs onto the pleopods earlier in the year than larger females, with eggs therefore hatching earlier. This may mean that, depending on the time of year observed, larger mature females (with mature ovaries, but eggs not yet hatched) or smaller mature females (whose eggs have already hatched) may be misidentified as immature when the diagnostic is the presence of eggs. A similar pattern has also been observed in *Nephrops* (Bailey 1984). Rather than examining the whole year, it is considered most appropriate to only examine the period when the overall proportion of ovigerous females is high in catches. Over the time series of observer sampling for SCI 4A the highest proportion of ovigerous females has been observed between February and April (Table 4). Within this subset of the data, the majority of ovigerous females were classed as stage 2, with a few larger females also classed as stage 3 and 4 (Figure 15). No data are available for the maturity of male scampi, so their maturity ogive was assumed identical to that of females, although studies on *N. norvegicus* have suggested that male maturity may occur at a larger size (although possibly the same age) than females (Tuck et al. 2000).

**Table 4: Details of number of females measured and recorded as ovigerous (egg carrying), and percentage ovigerous, by month, from observer sampling.**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Females	3 709	884	750	771		258	272			3 499	344	3 406
Ovigerous	1 523	578	658	538		69	75			1 214	47	710
% ovigerous	41	65	88	70		27	28			35	14	21



**Figure 15: Proportion of female scampi by egg stage (Table 3), recorded by observers (February – April).**

Analysis of the proportion ovigerous females (stages 2–4 combined), modelled as a function of length, was conducted within a GLM framework, with a quasibinomial distribution of errors and a logit link (McCullagh & Nelder 1989),

$$\text{logit}(m) = a + bL$$

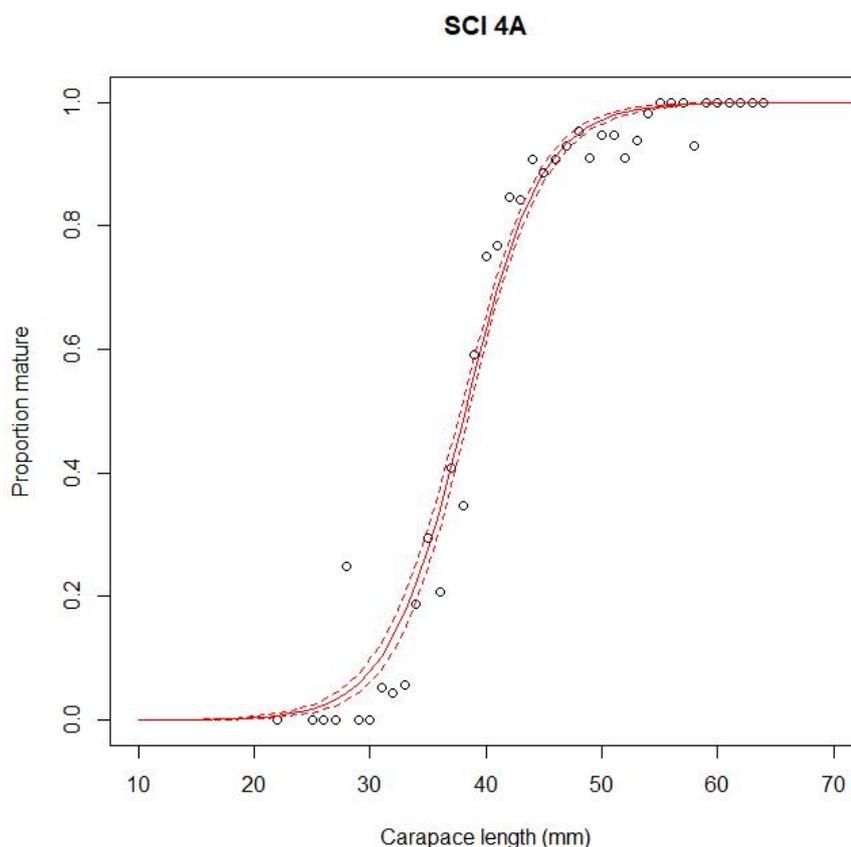
where  $a$  and  $b$  are constants, and  $L$  is the orbital carapace length, which equates to the logistic model. The model was weighted by the number measured at each length. After obtaining estimates for the parameters  $a$  and  $b$ , the length at which 50% are mature ( $L_{50}$ ) was calculated from:

$$L_{50} = -\frac{a}{b}$$

with selection range (SR,  $a_{25}$  to  $a_{75}$ ) calculated from:

$$SR = \frac{(2 \cdot \ln(3))}{b}$$

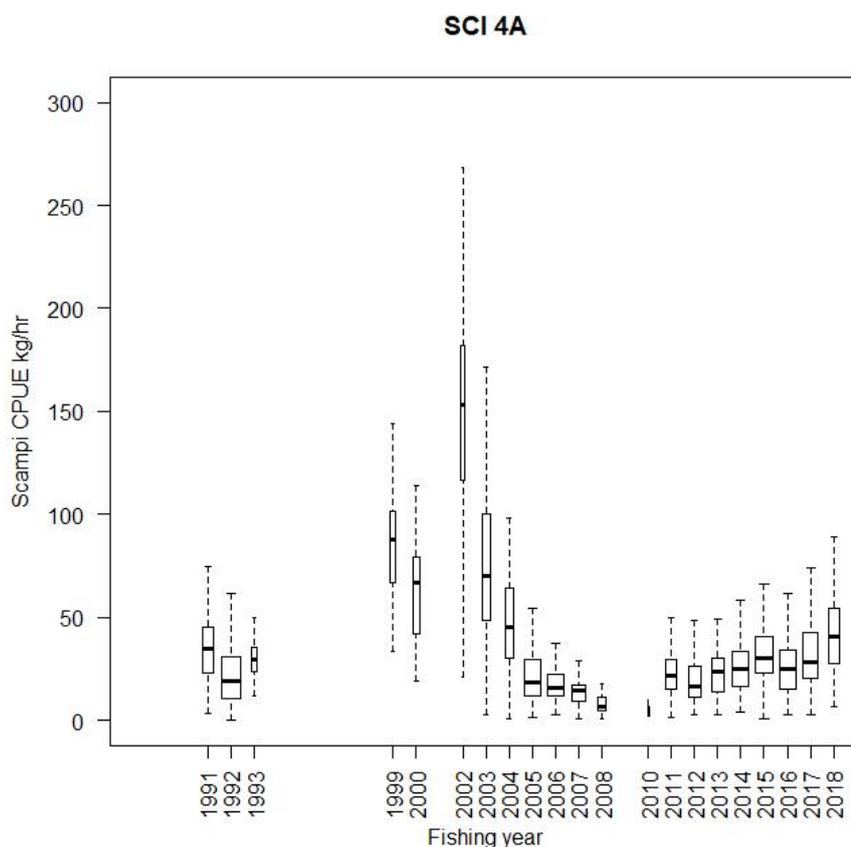
The  $L_{50}$  estimate for the SCI 4A data was 38.2 mm, with a selection range of 7.3 mm. The maturity curve fitted to these data is plotted in Figure 16. This size at maturity is slightly smaller than that estimated for SCI 3, but is comparable with SCI 6A, and larger than SCI 1 and SCI 2.



**Figure 16: Proportions of female scampi carrying eggs at length, from observer sampling in SCI 4A between February and March. Solid line represents logistic curve fitted to the data ( $L_{50}$  38.18 mm and selection range 7.33 mm). Dashed lines represent  $\pm 1$  S.E.**

### 2.3 Abundance indices

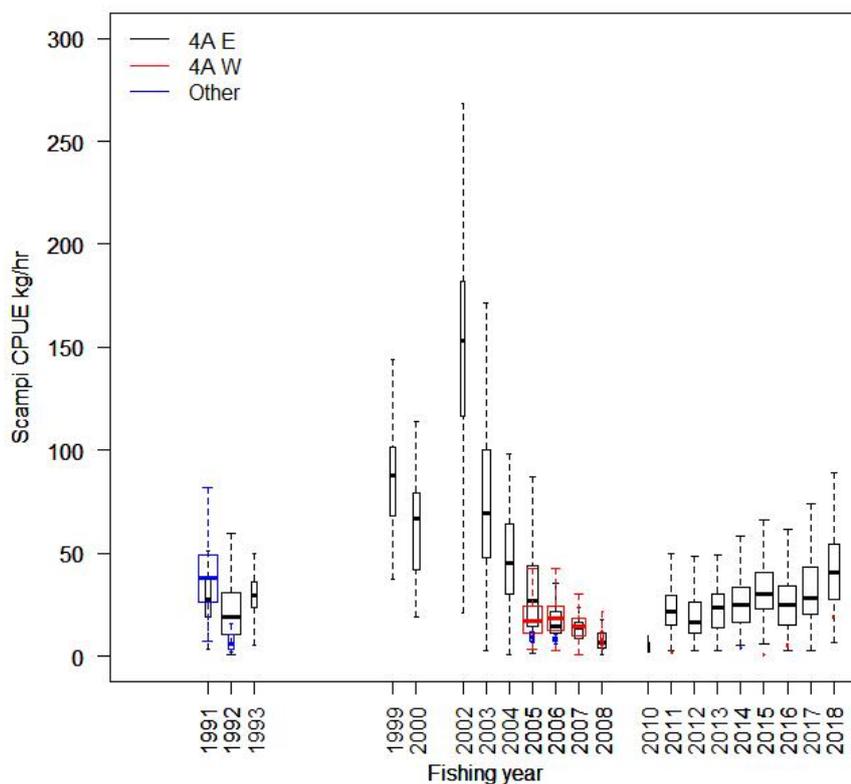
Unstandardised CPUE for the SCI 4A fishery (Figure 17) shows roughly a quadrupling of catch rates between the early 1990s and the early 2000s, the period when fishing was relatively intermittent, and effort was low (Figure 3). Fishing effort increased markedly following the high catch rates observed in 2002, with targeted scampi fishing recorded every year between 2002 and 2008, over which time the CPUE declined steadily. There was no scampi fishing in 2009, and minimal activity in 2010, but since 2011 effort has increased (reaching historical peak levels in 2015, roughly halving since then), while catch rate has shown a steady increase over time.



**Figure 17: Boxplot (with outliers removed) of individual observations from TCEPR of unstandardized catch rate (catch (kg) divided by tow effort (hours)) with tows of zero scampi catch excluded, by fishing year for the SCI 4A fishery. Box width is proportional to the square root of the number of observations.**

A examination of CPUE by subarea does not suggest that catch rates vary spatially within the main areas fished (Figure 18).

## SCI 4A



**Figure 18: Boxplot (with outliers removed) of individual observations from TCEPR of unstandardized catch rate (catch (kg) divided by tow effort (hours)) with tows of zero scampi catch excluded, by fishing year and subarea for the SCI 4A fishery. Box width is proportional to the square root of the number of observations.**

There have been no targeted scampi surveys of SCI 4A, but the Chatham Rise middle depths survey, targeting hoki, has conducted standardised trawl sampling in the region since 1992 (Stevens et al. 2018). While the trawl gear used on this survey is not designed to catch scampi, it provides the only fishery independent abundance index for this stock.

The core survey area of the Chatham Rise middle depths survey extends from 200 – 800 m, with stratification based on depth (200 – 400 m, 400 – 600 m, and 600 – 800 m) and location. Scampi targeted fishing in this region appears to be limited to depths between 300 and 500 m (Figure 11), and so only stations from the two shallower depth bands have been considered. The relevant depth range for scampi has been well sampled by the middle depth survey, with scampi having been caught all across the region (Figure 19).

Scampi stock biomass was estimated for the whole survey coverage (including SCI 3 and SCI 4A), and for SCI 4A alone, using NIWA's SurvCalc software (Francis & Fu 2012). Both series show a similar pattern over time, with biomass increasing from the early 1990s to the early 2000s, declining to 2008, and then increasing slowly in more recent years (Figure 20). This is a similar trend to that shown by the unstandardized CPUE data (Figure 21)

SCI 4A, middle depths survey

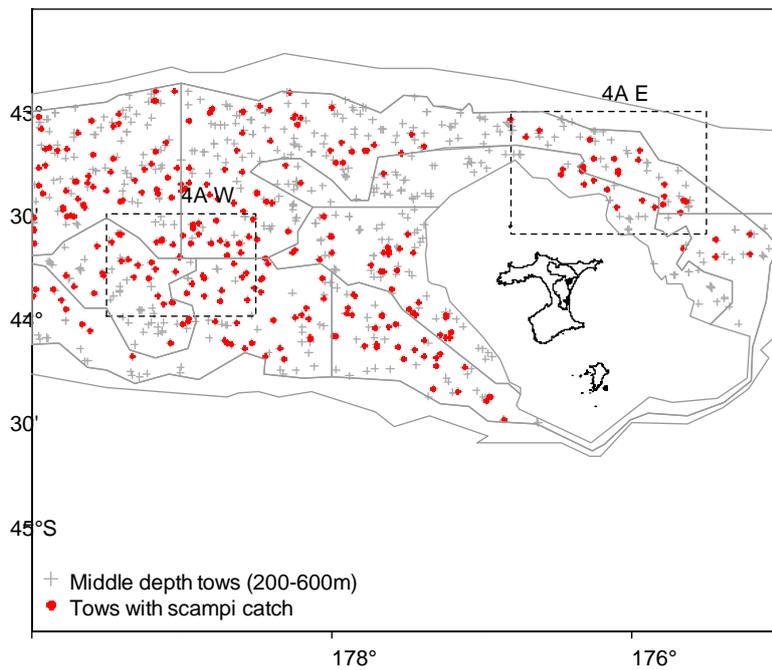


Figure 19: Locations of Chatham Rise middle depth trawl survey stations within the SCI 4A area (200 – 600 m depth range). Grey lines represent survey strata.

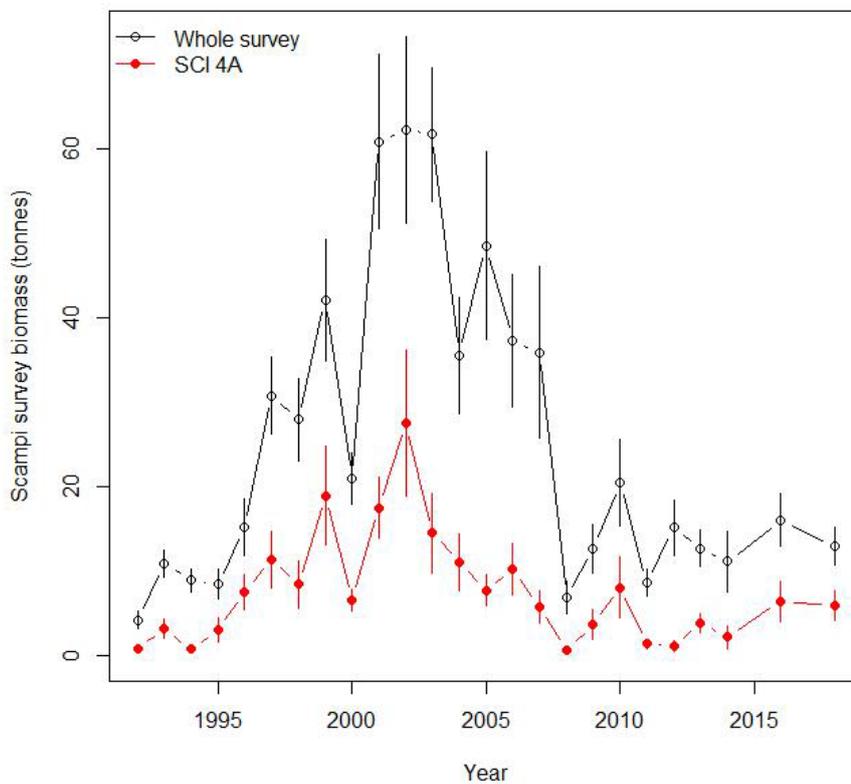
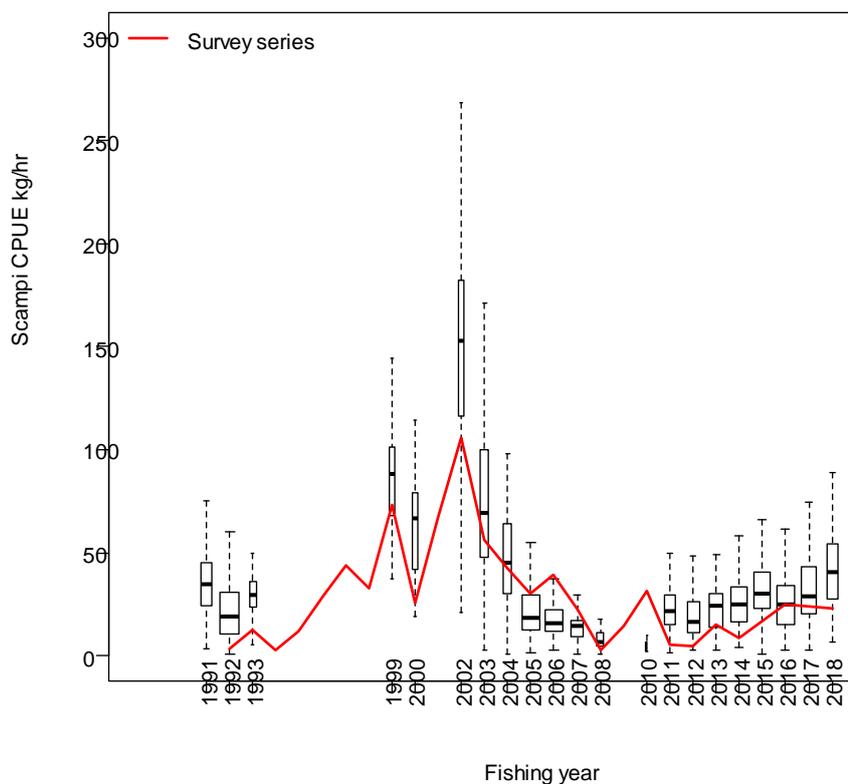


Figure 20: Scampi biomass estimated from the Chatham Rise middle depths survey, for the whole survey area (including SCI 3 & SCI 4A) and for SCI 4A.

## SCI 4A



**Figure 21: Unstandardised CPUE for the SCI 4A area, overlaid with the Chatham Rise middle depths scampi biomass index, scaled to the median CPUE.**

### 3. STANDARDISED CPUE INDEX

The groomed TCEPR records described above have been used to estimate standardised CPUE indices for SCI 4A. Separate indices have been generated for the whole SCI 4A area, and just those fishing events within the 4A E subarea.

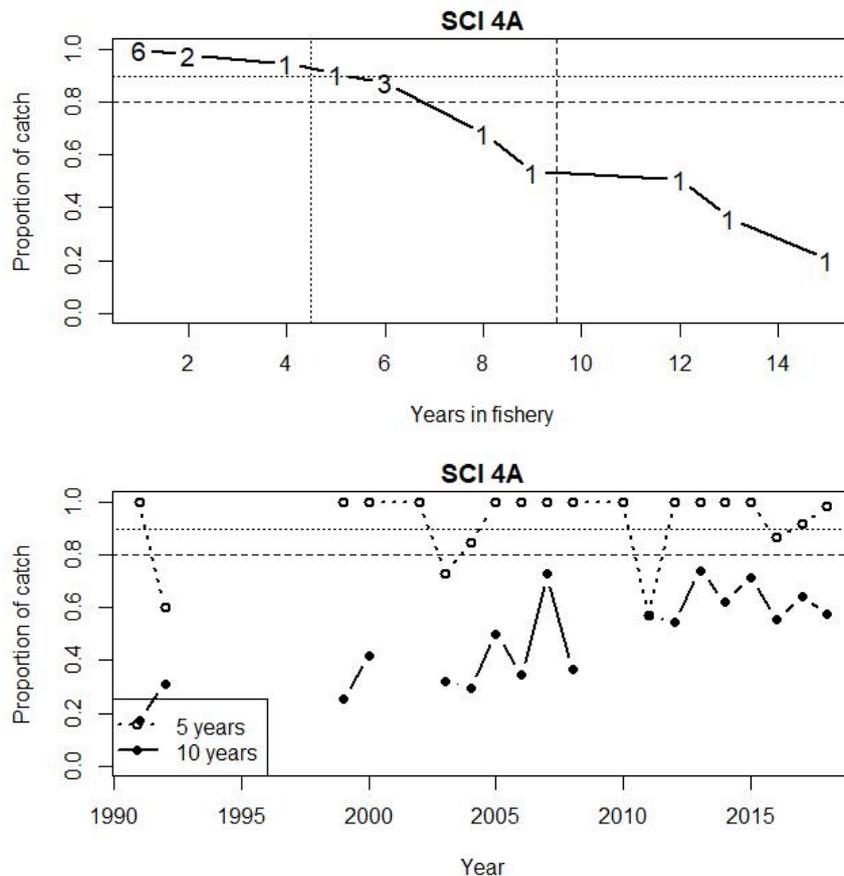
Levels of fishing activity have varied considerably between vessels and over time within the SCI 4A area (Figure 9). Catch rates are likely to vary between vessels, and it is therefore important to identify and include core vessels contributing sufficient data to allow estimation of long-term trends and calibration between vessels, while excluding occasional visitors that may not represent the fishery as a whole. This process is undertaken by examining a combination of the number of years of activity in the fishery, the contribution of each vessel to the catch over the history of the fishery and its contribution to the catch on an annual basis.

#### 3.1 Core vessels

##### SCI 4A

A plot of vessel activity (number of scampi targeted tows recorded) over time is presented for SCI 4A in Figure 9. Vessel S has remained active throughout the history of the fishery (years that were fished by any vessel) while vessels U and V were active at the beginning and more recently, but with gaps in the 2000s. Some vessels were only active at the very start of the fishery, while others have entered more recently.

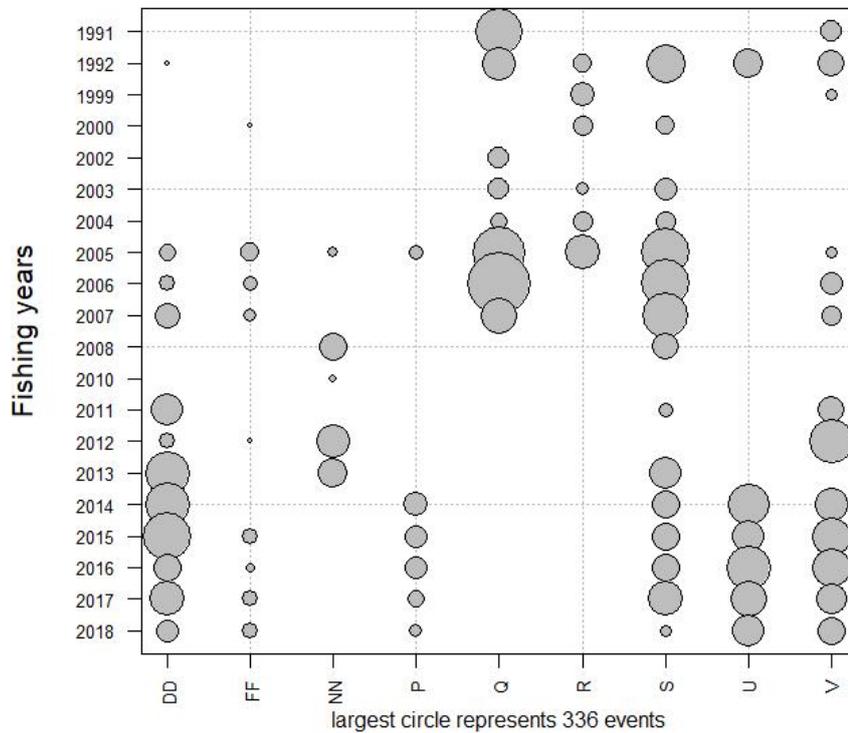
Figure 22 (upper plot) shows the proportion of the total catch (over the history of the fishery) in relation to the number of years the vessels contributing that catch have been active in the fishery, and on the basis of this, a cut off of at least 5 years of activity has been used to identify nine core vessels (vessels DD, FF, NN, P, Q, R, S, U and V), which have accounted for over 90% of the targeted scampi catch from SCI 4A. In previous scampi characterisations for other fisheries (e.g., Tuck 2017) the default has been to select vessels active for 10 or more years, but using that approach here would result in only three vessels contributing about 50% of historical catches, which is not considered adequate. The lower plot of Figure 22 shows the proportion of catch accounted for in each year by vessels active for over 5 or 10 years. Vessels active for at least 5 years have contributed 60% or more of annual catches, and often over 90%.



**Figure 22: Catch breakdown by vessel for SCI 4A. Upper plot - Proportion of total scampi catch (all years) plotted against the number of years the vessels reporting that catch have been active in the fishery. Numbers indicate number of vessels active for that duration. Vertical dotted line represents cut off for core vessels. Lower plot – Proportion of annual catch reported by vessels active in the fishery for over 5 and 10 years.**

The pattern of activity by year for the 9 selected core vessels is shown in Figure 23. Vessels S and V provide data throughout most of the years fished, while vessels DD, FF, NN and P largely provide data since 2005. Only vessel NN provides data for the 2010 fishing year.

### Tows by core vessels, SCI 4A



**Figure 23: Pattern of fishing activity by core vessel and fishing year for SCI 4A. The area of the circles is proportional to the number of tows recorded.**

### SCI 4A E subarea

To identify core vessels for the SCI 4A E subarea, the same approach was applied to the subset of the data from this area. Only 2 vessels have been active for 10 years or more, contributing about 40% of the total catches over the fishery (Figure 24), but decreasing the cut off to 5 years or more retains 8 vessels, contributing just over 85% of catches total. These 8 vessels (those selected as core vessels for the full SCI 4A area but not including vessel NN) accounted for at least 40% of the catch taken from SCI 4A E on an annual basis, and often over 80%.

The overall pattern of activity for core vessels in the SCI 4A E subarea is shown in Figure 25. Other than the exclusion of vessel NN, this is a very similar pattern to that for the overall SCI 4A area.

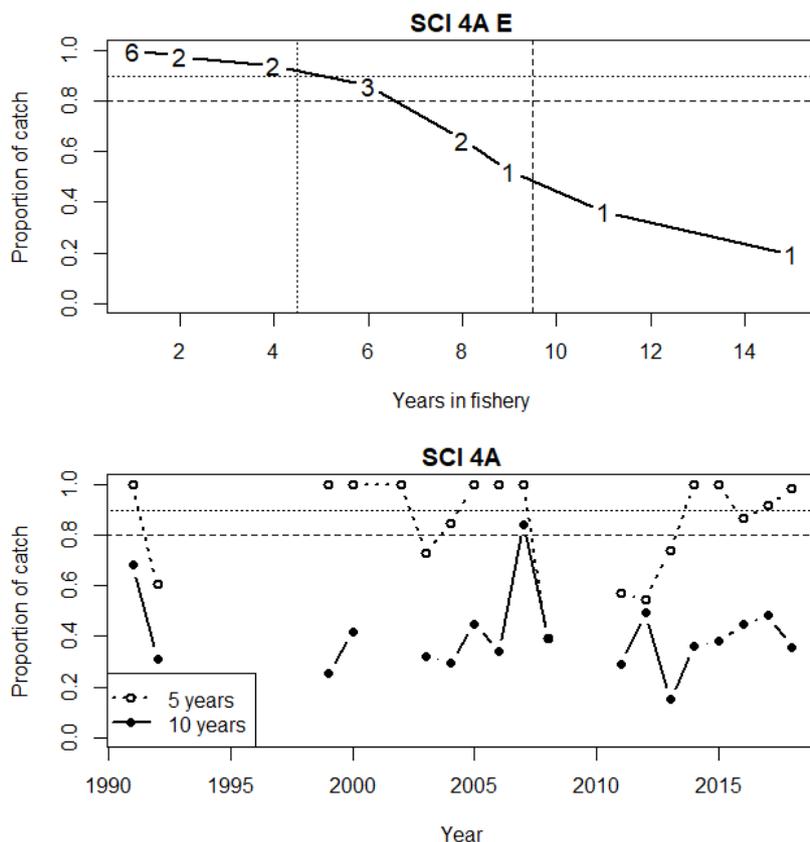


Figure 24: Catch breakdown by vessel for subarea SCI 4A E. Upper plot - Proportion of total scampi catch (all years) plotted against the number of years the vessels reporting that catch have been active in the fishery. Numbers indicate number of vessels active for that duration. Vertical dotted line represents cut off for core vessels. Lower plot – Proportion of annual catch reported by vessels active in the fishery for over 5 and 10 years.

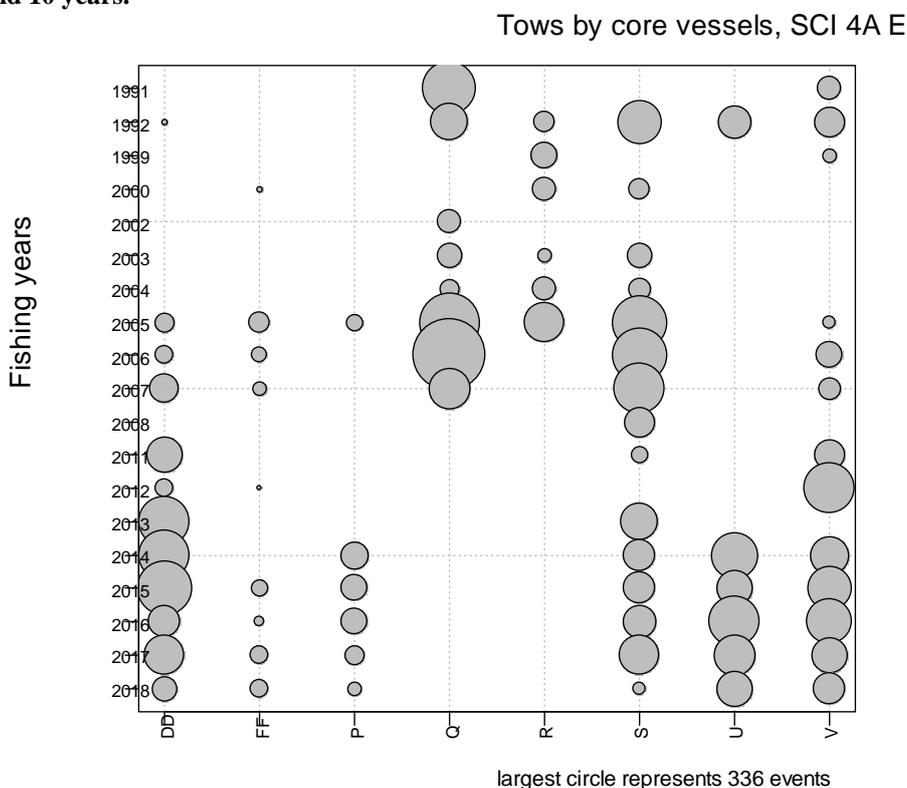


Figure 25: Pattern of fishing activity by core vessel and fishing year for subarea SCI 4A E. The area of the circles is proportional to the number of tows recorded.

### 3.2 Standardised indices

The same standardisation approach was applied to both analyses, and follows that applied to recent scampi CPUE standardisations (Tuck 2017). As with other recent scampi investigations, preliminary analyses explored appropriate error distributions, confirming that the gamma distribution (log link) provided a slight improvement (over log-normal and Weibull distributions) in the distribution of residuals, and this error distribution was used for calculation of the indices reported below.

Catch indices were derived using generalised linear modelling (GLM) procedures (Vignaux 1994; Francis 1999), using the statistical software package R. The response variable in the GLM was the scampi catch. The fishing-year was entered as a categorical covariate (explanatory) term on the right-hand side of the model. Standardised CPUE abundance indices (canonical) were derived from the exponential of the fishing-year covariate terms as described in Francis (1999).

In order to accommodate a non-linear relationship with the response variable (catch), the continuous variables (effort and vessel power) were “offered” to the GLMs as splines. Vessel, time of day, state of tide (i.e., moon state), month, twin or triple rig, and bycatch modification were “offered” to the GLMs as factors. Depth was offered as both a continuous (spline) and 50 m depth band (factor) variable, allowing the model to select which (if either) was retained. A forward fitting, stepwise, multiple-regression algorithm was used to fit GLMs to groomed catch, effort and characterisation data. The stepwise algorithm generates a final regression model iteratively and uses a simple model with a single predictor variable, fishing year, as the initial or base model. The reduction in residual deviance relative to the null deviance was calculated for each additional term added to the base model. The term that results in the greatest reduction in residual deviance was added to the base model if this results in an improvement in  $r^2$  of more than 1%. The algorithm repeated this process, updating the model, until no new terms can be added. Diagnostic plots for the final models are presented in Appendix 3 (Bentley et al. 2012).

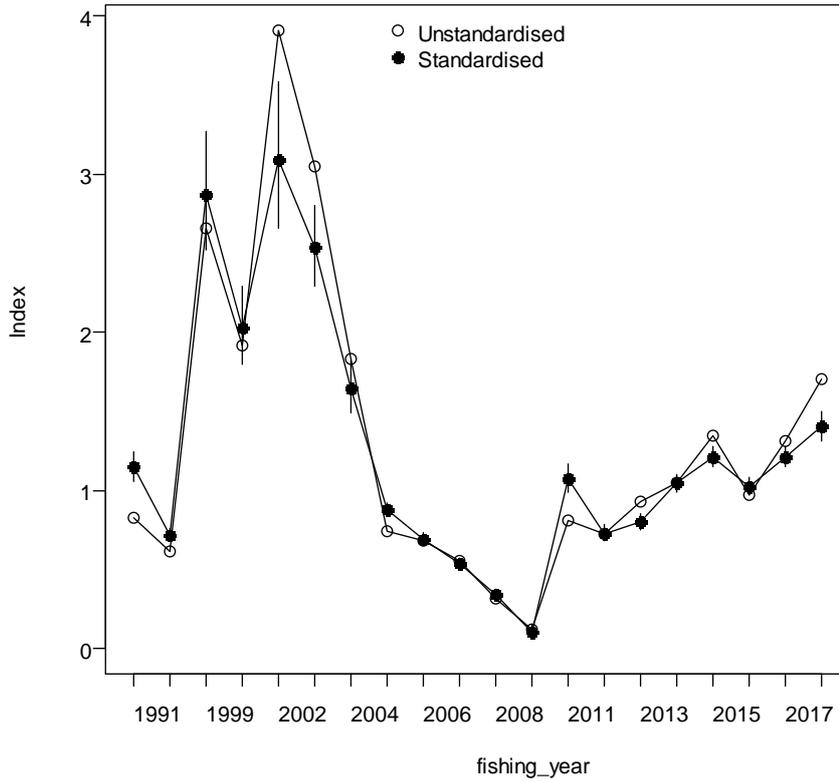
#### SCI 4A

Stepwise regression analysis of the dataset to estimate an annual CPUE index for SCI 4A resulted in a final model with fishing year (forced), time of day, month, effort (tow duration), and vessel retained (Table 5). Model diagnostics are presented in Appendix 3. The model had an  $r^2$  of 0.56. Month was the most influential variable, at 8.4%, with fishing duration and time of day having influences of 7.7% and 6.1%, and vessel 5.6%. The standardised and unstandardized annual indices are shown in Figure 26. The two indices follow a very similar pattern, although the unstandardized series increases to a greater peak in 2002 and increases at a slightly faster rate in the most recent years. The relative effects of the explanatory variables (excluding fishing year) are shown in **Error! Reference source not found**. Expected catch rates varied between months, but were generally lowest in March, and highest in October. Catch rates were also highest during the day, and lowest at night, being about half of the daytime rate. Expected catch increased for tow durations up to about 8 hours, but then declined. Catch rates have also varied between vessels.

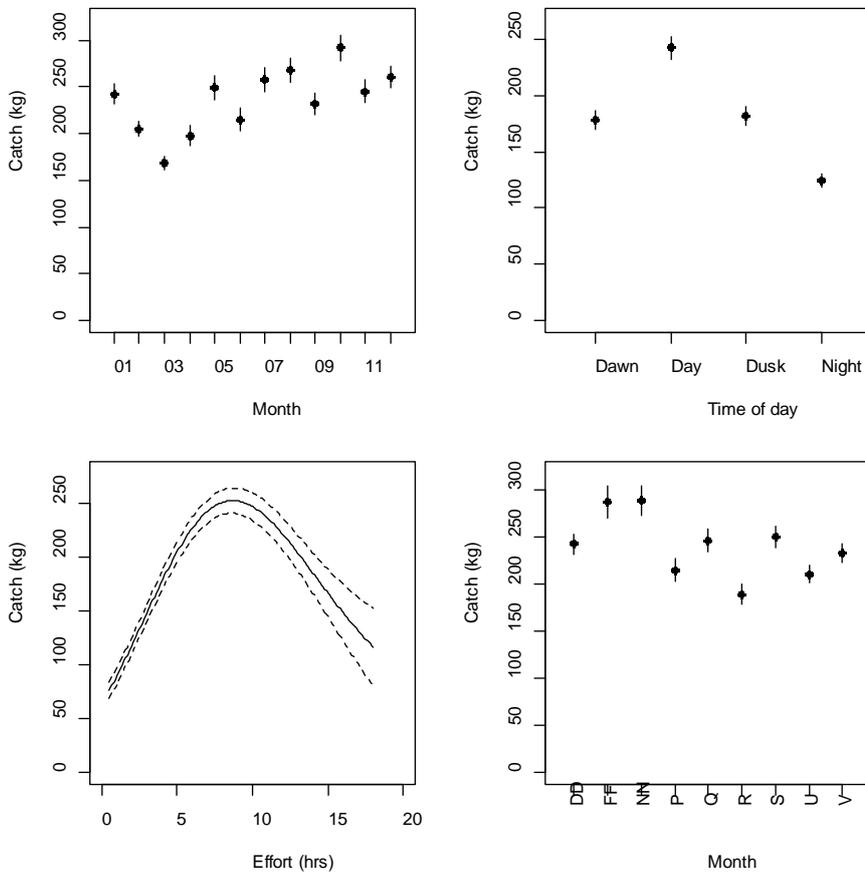
**Table 5: Analysis of deviance table for final standardisation model selected by stepwise regression for SCI 4A.**

	Df	Deviance explained	Residual deviance	Additional deviance explained (%)	Overall influence (%) <sup>*</sup>	$r^2$
NULL			5 440			
fishing_year	19	926.16	5 421	17.03%		0.38
TOD	3	251.69	5 418	4.63%	6.09%	0.48
month	11	113.31	5 407	2.08%	8.37%	0.53
bs(Duration)	3	44.22	5 404	0.81%	7.74%	0.54
vessel_code	8	30.01	5 396	0.55%	5.63%	0.56

\*- Overall influence as in table 1 of Bentley et al. (2012)



**Figure 26: Comparison of standardised (Table 5) and unstandardized annual CPUE index for SCI 4A. Note that the area was not fished in all years, and the x axis does not represent a continuous series.**



**Figure 27: Termplot (in natural space) for annual index standardisation model for SCI 4A (Table 5), showing relative effects of month, time of day, effort (tow duration), vessel.**

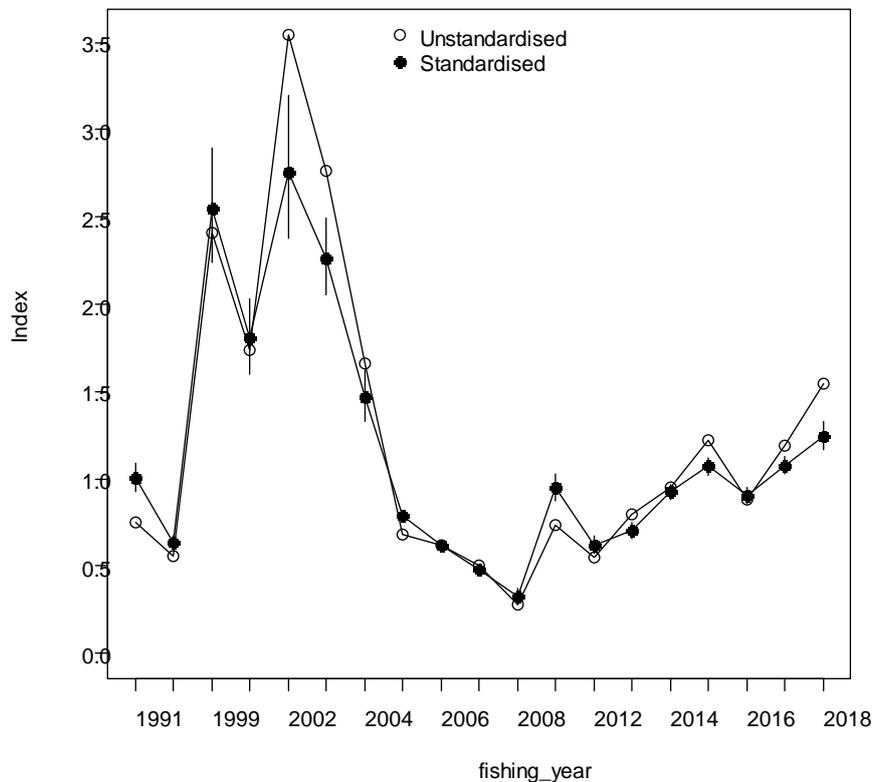
### SCI 4A E subarea

Stepwise regression analysis of the dataset to estimate an annual CPUE index for subarea SCI 4A E retained the same explanatory terms as the full area model, and resulted in a final model with fishing year (forced), time of day, month, effort (tow duration), and vessel retained (Table 6). Model diagnostics are presented in Appendix 3. The model had an  $r^2$  of 0.55. Month was the most influential variable, at 8.9%, with fishing duration and time of day having influences of 7.3% and 5.2%, and vessel 3.7%. The standardised and unstandardized annual indices are shown in Figure 28. As with the full area model, the two indices follow a very similar pattern, although the unstandardized series increases to a greater peak in 2002 and increases at a slightly faster rate in the most recent years. The relative effects of the explanatory variables (excluding fishing year) are shown in Figure 29. These plots show the same patterns as for the whole SCI 4A area.

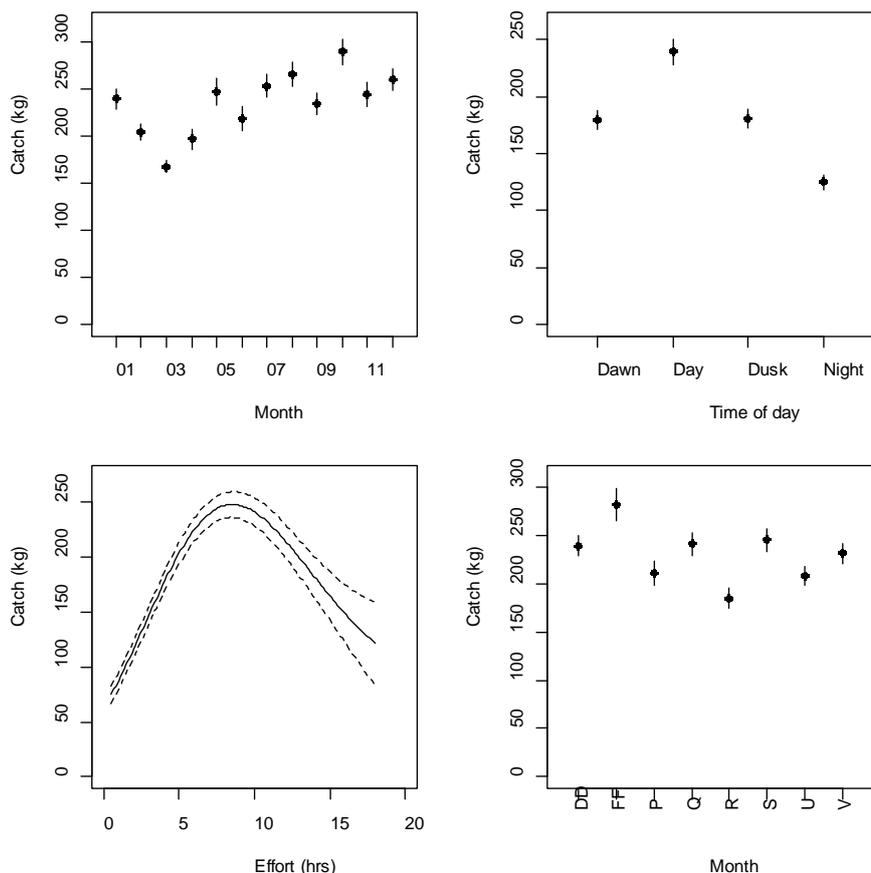
**Table 6: Analysis of deviance table for final standardisation model selected by stepwise regression for subarea SCI 4A E.**

	Df	Deviance explained	Residual deviance	Additional deviance explained (%)	Overall influence (%)*	$r^2$
NULL			5 192			
fishing_year	18	866.11	5 174	16.68%		0.37
TOD	3	228.75	5 171	4.41%	5.22%	0.47
month	11	109.52	5 160	2.11%	8.89%	0.52
bs(Duration)	3	42.75	5 157	0.82%	7.27%	0.54
vessel_code	7	24.15	5 150	0.47%	3.73%	0.55

\*- Overall influence as in table 1 of Bentley et al. (2012)



**Figure 28: Comparison of standardised (Table 6) and unstandardized annual CPUE index for SCI 4A E. Note that the area was not fished in all years, and the x axis does not represent a continuous series.**



**Figure 29: Termplot (in natural space) for annual index standardisation model for SCI 4A E (Table 6), showing relative effects of month, time of day, effort (tow duration), vessel.**

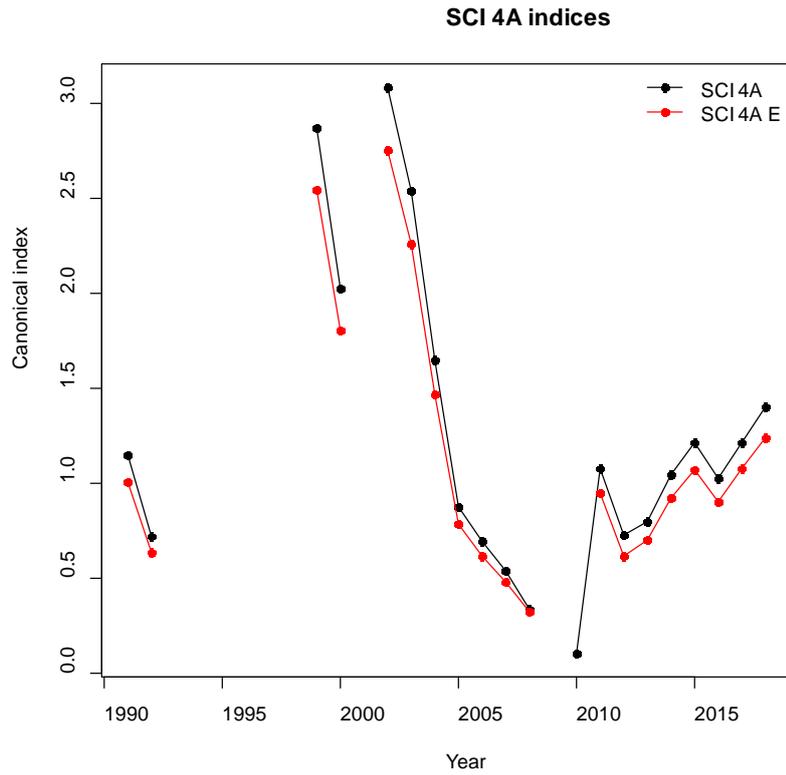
The SCI 4A E index is based on a subset of the data used to generate the SCI 4A index, and not surprisingly the two indices are very similar (Figure 30). For the SCI 4A index, only one vessel provided data for 2010, and this vessel was excluded from the SCI 4A E index.

#### 4. CONCLUSIONS

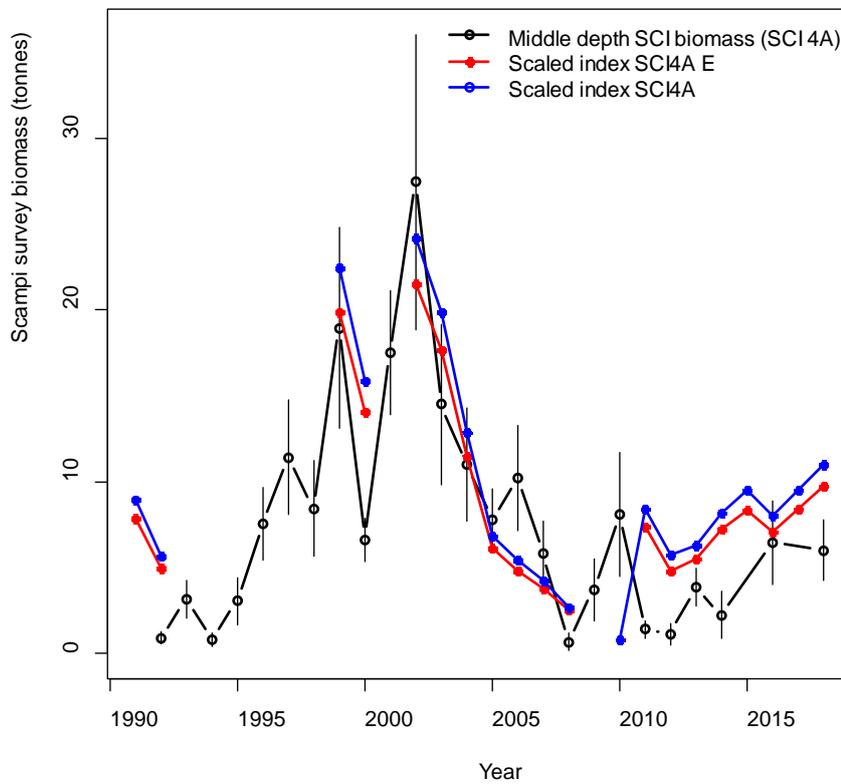
Catch and effort data from TCEPR forms, length composition data from observer sampling, and catch and length data from the Chatham Rise middle depths trawl survey have been collated to describe the SCI 4A fishery.

Scampi catches have predominantly been taken by scampi targeted fishing activity (more than 99%). Fishing effort and catches have varied over time, but have increased more recently and catches have fluctuated around the TACC since 2014. Scampi catches have occurred across the region but are predominantly from one area to the north of the Chatham Islands, with a second area (to the west) having also been fished between 2005 and 2007.

Standardised indices of CPUE suggest that abundance roughly trebled between the early 1990s and the early 2000s, declined to slightly below early 1990s levels by 2008, but have subsequently increased (Figure 30). These standardised indices show a very similar pattern to the biomass series estimated from the Chatham Rise middle depths trawl survey (Figure 31).



**Figure 30: Comparison of the two standardised CPUE indices for SCI 4A.**



**Figure 31: Comparison of the standardised CPUE indices for SCI 4A with the middle depths survey biomass series. CPUE indices have been scaled to the mean of the survey biomass for the years each index is available.**

Observer data are available from 4% of scampi targeted events, although coverage varies considerably between years. No consistent seasonal patterns in sex ratio of catches is apparent. Mean size in observed catches was markedly higher between 2003 and 2005 compared to other years, but length composition data from the Chatham Rise middle depths trawl survey did not show any patterns over time. The patchiness of observer sampling over time, and the trawl gear used on the middle depths survey raise concerns about the representativeness of both data sets.

## 5. ACKNOWLEDGEMENTS

This work was funded by Fisheries New Zealand project SCI2017-04. Data analysed within this study have been collected by a great number of MPI fishery observers and NIWA staff on research surveys. This report was reviewed by Bruce Hartill.

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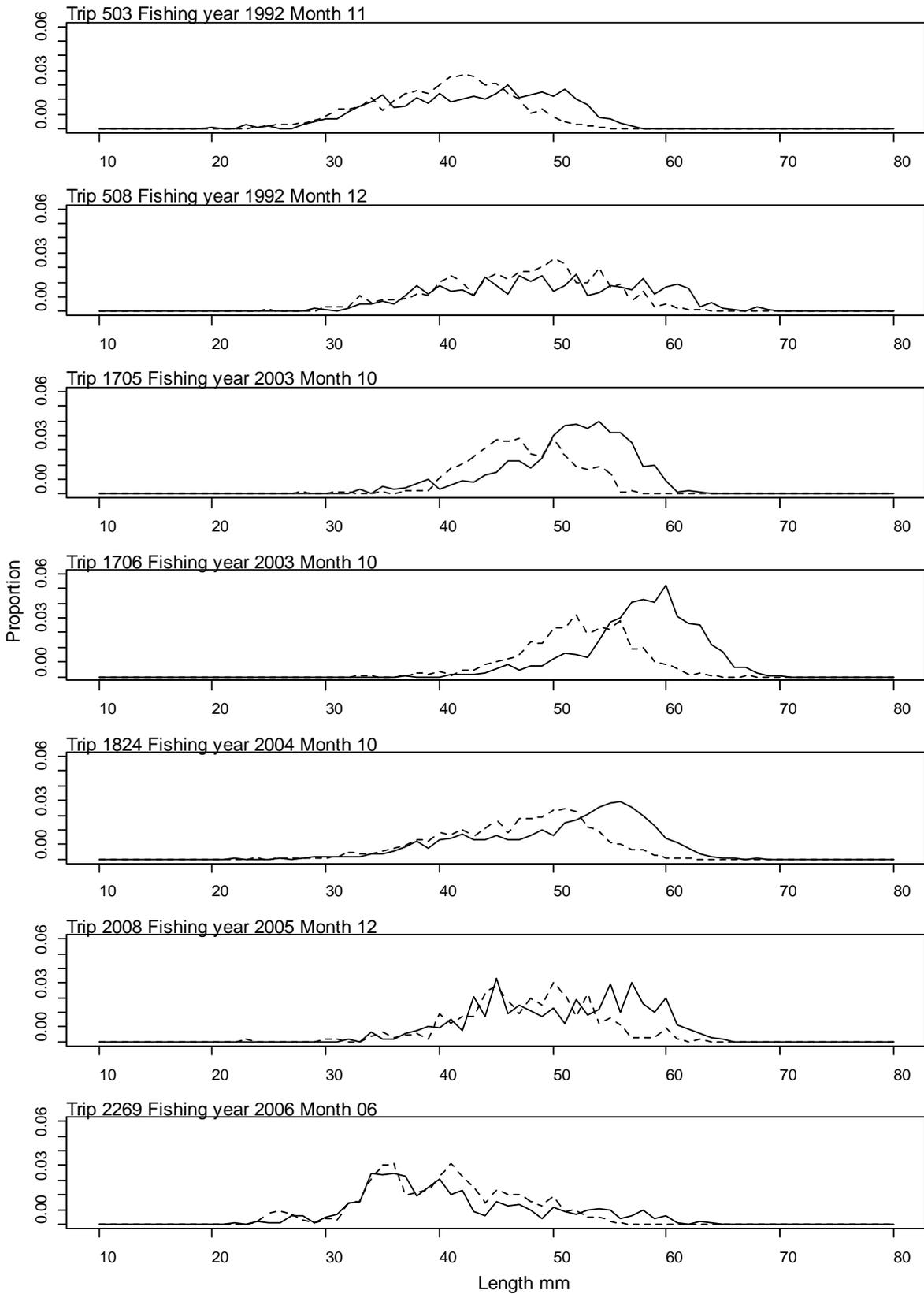
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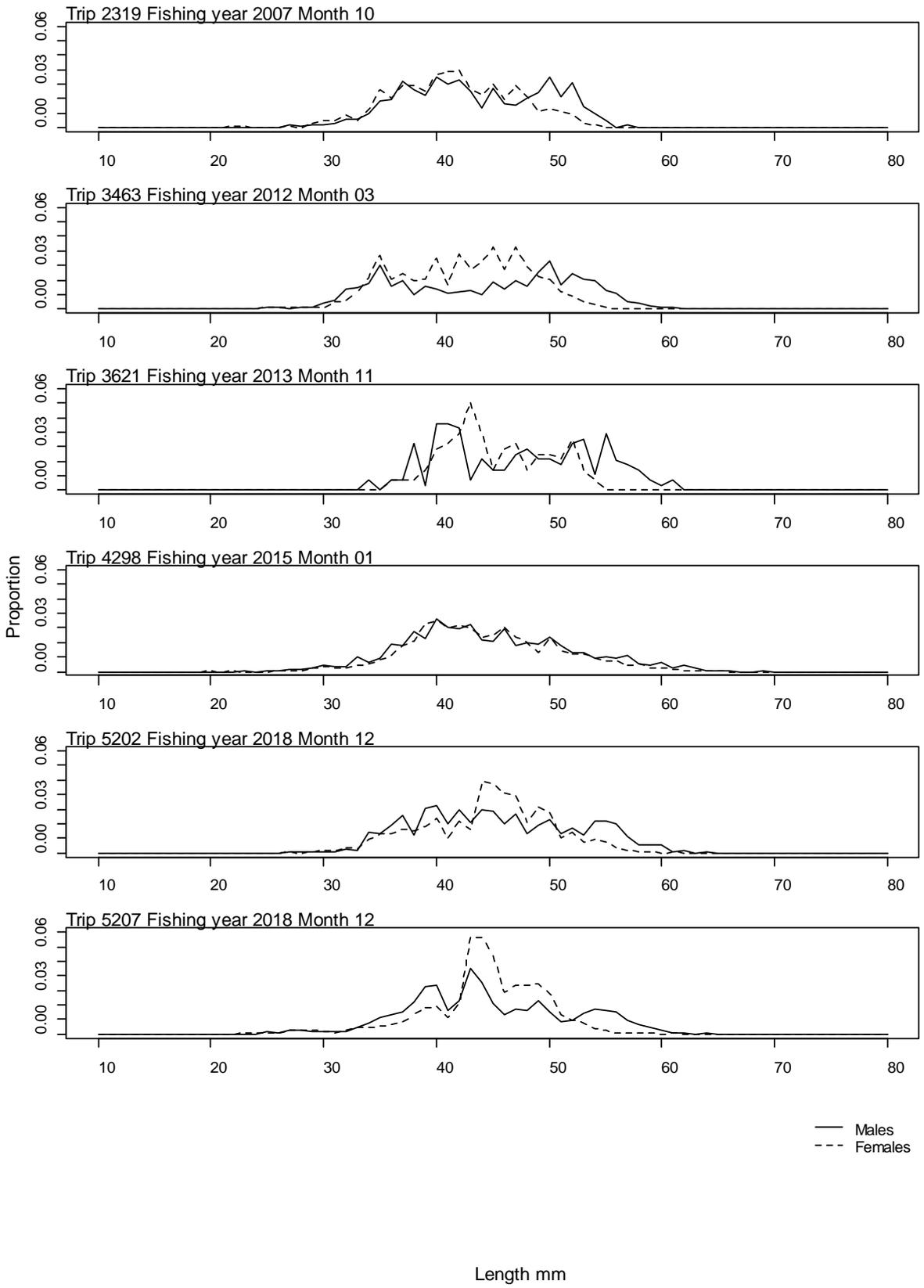
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7. APPENDIX 1: Scaled scampi length frequency distributions from observer samples.

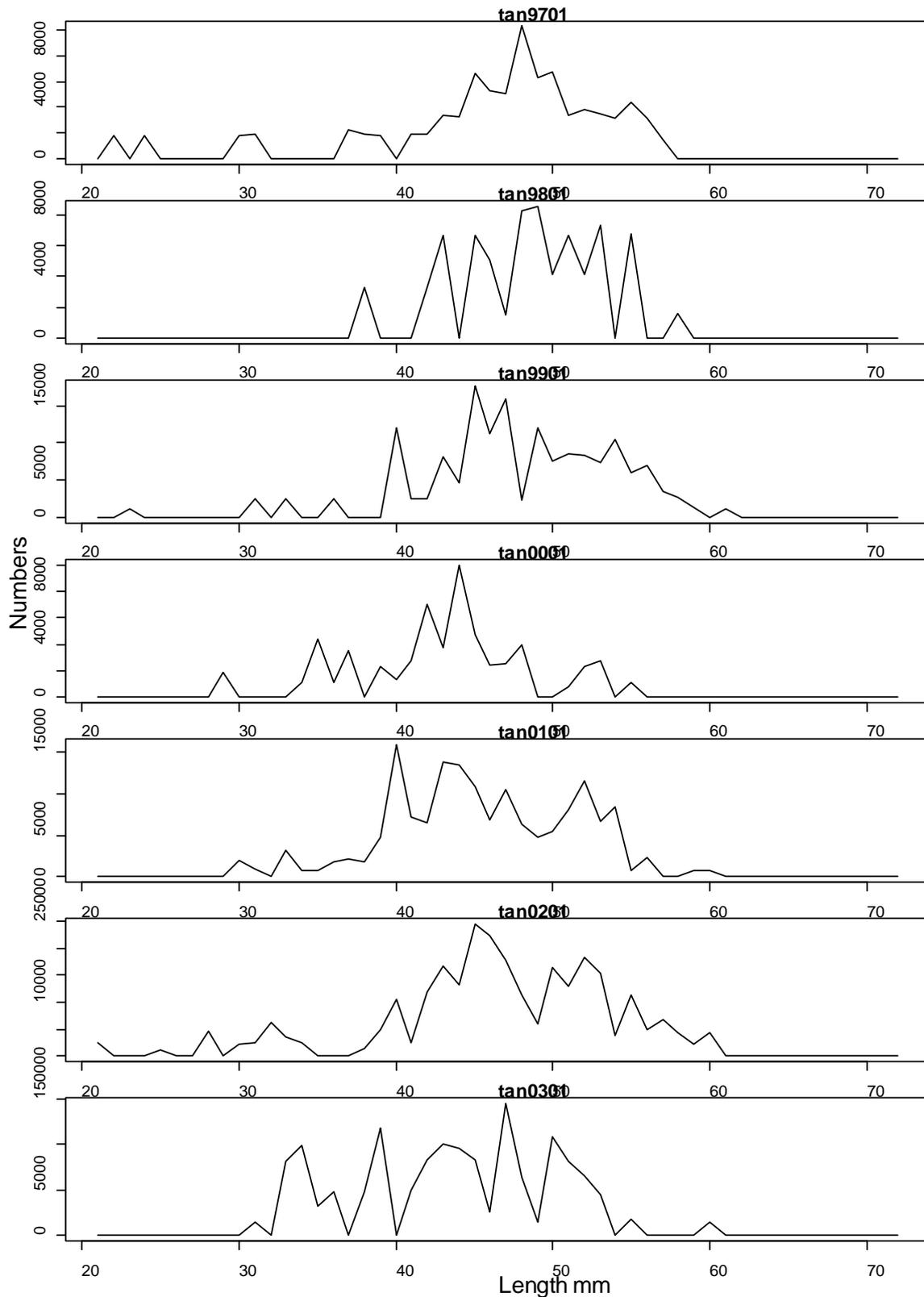
SCI 4A

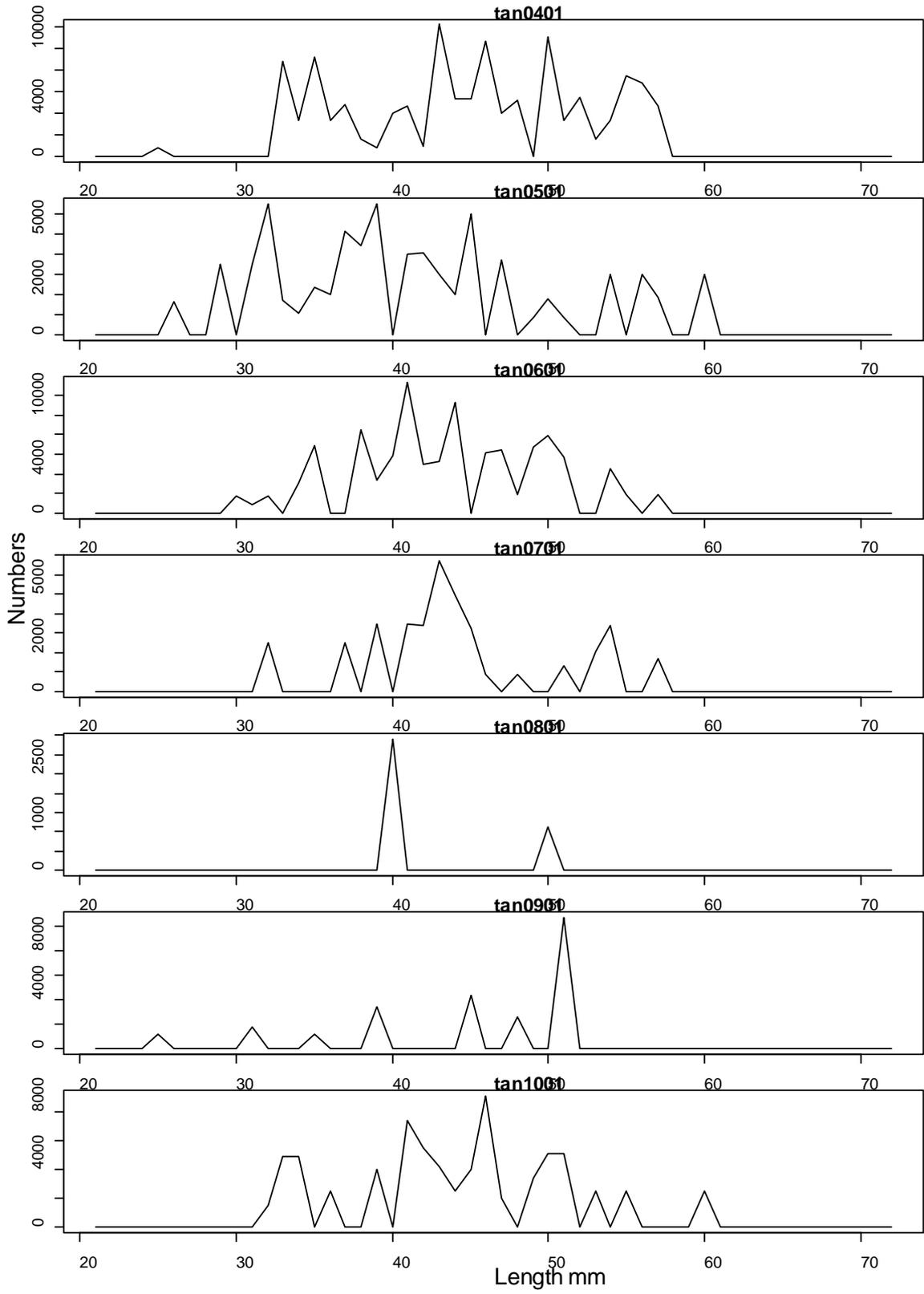


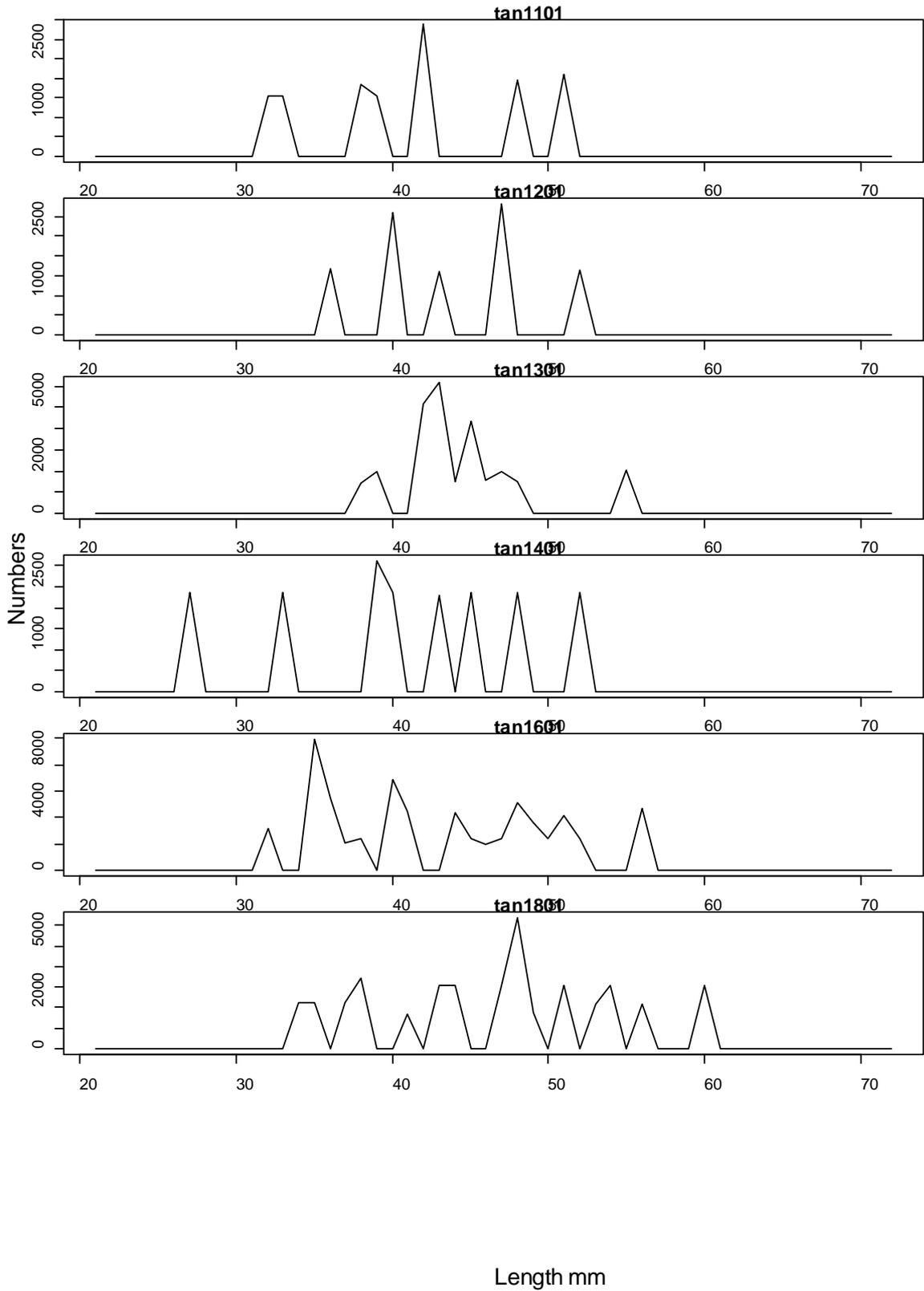


8. APPENDIX 2: Scaled scampi length frequency distributions from the Chatham Rise middle depths trawl survey.

SCI 4A

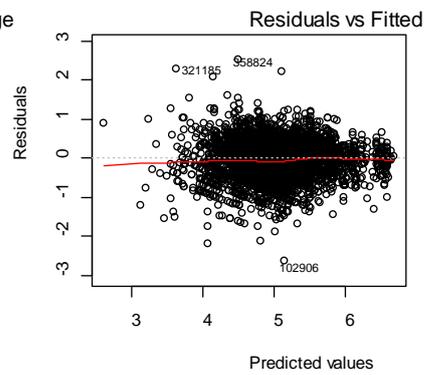
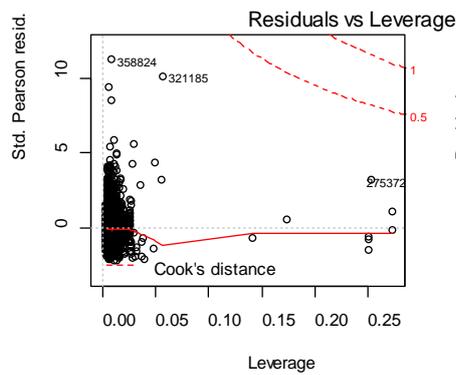
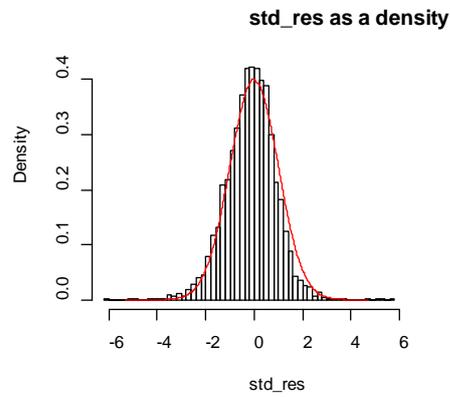
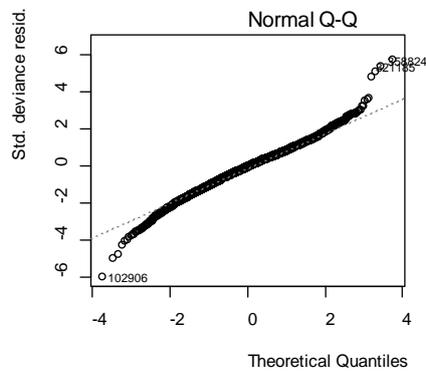
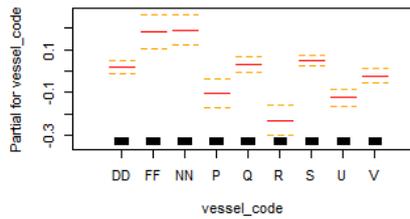
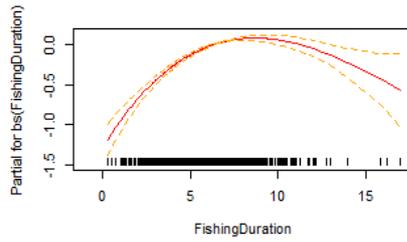
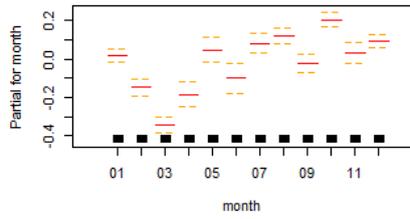
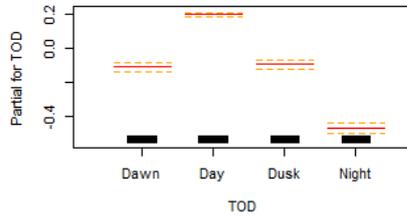
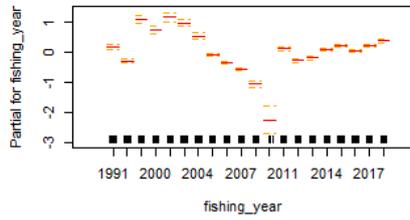


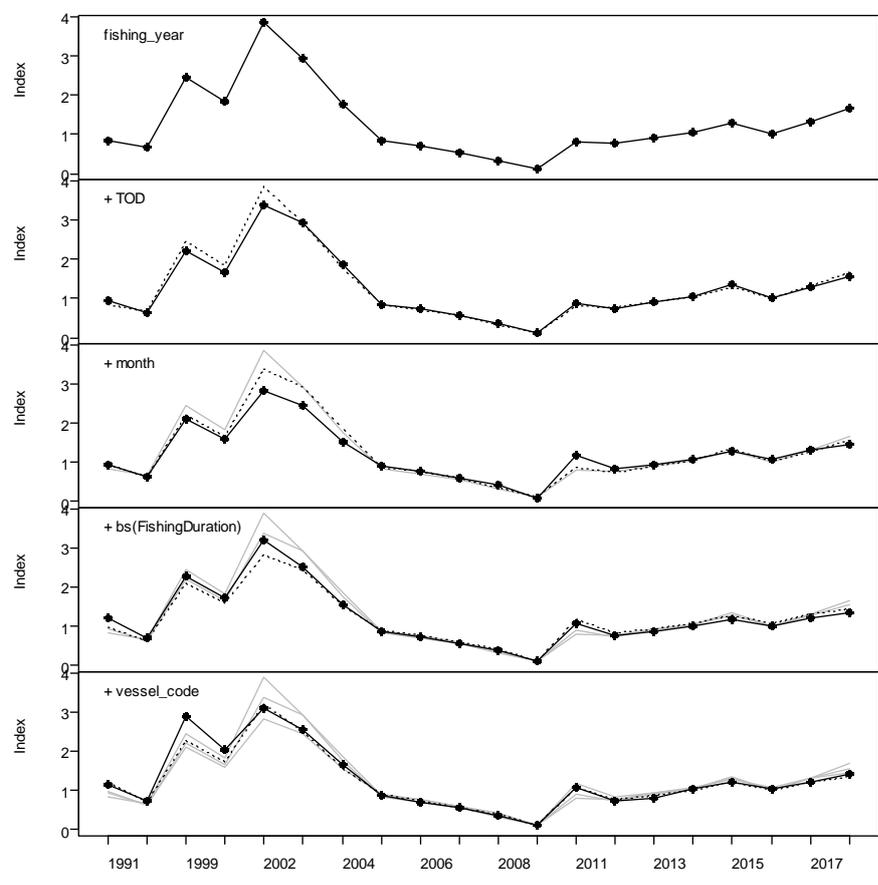
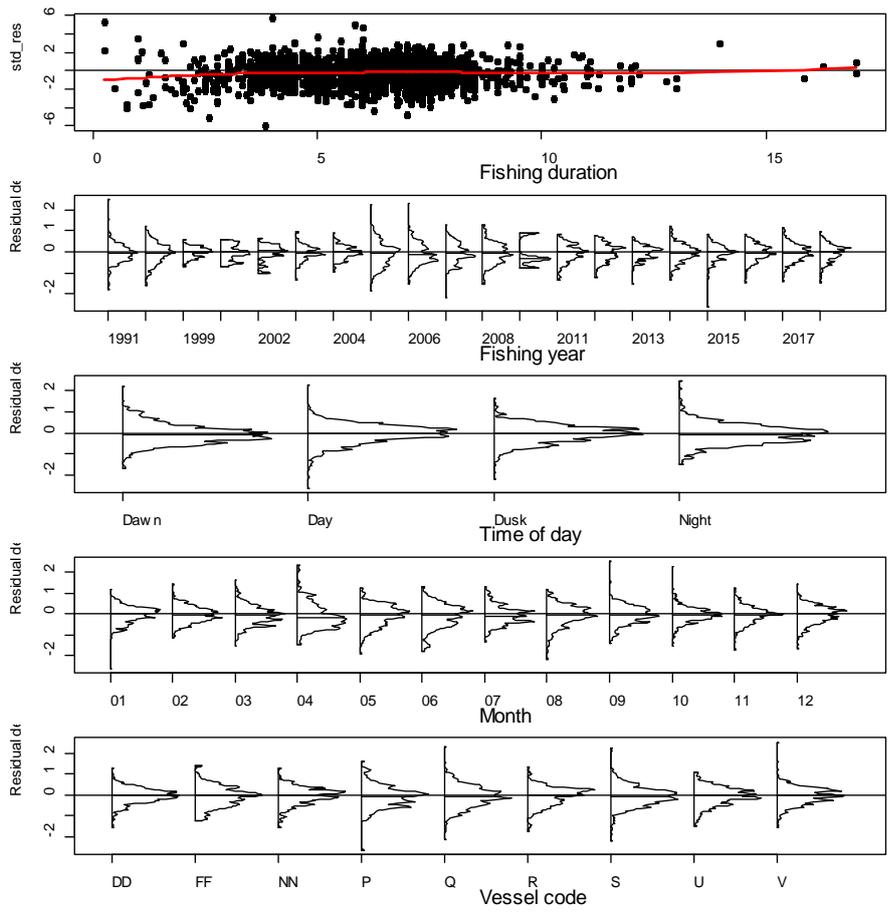


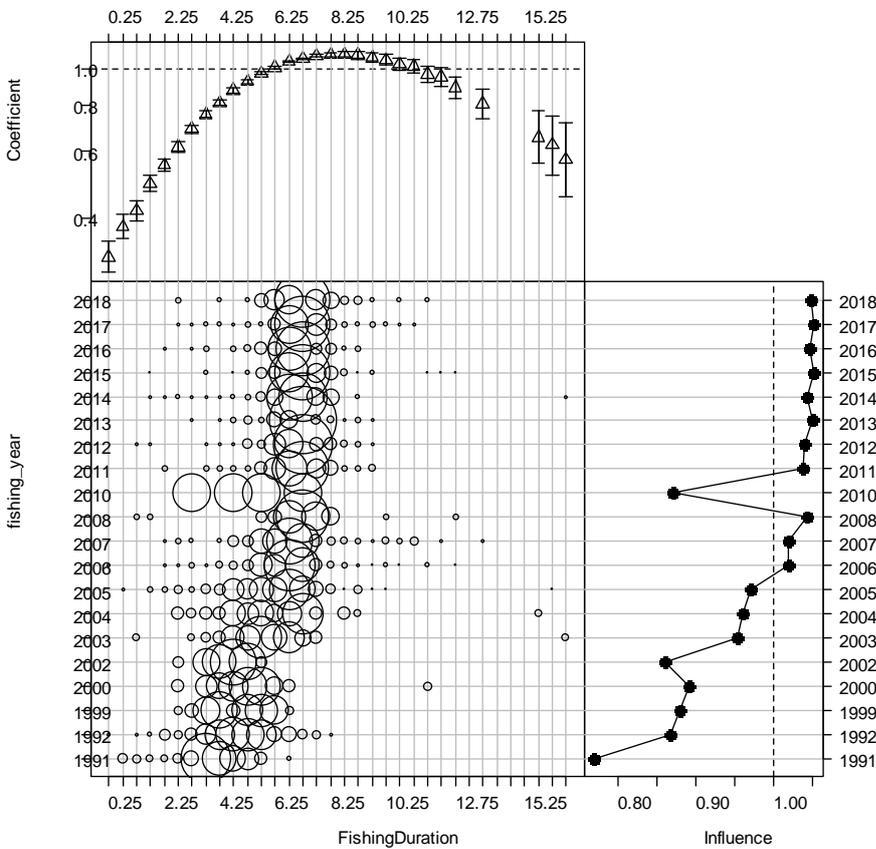
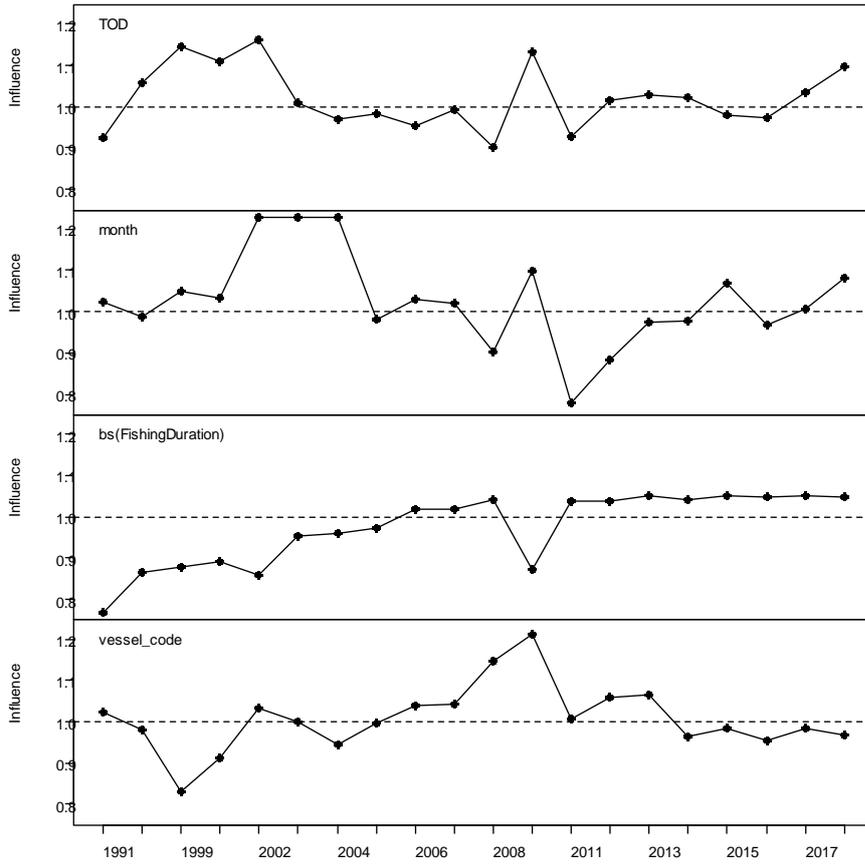


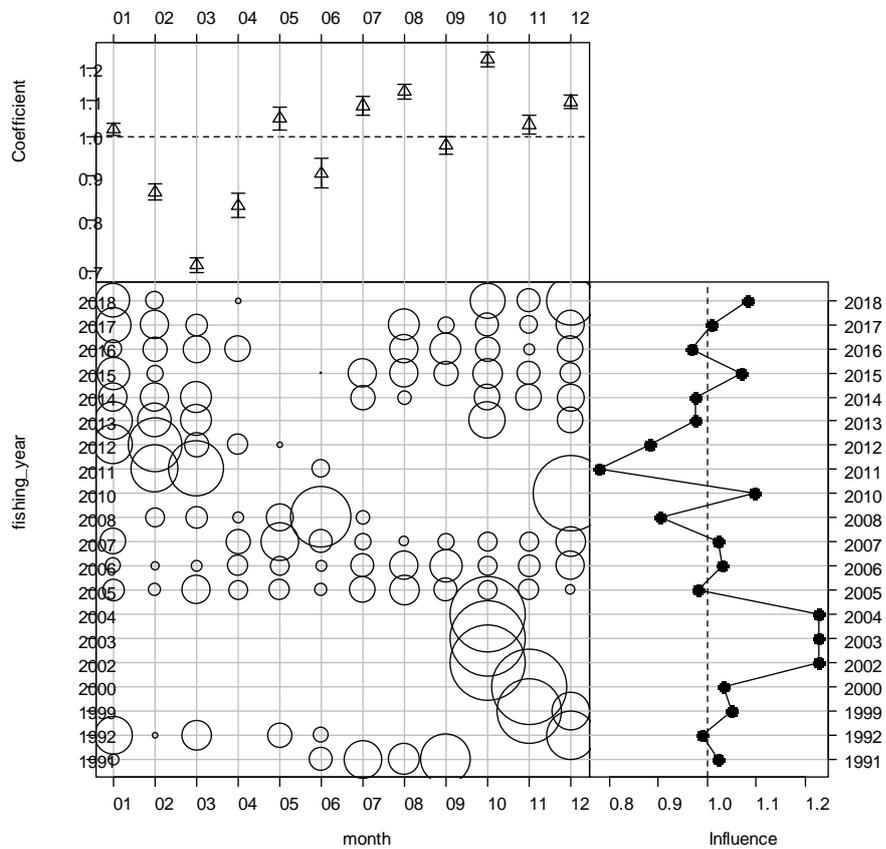
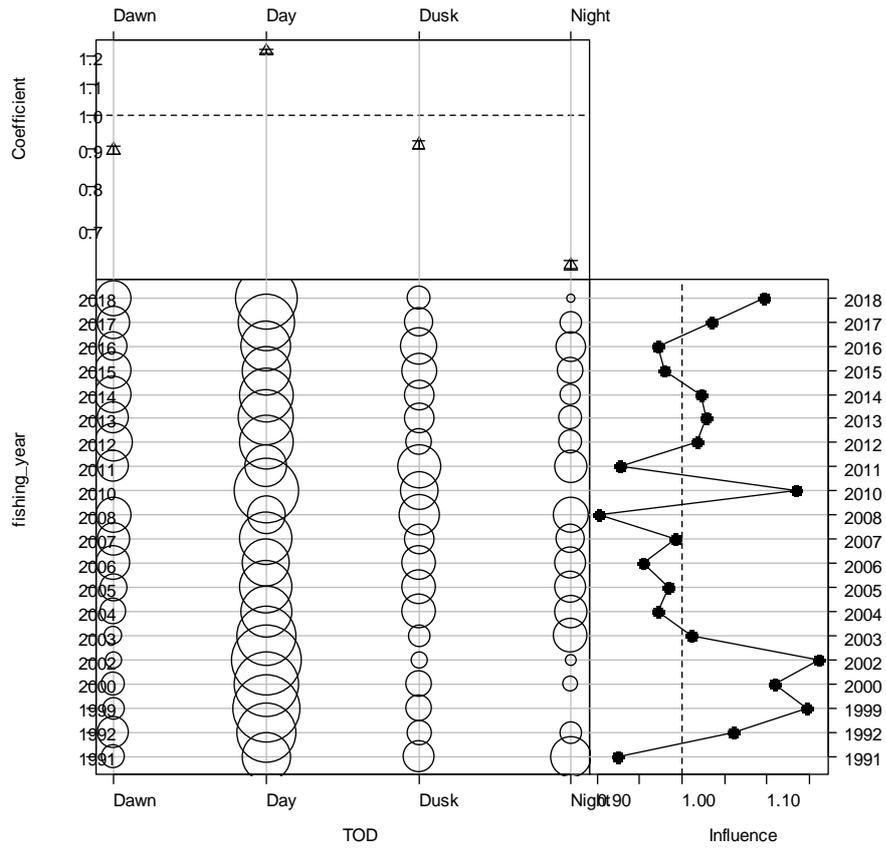
## 9. APPENDIX 3: CPUE standardisation diagnostic plots.

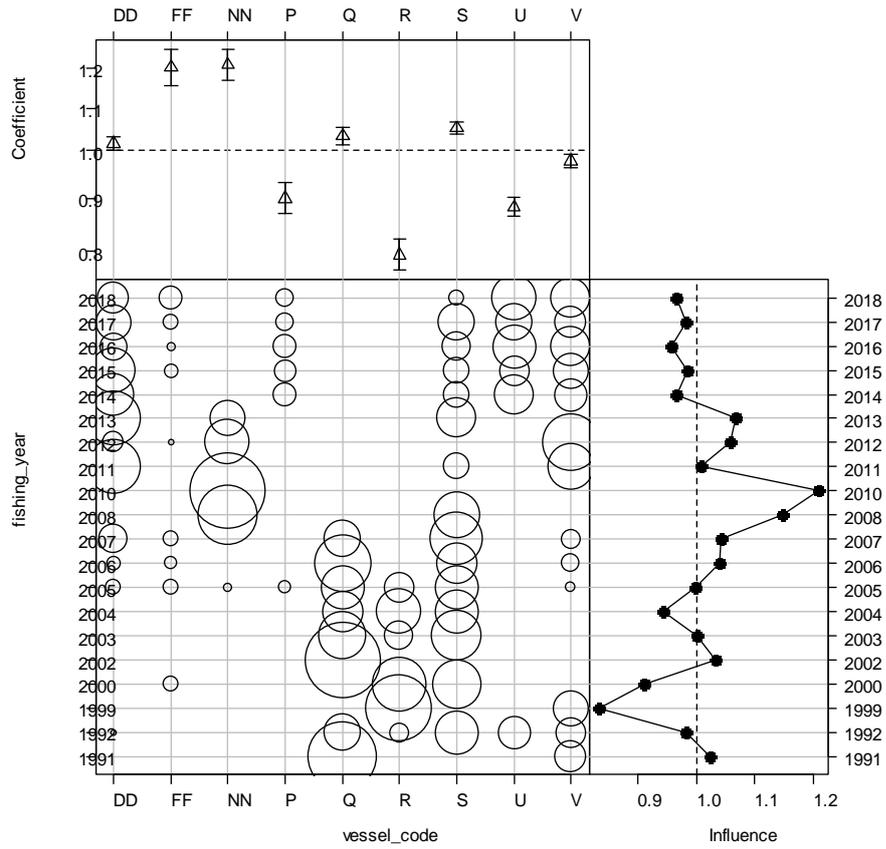
SCI 4A model (Table 5)











SCI 4A E model (Table 6)

