Fisheries New Zealand

Tini a Tangaroa

Estimation of the abundance of scampi on the Chatham Rise in SCI 3 and SCI 4A using trawl and photographic surveys

New Zealand Fisheries Assessment Report 2024/62

A. M. Wieczorek, M. J. Underwood, O. Evans, J. Hall, J. Hamill, H. Armiger, M. Smith, K. Spong, J. Drury, F. Barry, A. Miller, D.W. Stevens, B.A. Wood, S. Clinchard, D.R. Stotter

ISSN 1179-5352 (online)
ISBN 978-1-991308-68-9 (online)

September 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Please cite this report as:

Wieczorek, A.M.; Underwood, M.J.; Evans, O.; Hall J.; Hamill, J.; Armiger, H.; Smith, M.; Spong, K.; Drury, J.; Barry, F.; Miller, A.; Stevens, D.W.; Wood, B.A.; Clinchard, S.; Stotter, D.R. (2024). Estimation of the abundance of scampi on the Chatham Rise in SCI 3 and SCI 4A using trawl and photographic surveys. *New Zealand Fisheries Assessment Report 2024/62.* 41 p.

TABLE OF CONTENTS

PLAIN LANGUAGE SUMMARY

Photographic and trawl surveys of scampi on the Chatham Rise (SCI 3 and SCI 4A) were conducted in September and October 2023 from RV *Kaharoa*. There was an increase in number of scampi burrows, number of visible scampi, and the trawl estimate of scampi in SCI 3 compared to the previous survey in 2019. This was the first survey of SCI 4A.

As part of an investigation into scampi growth, a total of 5546 and 1172 scampi were tagged and released in SCI 3 and SCI 4A, respectively. To date no scampi have subsequently been recaptured by commercial fishing vessels.

EXECUTIVE SUMMARY

Wieczorek, A.M.; Underwood, M.J.; Evans, O.; Hall J.; Hamill, J.; Armiger, H.; Smith, M.; Spong, K.; Drury, J.; Barry, F.; Miller, A.; Stevens, D.W.; Wood, B.A.; Clinchard, S.; Stotter, D.R. (2024). Estimation of the abundance of scampi on the Chatham Rise in SCI 3 and SCI 4A using trawl and photographic surveys.

***New Zealand Fisheries Assessment Report 2024/62.* 41 p.**

Photographic and trawl surveys of scampi on the Chatham Rise (SCI 3 and SCI 4A) were conducted in September and October 2023 from RV *Kaharoa*. The photographic survey estimates for the SCI 3 survey area were 1264 million scampi burrows (coefficient of variation, CV 8%) and 438 million visible scampi (CV 8%). This was an increase in both, number of scampi burrows, and number of visible scampi compared to the previous survey in 2019. The trawl survey estimate for SCI 3 of 1302 t (CV 7%) was higher than in 2019. The photographic survey estimates for the SCI 4A survey area, which was surveyed for the first time, was 219 million scampi burrows (CV 12%) and 43 million visible scampi (CV 18%). The trawl survey estimated for SCI 4A, was 214 t (CV 28%).

As part of an investigation into scampi growth, a total of 5546 and 1172 scampi were tagged and released in SCI 3 and SCI 4A, respectively. To date no scampi have subsequently been recaptured by industry vessels. Any scampi which may be recaptured in the coming season will be incorporated into the existing tag recapture dataset for this stock and used to estimate growth rates within the stock assessment model. Additional data were collected during the survey, including visual assessment of microsporidian parasite infection rates in scampi, sampling of scampi for pathological analyses, CTD profiles, acoustic data, sediment samples, bycatch, and stomach contents analysis of potential scampi predators. Analysis of sediment samples showed sandy, clayey sand, and silty sand substrate in the SCI 3 area; the SCI 4A area was comprised mostly of silty sand. These substrate compositions add to our understanding of scampi emergence behaviours in these areas.

1. INTRODUCTION

The scampi fishery is based on the species *Metanephrops challengeri*, which is widely distributed around New Zealand. Total scampi landings in the 2022–23 fishing year were 1124 t (Total Allowable Commercial Catch TACC 1337 t) of which, 403 t came from SCI 3 (TACC 408 t), and 118 t came from SCI 4A (TACC 120 t). The SCI 3 fishing grounds have the highest landings of all SCI areas and SCI 4A has the 5th highest landings. Other major scampi fisheries are in SCI 1 (TACC 145 t), SCI 2 (TACC 153 t) and SCI 6A (TACC 306 t). Scampi are taken by light trawl gear in waters 300–500 m deep, although the range is slightly deeper in the SCI 6A region (350–550 m). Scampi occupy burrows in muddy substrates and are only available to trawls when they have emerged onto the seabed (Bell et al. 2006). Scampi emergence varies 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. 2015b). Little is known about the growth rate or maximum age of scampi.

The stock assessment of scampi is complex as emergence patterns mean that trawl catches do not always reflect scampi abundance. The use of catch-per-unit-effort (CPUE) indices in stock assessments has been questioned because of concerns that changes in these indices may be strongly influenced by changes in catchability caused by the behaviour of scampi rather than by actual changes in abundance. Photographic surveying has been used extensively to estimate the abundance of scampi in European fisheries (e.g., Morello et al. 2007; Campbell et al. 2009; Aristegui et al. 2021). Uncertainty over trawl catchability due to variability in emergence behaviour has led to the development of photo survey methods that rely on visual counts of scampi burrows rather than animals (Froglia et al. 1997; Tuck et al. 1997b; Cryer et al. 2003; Smith et al. 2003). However, these approaches still face uncertainties over burrow occupancy and population size distribution (ICES 2007; Sardà & Aguzzi 2012). Video surveying has been used extensively to estimate the abundance of the European scampi (*Nephrops norvegicus*) and photographic surveys have been carried out in New Zealand since 1998. To date, there have been six surveys in SCI 3 (2001, 2009, 2010, 2013, 2016, and 2019). SCI 4A was surveyed for the first time in this study. The reason for the surveying of SCI 4A is that a recent characterisation of the SCI 4A fishery indicated an established fishery. Annual landings from SCI 4A have been at or close to the TACC since 2014–15 and have matched or exceeded landings taken from New Zealand's most established fishery (SCI 1) since 2013–14 (Tuck 2020).

These photographic surveys provide two abundance indices: the density of major burrow openings; and the density of visible scampi (as an index of minimum absolute abundance). The index of major burrow openings has been used as an abundance index in recent stock assessments for SCI 1, SCI 2, and SCI 3 (McGregor 2023; Tuck 2019). Since 2016, visible scampi counts have been used for the SCI 6A assessment as in this region the relationship between scampi and burrows may be different from the other scampi fishery areas (Tuck et al. 2007; Tuck & Dunn 2009; Tuck 2017).

This report fulfils the final reporting requirement for Fisheries New Zealand research project SCI2022-02.

OVERALL OBJECTIVES

The overall objective of Fisheries New Zealand research project SCI2022-02 was to estimate the abundance of scampi (*Metanephrops challengeri*) in SCI 3 and 4A using trawl and photographic surveys.

SPECIFIC OBJECTIVES

1. To estimate the relative abundance of scampi (*Metanephrops challengeri*) in SCI 3 and 4A using photographic and trawl surveys.

2. To carry out tagging of scampi or to collect other biological data in SCI 3 and 4A as agreed by Fisheries New Zealand and the research provider.
3. Broader outcomes.

2. METHODS

The design of the SCI 3 and 4A 2023 survey was presented to the Deepwater Working Group and was documented in a Voyage Programme submitted to Fisheries New Zealand in August 2023. The survey was undertaken from the NIWA research vessel RV *Kaharoa* in September–October 2023.

The survey area for both trawl and photographic surveys in SCI 3 has remained consistent since 2013. Strata boundaries were revised in 2013 to exclude some areas where little commercial scampi fishing occurs (Figure 1). The revised survey coverage accounts for about 99 % of landings from the fishery over its history (Tuck 2019). In SCI 4A fishing events targeting scampi (1990–1991 and 2017–2018) have mainly focussed on two distinct patches to the North and West of the Chatham Islands and have resulted in the design of survey stratum 04AE and 04AW, respectively (Tuck 2020).

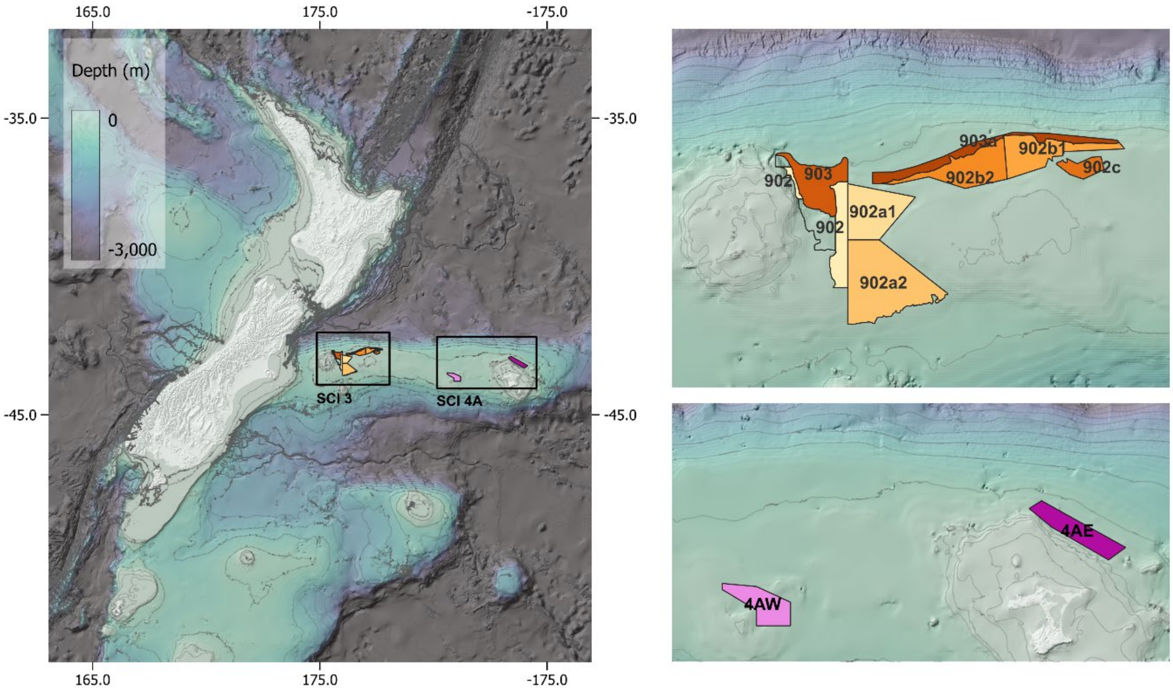

Figure 1: Survey areas SCI 3 (orange) and SCI 4A (magenta) on the Chatham Rise. In SCI 3 the stratum boundary without fill indicates original outline of stratum 902.

The survey covered the full area of SCI 3 and included eight strata (902, 902a1, 902a2, 902b1, 902b2, 902c, 903, and 903a) (Figures 1 and 2). A single phase stratified random survey design was used. The allocation of survey effort for SCI 3 followed that used during the 2019 survey, when a greater emphasis was placed on trawling than in previous surveys of this fishery. Forty photographic and 34 trawl stations were allocated to the strata using NIWA's *allocate* function (Francis 2006) to minimise the overall coefficient of variation (CV). The allocation is based on reader count data of major burrows on the ground for the most recent survey year (i.e., 2019). Only the most recent survey count was used because neither adults nor juveniles of *Metanephrops challengeri* have been observed to undergo long distance migrations (van der Reis 2021) and therefore the most recent data were likely to act as the best predictor of distribution patterns. The distribution of stations across the eight strata (Table 1) was predicted to result in a CV of 5.4% and 5.9% for the camera and trawl component, respectively.

Two days were spent surveying each of the two SCI 4A strata (4AW and 4AE, Figures 1 and 3). One day was allocated for trawling and one day for camera work, aiming to cover up to seven photo stations and four trawl stations per stratum, weather permitting (Table 2).

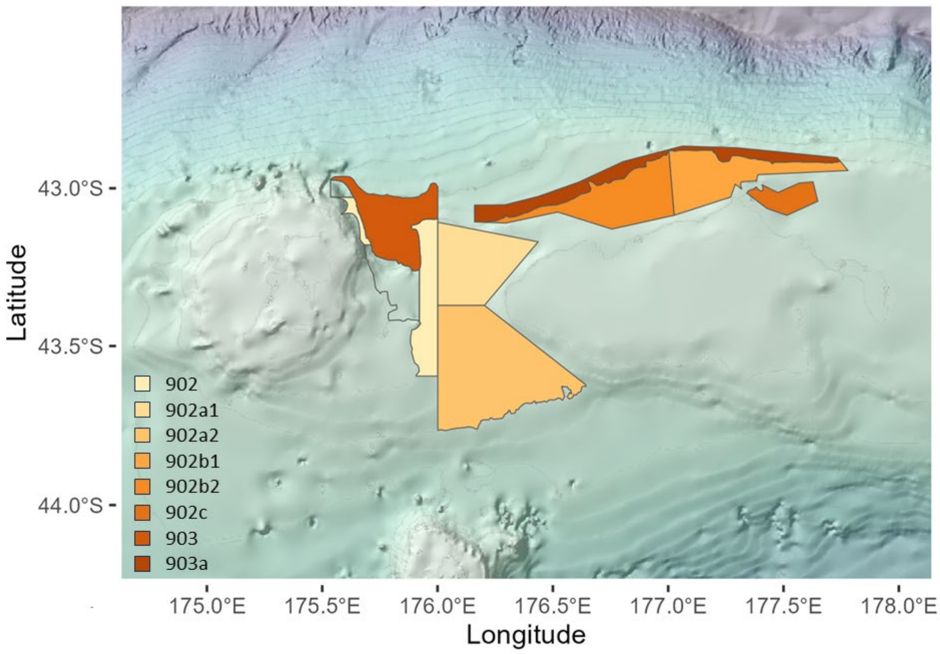

Figure 2: Survey strata for the 2023 photographic survey of SCI 3. Stratum boundary without fill indicate original outline of stratum 902.

Table 1: Details of strata and number of allocated and completed stations for the 2023 SCI 3 survey.

Stratum	Depth (m)	Area (km^2)	Photo stations		Trawl stations	
			Allocated	Completed	Allocated	Completed
902	300–400	440	5	5	4	3
902a1	300–400	700	6	6	5	3
902a2	300–400	1 432	9	8	8	4
902b1	300–400	605	4	4	3	3
902b2	300–400	661	7	7	5	4
902c	300–400	172	3	3	3	3
903	400–500	552	3	3	3	3
903a	400–500	459	3	3	3	3
Total		5 023	40	39	34	26

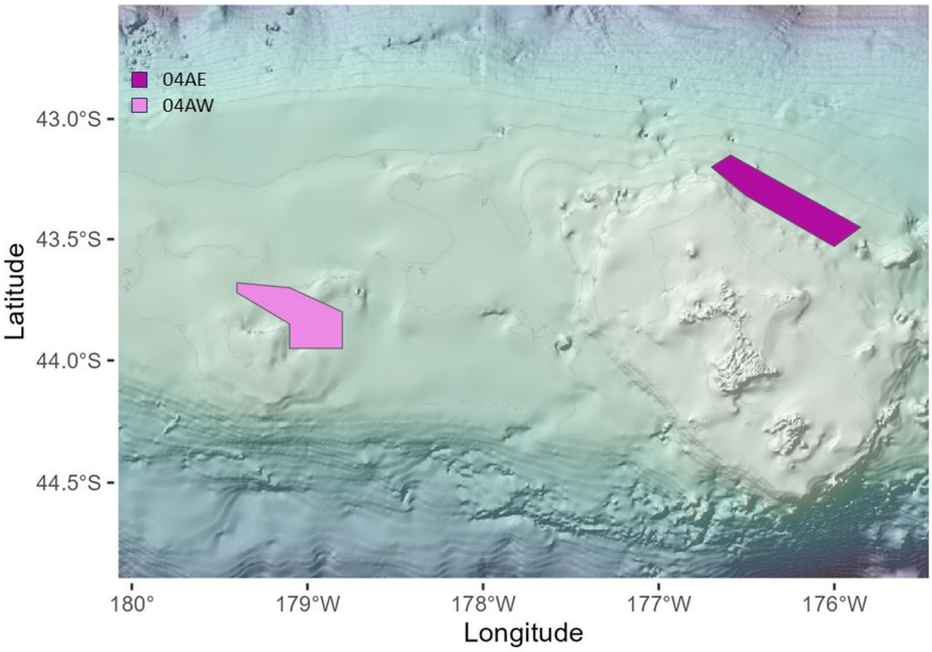

Figure 3: Survey strata for the 2023 photographic survey of SCI 4A.

Table 2: Details of strata and number of allocated and completed stations for the 2023 SCI 4A survey.

Stratum	Depth (m)	Area (km^2)	Photo stations		Trawl stations	
			Allocated	Completed	Allocated	Completed
4AW	250–500	791	7	7	4	3
4AE	250–500	872	7	7	4	3
Total		1 663	14	14	8	6

The *get.random.stations* function in *SurvTools* (Bian 2021) was used to randomly allocate stations within the eight SCI 3 strata and the two SCI 4A strata while making sure that a minimum 2 nautical miles (nmi) distance between camera stations, 4 nmi between trawl stations, and a 0.5 nmi distance to the strata boundary was maintained (Figure 4 and Figure 5). The function was run once to acquire all photographic stations (black dots, Figure 4 and Figure 5) and the first randomly generated photographic stations in each stratum were then chosen as trawl stations for the respective stratum (circles, Figure 4 and Figure 5). If any of the trawl stations were less than 4 nmi apart from one another, another station in the same stratum was substituted. At least two additional stations were generated for each stratum, which were available to substitute any of the existing stations. In stratum 903a one haul was deemed as foul due to gear failure (damaged or malfunctioning trawl, gear performance = 3). This trawl station was substituted with the first one on the list of back-up stations (Figure 4).

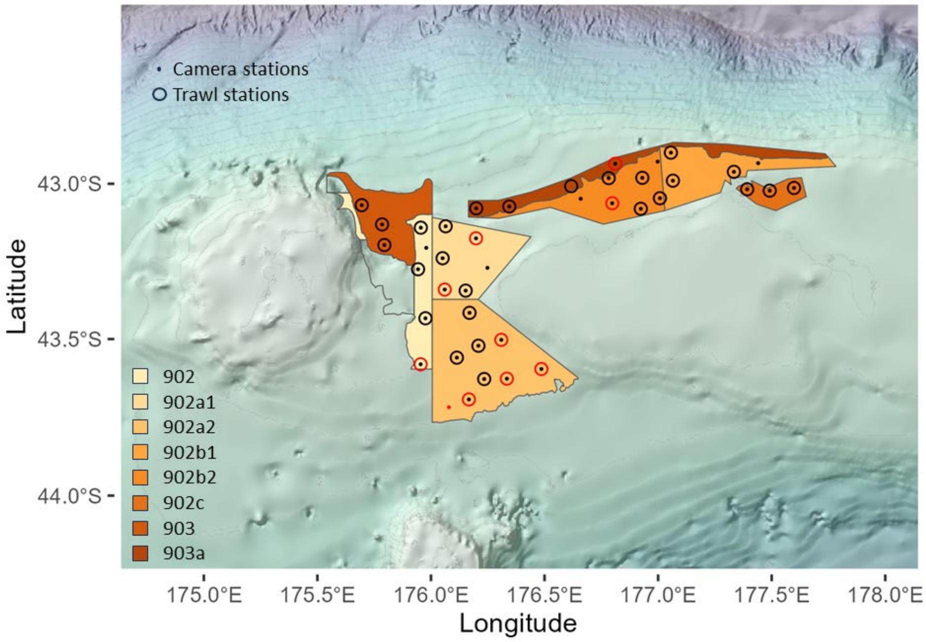

Figure 4: Station locations within each stratum for 2023 survey in SCI 3. Stations with a solid point and an open circle indicate it was both a photographic and trawl station. Stations in black indicate a completed station while stations in red indicate stations that were not completed.

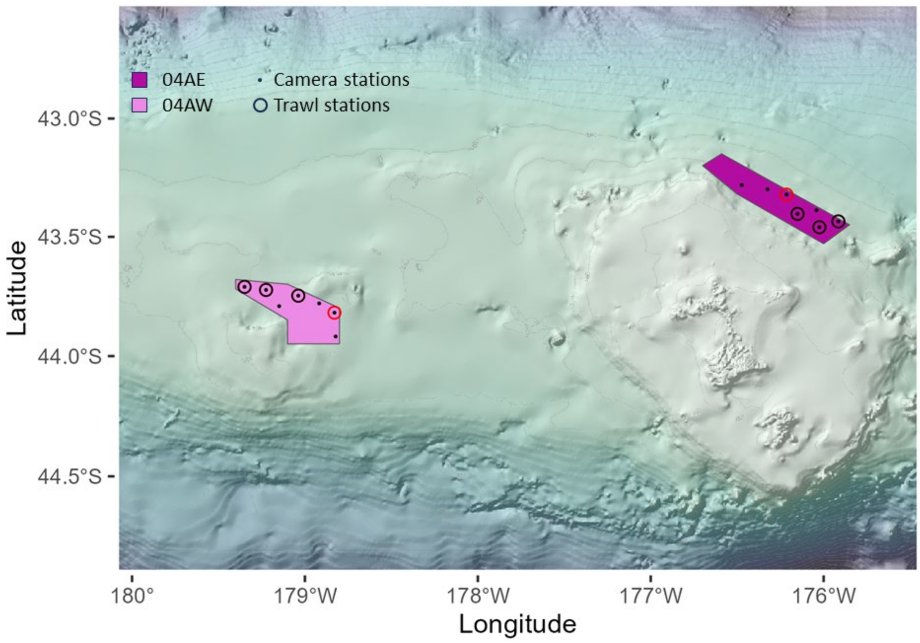

Figure 5: Station locations within each stratum for 2023 survey in SCI 4A. Stations with a solid point and an open circle indicate it was both a photographic and trawl station. Stations in black indicate a completed station while open circles in red indicate trawl stations that were not completed.

2.1 Photographic survey

Photographic sampling was undertaken between 06:00 and 18:00 NZST to coincide with the period of maximum trawl catchability of scampi (Tuck et al. 2015b). Although the time of day should have no direct effect on the detectability of scampi burrows and their openings, sampling at a time when the greatest number of scampi are likely to be out of their burrows means that a greater number of individuals can be measured to obtain a photographic length frequency distribution.

NIWA's high resolution deepwater digital camera system (Luminix, GX1) was used to take photographs 3–5 m from the seabed using a custom-built steel cage on either a trawl warp or conducting cable, as decided by vessel crew. This system has automatic flash exposure (Nikon, Autofocus Speedlight SB-800), which provided good focus and precision for measurements of scampi and burrow opening dimensions. The camera was triggered using an interval timer in conjunction with a micro-ranger attached to the camera. Image size (area of seabed viewed) was determined using parallel lasers (DeepSea Power & Light, SeaLaser®100) set 200 mm apart on the camera frame. The distance between the lasers was regularly checked before deployment. To take each photograph, the camera system was lowered and maintained about 4 m off the bottom using a Marport SeineSensor (SE-150-W Marport A1 SE150 OMNI Seine Depth Sensor) that displayed the distance off-bottom in "real time" on the bridge using Scala software. Between 30 and 40 frames were exposed as the ship drifted, using a time delay sufficient to ensure that adjacent photographs did not overlap (Cryer et al. 2002).

Images were stored on 32 GB flash cards in the camera. This allowed images to be stored in raw format (NTF) for greater versatility in image enhancement, resulting in files of about 18.7 MB. After the completion of a station, the images from the flash card were downloaded through a USB cable connection from the camera housing to a dedicated hard drive. After each station, downloaded images were briefly checked and counted to ensure that a sufficient number (30–40 high quality images) had been collected and then backed up to a portable hard drive.

Image selection and scoring

Images were examined and scored using a standardised protocol (Cryer et al. 2002, Wieczorek et al. 2024) applied by a team of five trained readers. For each image, the main criteria for usability were the ability to discern fine seabed detail and the visibility of more than 50% of the frame (i.e., free from disturbed sediment, poor flash coverage, or other features). If these criteria were met, the image was "adopted" and "initiated" (Cryer et al. 2002). The percentage of the frame within which the seabed was clearly and sharply visible was estimated and marked using polygons in NICAMS (NIWA Image Capture and Manipulation System, developed using the ImageJ software). The criteria used by readers to judge whether or not a burrow should be scored were, of necessity, partially subjective because readers could not be certain that any particular burrow belonged to an individual scampi and that the burrow was currently inhabited unless the individual was photographed in it. However, after viewing large numbers of scampi associated with burrows, NIWA has developed a set of descriptors that guide categorisation (Cryer et al. 2002; Wieczorek et al. 2024). Images of scampi associated with burrows "major" and "minor" openings each have their own characteristics and were scored separately (Figure 6). We define "major" burrow openings as those where scampi are usually observed, and "minor" burrow openings the rear openings associated with most burrows. Each opening (whether major or minor) was further classed as "highly characteristic" or "probable" based on the extent to which each was typically observed to be used by scampi. Scores were saved in the *prod_nicams* database within the NICAMS software system.

An investigation into mud burrowing megafauna on scampi grounds concluded that it was unlikely that other species would generate burrows that could be confused with those generated by scampi (Tuck & Spong 2013). Burrows and holes which could conceivably be used by scampi but were not assessed to be "highly characteristic" or represent a "probable" burrow were not counted. The counts of burrow openings may, therefore, be conservative. Many ICES stock assessments of European scampi

(*Nephrops norvegicus*) are conducted using relative abundance indices based on counts of “burrow systems” (burrows with multiple openings rather than individual burrow openings) (Tuck et al 1994; 1997c). Burrow openings, rather than assumed burrow systems, were counted here because burrow systems are relatively large compared with the quadrat (photograph) size and accepting all systems totally or partly within each photograph has been shown to be positively biased by edge effects (Marrs et al. 1996; 1998).

Once the images from the survey had been scored by three readers, any images for which the was disagreement by more than 1 in burrow counts (combined for “highly characteristic” and “probable”) were re-examined by all readers (who may or may not change their score considering observations from other readers). All images where there were any differences between readers on the count of visible scampi (including difference of interpretation as to whether a scampi was “in” or “out” of a burrow) were also re-examined by all readers. After re-assessing their own interpretation against the original image, readers were encouraged to compare their readings with the interpretations of other readers. This re-reading process was used to maintain consistency among readers, as well as to refine the count for a given image.

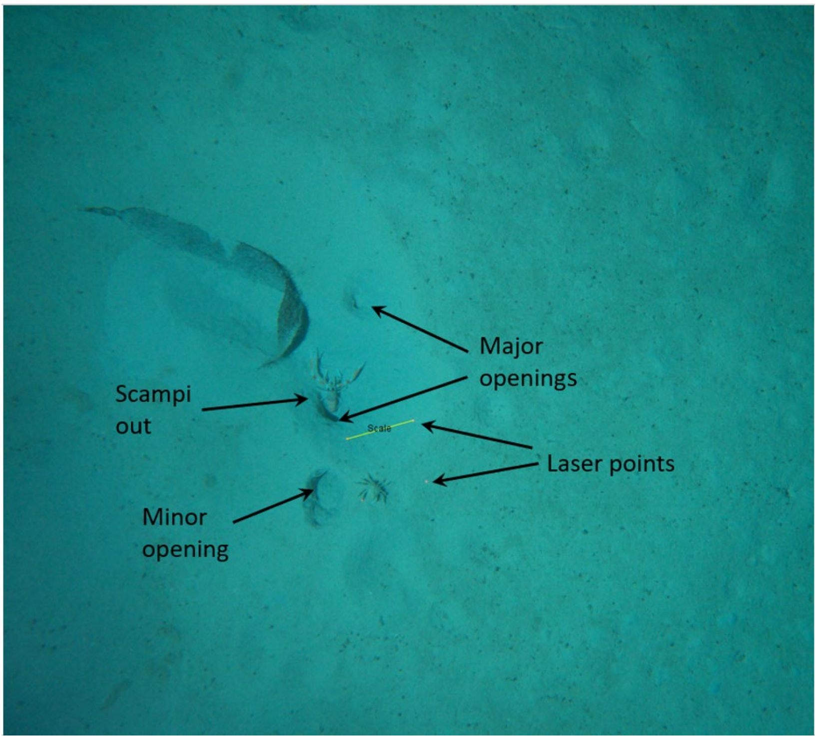

Figure 6: Example image showing red laser scaling dots, several characteristic scampi burrows, and one scampi.

Image storage

All survey images (and associated annotations) from surveys (and reference sets) since 2012 are maintained on NIWA's *prod_nicams* database on the Biscay database server, which is backed up daily. Annotated images from previous surveys and associated datasets are saved in the Fisheries New Zealand project archive. Within NICAMS, features counted by each reader are individually identifiable within each image, providing an audit trail.

Reader and year calibration

Reference set images from previous SCI 3 surveys were reread half-way through the reading of the 2023 survey images so that the scampi and burrow counts could be recalibrated to correct for changes in reader interpretation of seafloor structures over time. Each image in each reference set was read by all five readers following the standard image scoring and re-reading procedure described above.

The SCI 3 image reference set was initially generated in 2009 (Tuck et al. 2011) and has been extended since to include reference set images from each survey. This progressive extension of the reference set over time has resulted in an image reference set that was excessively large, requiring some curtailment conducted between 2001 and 2023. The reference set that was read alongside the 2023 images was therefore restricted to the five most recent surveys and included 30–36 images from both high and low burrow density stations in each year.

All the image count data (including reference set counts) for each fishery were combined into a single dataset, and combined *reader-year* and *year-station* terms were generated for each observation so that changes in reader ability to interpret and detect visible scampi and major burrows could be inferred from reference set image reads. Data from images with a readable area smaller than 2 m^2 and greater than 16 m^2 were dropped from the data set to avoid a possible image size effect (the risk of misidentifying burrows increases as the object to pixel ratio decreases). Burrow and scampi count data from individual images were aggregated by station (or appropriate combination of reference set images). During previous image read analyses, image count data would be adjusted through a Generalised Linear Mixed Model (GLMM) framework whereby reads from the reference set were used to derive "adjusted" count data which takes differences between readers and reader drift into account. However, as the GLMM framework is currently under review within the SEA2023-13 project and following the recommendation of the Deepwater Working Group (1 May 2023) and discussions within the SCI2023-03 project, the station level burrow (and scampi) count data were not examined within a GLMM framework and only "unadjusted" counts are presented within this report.

Glossary

Term	**Definition**
Major burrow	Definite and probable major openings
Scampi in	Scampi with telson is not visible
Scampi out	Scampi where entire telson is visible **or** tail is very obviously "tucked under" and scampi is free-swimming
Visible scampi	Includes scampi in and out
Unadjusted	Raw mean counts
Adjusted	Adjusted counts (full model): mean from a distribution representing the different counts possible from all reader-year combinations.
Reference set	Selected images (mix of scampi and burrow densities) from previous surveys that are re-read during each image reading cycle

2.2 Trawl survey

Trawl survey sampling was undertaken after completion of the photographic survey, between 06:00 and 18:00 NZST to coincide with the period of maximum emergence of scampi (Tuck et al. 2015b). Trawl sampling was conducted with the RV *Kaharoa* scampi trawl, as with previous scampi surveys from this vessel (Tuck et al. 2011, Tuck et al. 2021).

Trawl survey catch rates were estimated on the basis of distance towed and a wingspread swept width of 25 m, scaled to stratum area to estimate total biomass and abundance. Tows were superimposed as closely as possible along photographic transects, were 3 nmi long, and towed at a speed over the ground of 2.8–3.0 knots. Exact distances trawled were determined using GPS and netsonde records.

2.3 Scampi tagging

The second objective of the voyage was to tag and release scampi to investigate growth.

Tagged scampi returns have been low overall in the SCI 3 area (2009–2021: 0.22% recaptured) but even fewer scampi have been returned from tagging initiatives in SCI 1 (2012–2021: 0.02%) and SCI 2 (2012–2021: 0.04%). Returns of tagged scampi have been best in SCI 6A (2007–2021: 3.75%). The short-term survival rate of re-released scampi has been estimated at 88% (Tuck et al. 2015a).

One proposed reason for fewer returns of tagged scampi in SCI 3, and yet fewer returns in SCI 1 and SCI 2, is that the temperature within holding tanks may differ too much from the ambient temperature the scampi experience at depth (for depths greater than 380 m in SCI 3 in 2019, the mean temperature was 9.1 °C (s.d. = 0.9 °C), Figure 7). To date, during SCI 1, SCI 2 and SCI 3 surveys, the seawater in the tanks had been pumped from the sea surface and chilled by the addition of ice blocks which were added to the holding tanks. This may have resulted in temperature fluctuations potentially causing stress to the animals. This is the first survey where a seawater cooling system has been used to ensure that scampi were kept at a constant temperature. Temperature within the tank was based on temperature profiles from the 2019 SCI 3 survey (Figure 7) and varied between 9–10 °C.

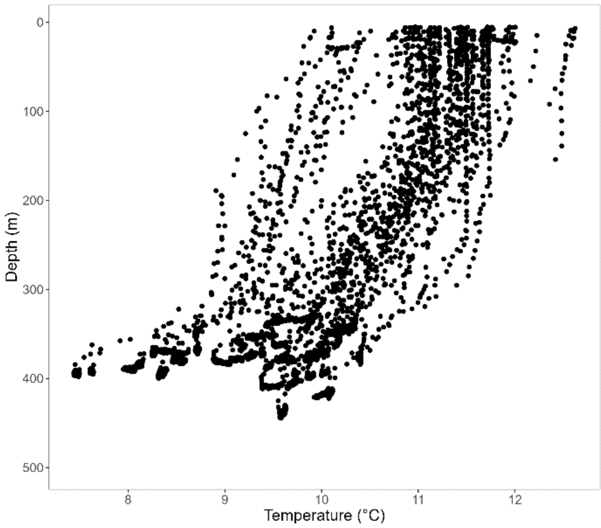

Figure 7: Left: biplot of temperature by depth from CTD data recorded during SCI 3 survey in 2019; right: New seawater cooling system (white tank), connected to scampi holding tank (blue tank).

Scampi were rapidly sorted from the catch and placed in darkened holding tanks filled with well aerated, chilled seawater. Scampi considered to be lively and largely undamaged (i.e., not crushed, but allowing for some lost appendages) were selected for tagging. Sex, orbital carapace length, the presence and stage of any eggs, and any apparent injuries and damage were recorded. Scampi were then individually removed from darkened seawater bins and sequentially numbered streamer tags (Hallprint, model PST 4S) were applied transversely through each animal, between the carapace and the cuticle of the first abdominal segment (Figure 8). Exposure to light was minimised and lightweight rubber gloves were worn for handling to minimise damage from dry, warm hands. Following tagging, scampi were returned as soon as possible to temperature-regulated seawater holding bins.

The prospects of survival for individual scampi released at the surface over depths 350–550 m is thought to be very low (Tuck et al. 2015a). Therefore, scampi were released onto the seabed in groups after each completed tow. Releases were made using weighted disposable and biodegradable paper bags as per Cryer & Stotter (1997) (Figure 9). Where possible, the release location was close to the capture location. Both release and capture location were recorded. Following the DWWG meeting in August 2023, a notice was distributed to vessel operations to notify the SCI2022-02 project leads of any recaptured scampi. A small reward was offered for the return of tagged scampi. Tagged and released scampi that are recovered by industry provide estimates of growth, an important component of stock assessment. To date no scampi from the SCI 3 or SCI 4A areas have been returned from this survey.

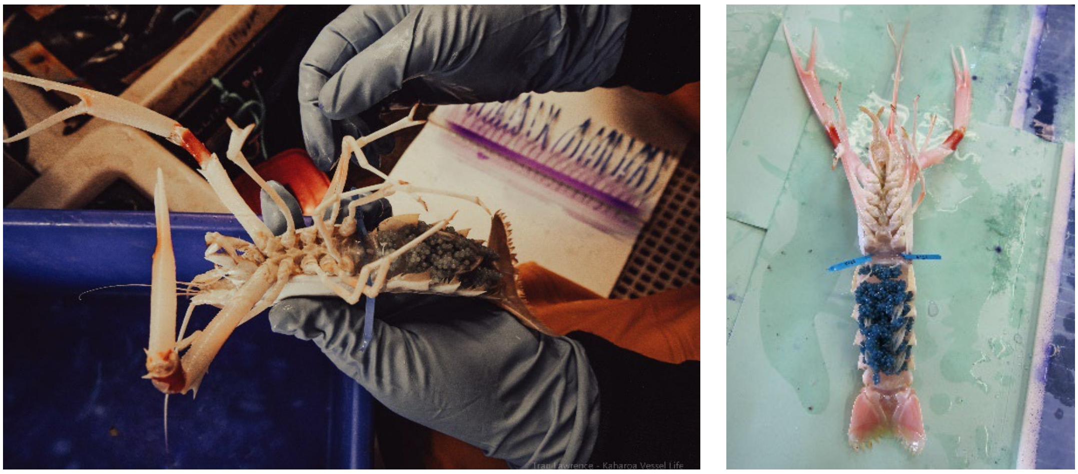

Figure 8: Photographs showing location of streamer tag in scampi; image on the left from Tran Lawrence, NIWA.

Figure 9: Tagged scampi being released in weighted brown paper bags; image Tran Lawrence, NIWA.

2.4 Other sampling

In addition to the main survey objectives, a range of other tasks were undertaken during the voyage as the opportunity arose.

2.4.1 Microsporidian infection of scampi

A microsporidian parasite (*Myospora metanephrops)* was identified and described from samples of scampi collected from SCI 6A during the 2007 and 2008 surveys (Stentiford et al. 2010). During these surveys, some scampi displayed an unusual external appearance (Figure 10). Histology was used to demonstrate replacement of skeletal and other muscles by the parasite; infection at visually detectable levels is considered fatal (Stentiford & Neil 2011). Low levels of infection were reported during these first observations (Tuck et al. 2009), but routine recording of infection rates was only started in 2019 (Tuck et al. 2020). In 2019, during the SCI 6A and SCI 3 survey, 9.3% (of 4821 scampi inspected) and 0.2% (of 4584 scampi inspected) displayed visible signs of infection, respectively.

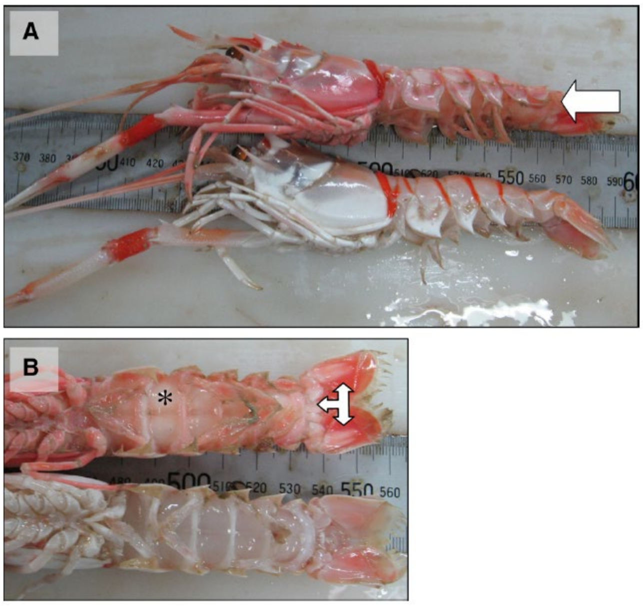

Figure 10: *Myospora metanephrops* infected and non-infected *Metanephrops challengeri* (scampi). (A) Infected scampi (arrow) appears differentially pigmented with increased opacity in all body sections relative to non-infected scampi. (B) Infection is most apparent in major flexor muscles (asterisk) and telson muscles (arrow) of infected scampi compared to non-infected scampi (source Stentiford et al. 2010).

During the 2023 SCI 6A survey 5.3% of inspected scampi had visible, conspicuous signs of infection (Wieczorek et al. 2024). In a subsequent pathological analysis of 30 scampi collected in the 2023 SCI 6A survey, it was found that only scampi showing conspicuous signs of infection (Figure 11) were in fact infected. Therefore, a more conservative approach was taken during 2023 in the SCI 3 and SCI 4A survey where all scampi were assessed for *Microsporidian* infection and categorised as infected or non-infected on the basis shown in Figure 11.

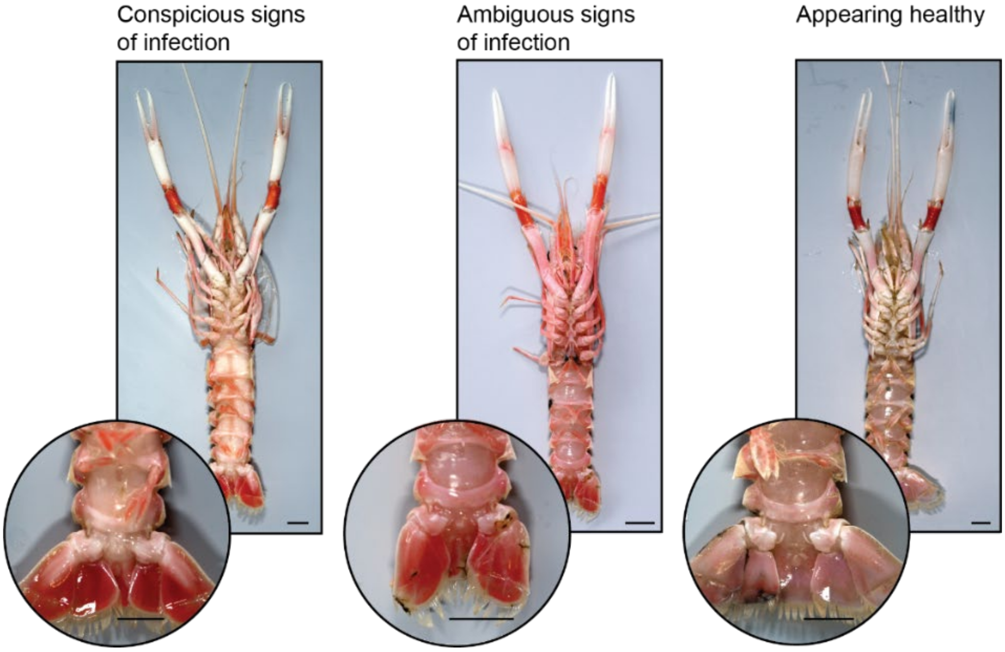

Figure 11: Example images of ventral view and close-up of tail and telson segment of scampi which displayed conspicuous signs of microsporidian infection, ambiguous signs of infection, and those that appeared healthy; black bars represent 1 cm.

2.4.2 CTD profiles

A Microcat Sea-Bird CTD (conductivity, temperature, depth) instrument was attached to the camera system and CTD profiles were recorded at all photographic stations. The CTD was not attached to the trawl because NIWA fishing gear technologists recommended to not attach this instrument to the scampi trawl gear given its low headline height and light construction.

2.4.3 Sediment sampling

Existing seabed sediment data have been collated for New Zealand (Bostock et al. 2018), but sample coverage in some scampi grounds was sparse. Relationships between scampi density and sediment parameters are considered likely to be informative (Tuck et al. 1997a). In SCI 6A, sediment grain size (i.e., sandy substrate) may be a governing factor in scampi emergence rates (Tuck et al. 2020). In recent years, NIWA has collected sediment samples when time allowed using a small clamshell grab (0.01 m^2 footprint (Figure 12) without disruption of survey activities (e.g., while images were quality checked or at the end of the working day, when there was insufficient time for completion of another station).

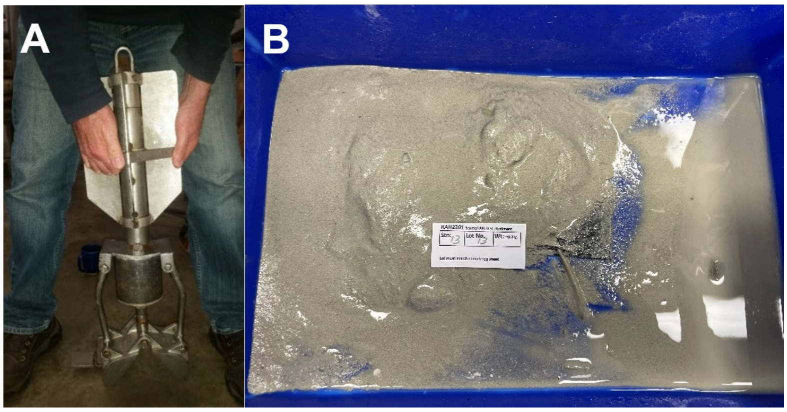

Figure 12: A: clamshell grab used to collect sediment samples during the survey, B: example of sediment sample retrieved from clamshell grab.

2.4.4 Bycatch and predation on scampi

Finfish caught on trawl stations were identified to species, measured, sexed, and weighed using Marel motion-compensating electronic scales accurate to 5 g. Lengths were measured for all QMS finfish (principally hoki, ling, gemfish, sea perch, and red cod) and all historically measured non-QMS finfish. Data were captured electronically using NIWA's wet lab system. Other bycatch species (invertebrates) were also identified and weighed. Benthic fauna were identified to species or (at least) family. Unusual or unidentified organisms were inventoried and preserved (by freezing) for identification ashore. All data were error-checked during the voyage and transferred to the *trawl* database.

Recent ecosystem modelling applications on the Chatham Rise (McGregor et al. 2019) suggest that predation pressure on scampi may have varied considerably over time; understanding this may help understand observed population fluctuations. Because there are limited data on scampi predators, where possible, the stomach contents of a variety of fish species caught during research trawling were examined to quantify the incidence of scampi (scampi presence and size in relation to fish species and size) and the proportion of the stomach contents containing scampi. Specific sampling protocols followed those developed for stomach content sampling on the Chatham Rise and Sub-Antarctic trawl surveys (Horn & Dunn 2010) and data were recorded within the *biological_table* of the *trawl* database.

3. RESULTS

The voyage was completed between 1 September and 9 October 2023. Weather during the survey was challenging with a total of 11 days of survey time lost to bad weather and 3 days lost to mechanical issues. In SCI 3, 39 photographic stations out of the 40 designated stations and 26 trawl stations out of the designated 34 trawl stations were completed (Figure 4). In SCI 4A, all 14 photographic stations and 6 trawl stations out of the designated 8 trawl stations were completed. A minimum of 3 trawl stations in each stratum were completed (Figure 5).

3.1 SCI 3 photographic survey

Visibility was generally good at most stations, however, at some stations large swells made it difficult to maintain the camera at a consistent altitude above the seabed. Over the whole SCI 3 survey, a total area of 8 468 m^2 of seabed was photographed with acceptable quality images. An average of 34.5 (s.d. = 7.2) usable images were collected at each station and the average usable area of the seabed visible in each image was 6.30 m^2 (s.d. = 2.2 m^2), providing an average area viewed of 217.1 m^2 (s.d. = 62.5 m^2) at each station. Previous surveys in SCI 3 have had an average viewed area per station of 195–285 m^2.

In SCI 3, 39 photographic stations out of the 40 designated stations were completed (Figure 4, Table 1).

3.1.1 SCI 3 major burrow counts

The locations of photographic stations and relative burrow densities are shown in **Error! Reference source not found.**. The unadjusted burrow density estimates at the station level varied from 0.06 to 0.43 m^{-2} (mean density of 0.25 m^{-2}), with the highest densities observed in the northern strata (903 and 902b2; **Error! Reference source not found.**). Scaling the observed densities of scampi burrows to the strata area resulted in an abundance estimate of 1264.2 million, with a CV of 8 % (Table 3).

Table 3: Estimates of the density and abundance of major burrow openings from the 2023 SCI 3 survey, by stratum, based on unadjusted counts. Fishery estimates of density and abundance represent the combined stratum estimates.

								Strata	
Major burrows	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023
N. stations	5	3	6	8	4	7	3	3	39
Mean density (m^{-2})	0.17	0.36	0.20	0.22	0.28	0.33	0.20	0.24	0.25
CV (%)	32	16	24	12	32	05	16	18	08
Abundance (Millions)	76.1	200.7	136.8	315.5	171.7	218.7	34.3	110.2	1 264.2

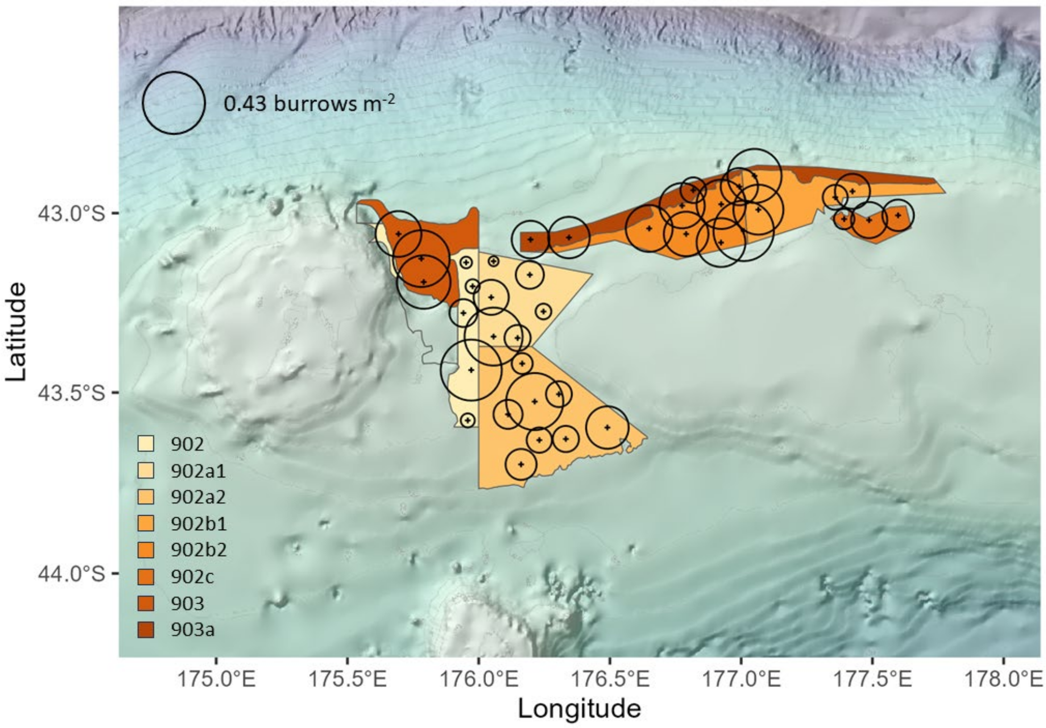

Figure 13: Distribution of burrow openings for the 2023 photographic SCI 3 survey. Area of symbol represents relative burrow density. Largest circle represents 0.43 burrows per m^2.

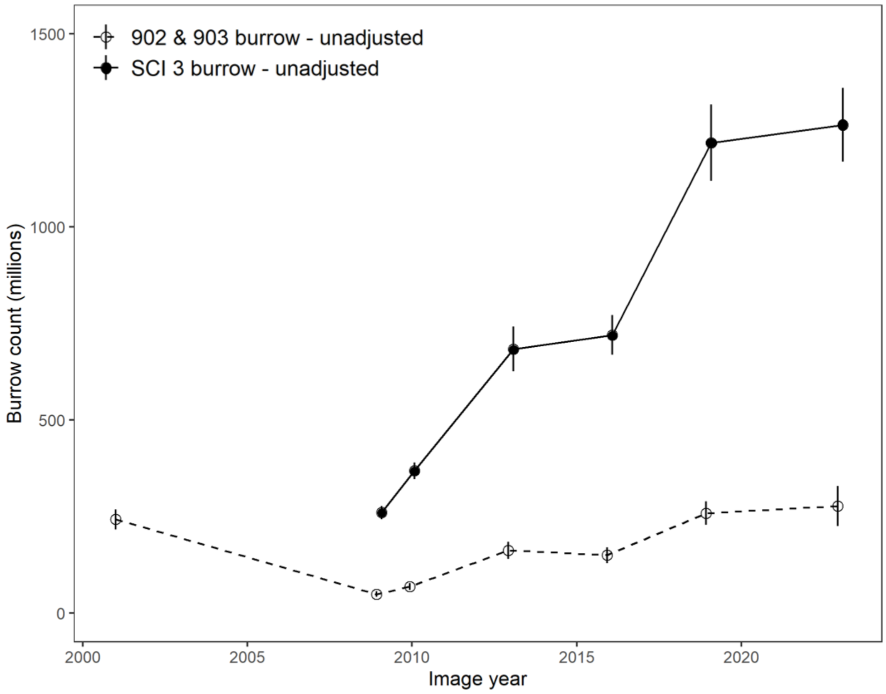

Figure 14: Estimated abundance of major scampi burrow openings (± CV) for SCI 3 over time. Estimated abundance is presented for the whole SCI 3 survey area and for the combined 902 and 903 strata. The 2001 estimate is based on the October/November survey.

3.1.2 SCI 3 visible scampi

Densities of visible scampi ranged from 0.02 to 0.19 m^{-2} (Figure 15). Scaling the observed densities of visible scampi to strata area resulted in a minimum abundance estimate of 437.6 million animals for the surveyed area, with a CV of 8 % (Table 4). Counting animals out of burrows and walking free on the bottom (which would be more vulnerable to trawling) were estimated at 51.0 million animals, with a CV of 14 % (Table 5). The estimated visible scampi abundance in 2023 was higher than the previous survey in 2019 and the subset of scampi that were fully emerged also increased (Figure 16). Overall survey mean densities for the current and previous surveys in SCI 3 are provided in Table 6. Unadjusted major burrow and scampi density estimates for all SCI 3 surveys, by stratum and for all strata combined, are presented in Table Appendix 1.

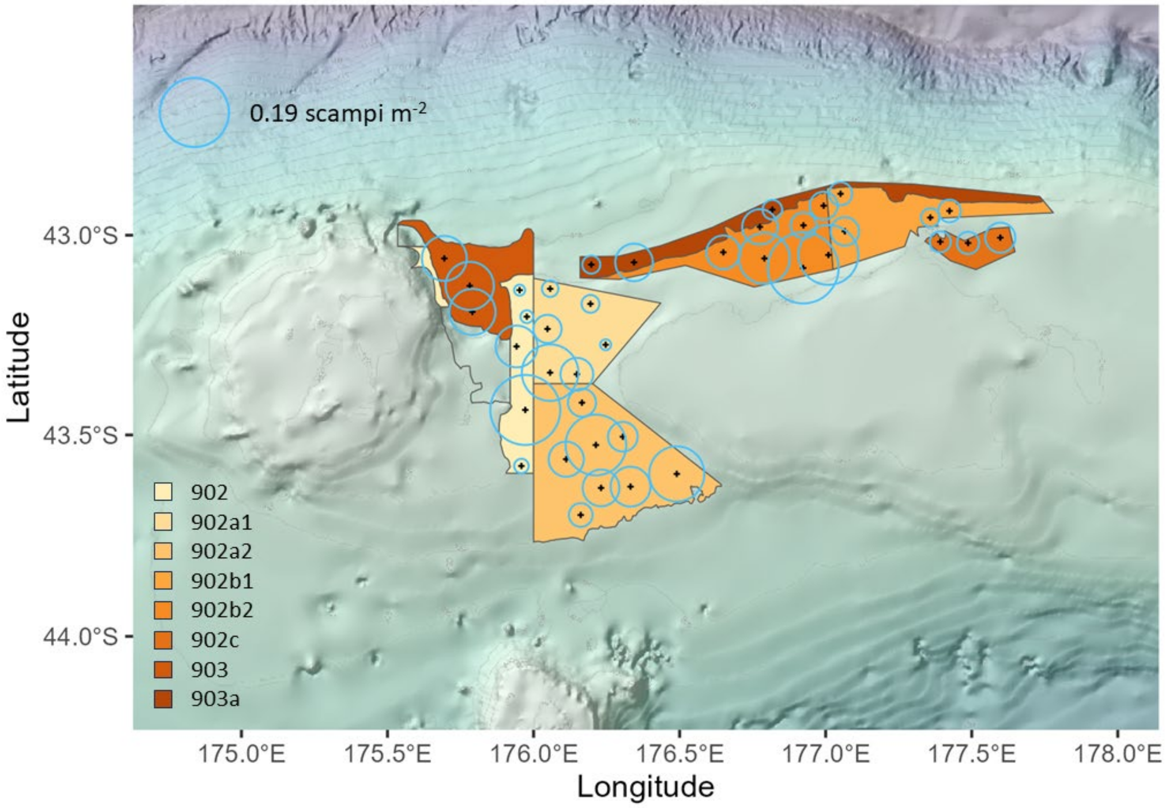

Figure 15: Distribution of scampi density for the 2023 SCI 3 photographic survey. Area of symbol represents relative visible scampi density. Largest circle represents 0.19 visible scampi per m^2.

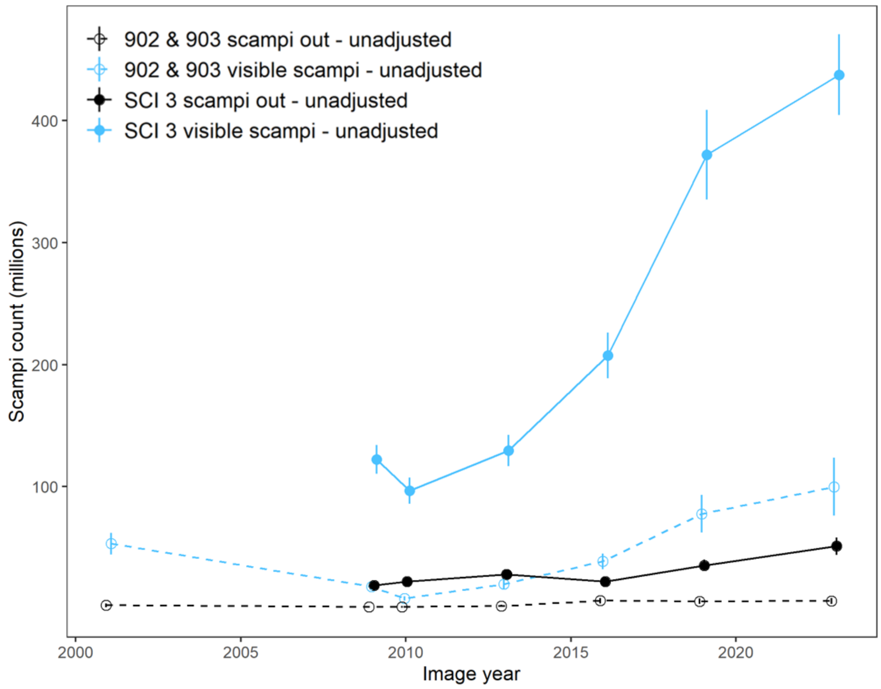

Figure 16: Estimated abundance of all visible scampi and those seen outside of a burrow (± CV) for the combined 902 and 903 strata, and whole SCI 3 time series. The 2001 estimates are based on the October/November survey.

Table 4: Estimates of the density and abundance of visible scampi from the 2023 SCI 3 survey by stratum. Fishery estimates of density and abundance represent the combined stratum estimates.

	Strata								
Visible scampi	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023
N. stations	5	3	6	8	4	7	3	3	39
Mean density (m^{-2})	0.07	0.12	0.07	0.10	0.06	0.11	0.06	0.06	0.09
CV (%)	39	15	25	13	23	09	21	30	08
Abundance (Millions)	33.4	66.5	47.6	142.2	34.8	74.3	10.4	28.6	437.6

Table 5: Estimates of the density and abundance of scampi out of burrows from the 2023 SCI 3 survey by stratum. Scampi "out" were defined as those for which the telson was not obscured by the burrow. Fishery estimates of density and abundance represent the combined stratum estimates.

	Stratum								
Scampi out	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023
N. stations	5	3	6	8	4	7	3	3	39
Mean density (m^{-2})	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
CV (%)	45	100	40	34	33	20	0.36	48	14
Abundance (Millions)	3.4	2.7	6.4	14.0	7.3	8.5	3.6	5.2	51.0

Table 6: Overall survey mean densities (m^{-2}) of major burrow openings, visible scampi, and scampi out of burrows for the SCI 3 time series (data for the combined 902 & 903 strata and the current survey coverage presented in separate blocks).

	Major opening	Visible scampi	Scampi "out"	Scampi as % of openings	% of visible scampi "out"
902&903					
2001	0.245	0.054	0.003	22.0	4.8
2009	0.049	0.018	0.001	36.9	7.5
2010	0.071	0.008	0.001	11.7	15.4
2013	0.153	0.02	0.002	13.2	11.5
2016	0.16	0.04	0.007	25.1	17.6
2019	0.254	0.074	0.006	29.2	7.5
2023	0.244	0.093	0.007	37.9	7.2
SCI 3					
2009	0.051	0.023	0.004	44.7	16.5
2010	0.076	0.019	0.004	24.4	23.4
2013	0.137	0.026	0.005	19.3	20.5
2016	0.16	0.047	0.005	29.1	11.7
2019	0.251	0.077	0.007	30.8	8.9
2023	0.248	0.085	0.011	34.4	12.7

3.2 SCI 3 trawl survey

The locations of the SCI 3 trawl survey stations and relative scampi catch rates are shown in Figure 17. Biomass estimates are provided by strata for the 2023 survey in Table 7 and are compared with previous surveys estimated over the same strata in Table 8. The trawl survey estimate was 1301.9 t (7 % CV) (Table 7). The trawl survey estimate for 2023 was slightly higher than in 2019 (Table 8, Figure 18) which was consistent with burrow count and visible scampi estimates (Figure 14, Figure 16).

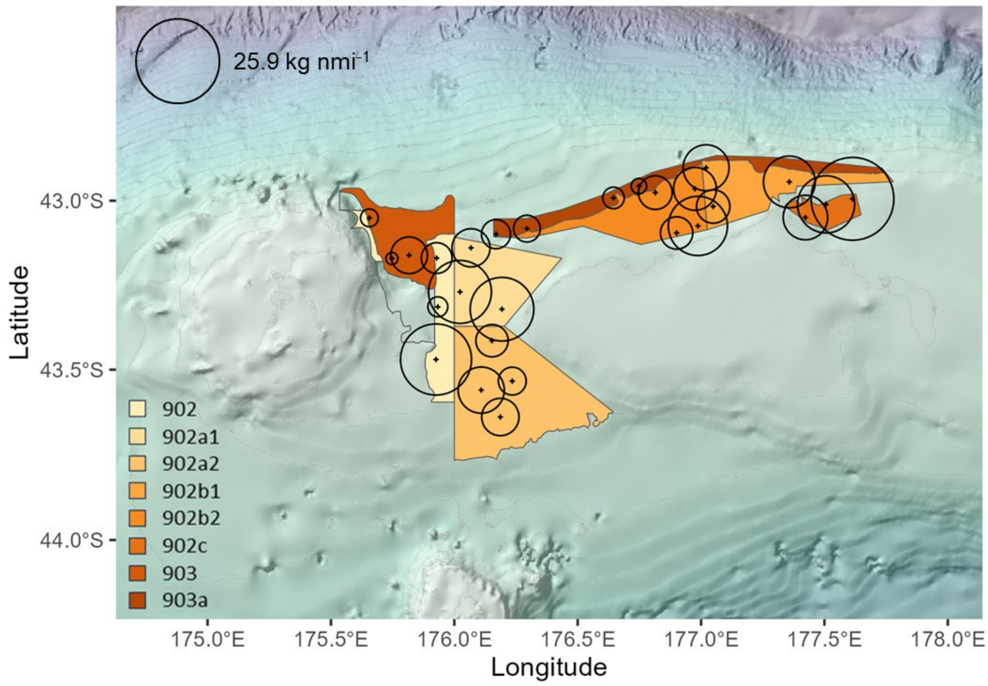

Figure 17: Distribution of scampi catch rates for the 2023 trawl survey of SCI 3. Area of symbol represents relative scampi catch rate. Largest circle represents 25.9 kg nmi^{-1}.

Table 7: Trawl survey biomass estimates (tonnes) by stratum for SCI 3. Mean values are expressed as kilograms per nautical mile.

								Stratum	
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Total
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023
N. stations	3	3	6	4	3	4	3	3	26
Mean density (kg nmi^{-1})	12.4	6.6	17.0	11.0	13.5	12.9	19.2	7.7	12.0
CV	4	37	16	11	13	15	19	9	7
Biomass (tonnes)	118.1	78.2	257.7	339.8	176.2	184.4	71.3	76.3	1 301.9

Table 8: Time series of scaled trawl survey scampi stock biomass estimates (tonnes) by survey and stratum for SCI 3.

										Stratum	Total
Year	902	903	902a	902a1	902a2	902b	902b1	902b2	902c	903a	
2001	63.4	190.9									
2009	31.8	8.4	295.5			49.7			24.2	8.5	418.1
2010	22.6	26.4	347.7			123.3			37.7	38.4	596.1
2013	72.1	54.4		90.1	87.9	163.8			38.4	44.7	551.3
2016	51.5	88.1		83.0	235.8		183.9	138.3	32.3	100.2	913.1
2019	99.6	57.9		253.4	303.2		240.9	118.9	47.8	98.2	1 219.9
2023	118.1	78.2		257.7	339.8		176.2	184.4	71.3	76.3	1 301.9

In SCI 3, 978 kg of scampi were caught, accounting for 7.4% of the total catch (13 239 kg). Scampi were the fifth most abundant species. By weight, the most abundant species in the catch were javelin fish (*Lepidorhynchus denticulatus*, 18.0%), bigeye sea perch (*Helicolenus barathri,* 15.8%), silver warehou (*Seriolella punctata*, 12.6%) and hoki (*Macruronus novaezelandiae*, 11.1%), with the remainder comprising a variety of other species of fish, chondrichthyans, and invertebrates (Table Appendix 3). Within commercial fishing activities, scampi make up a greater proportion of the total catch, as bycatch mitigation approaches reduce finfish catches.

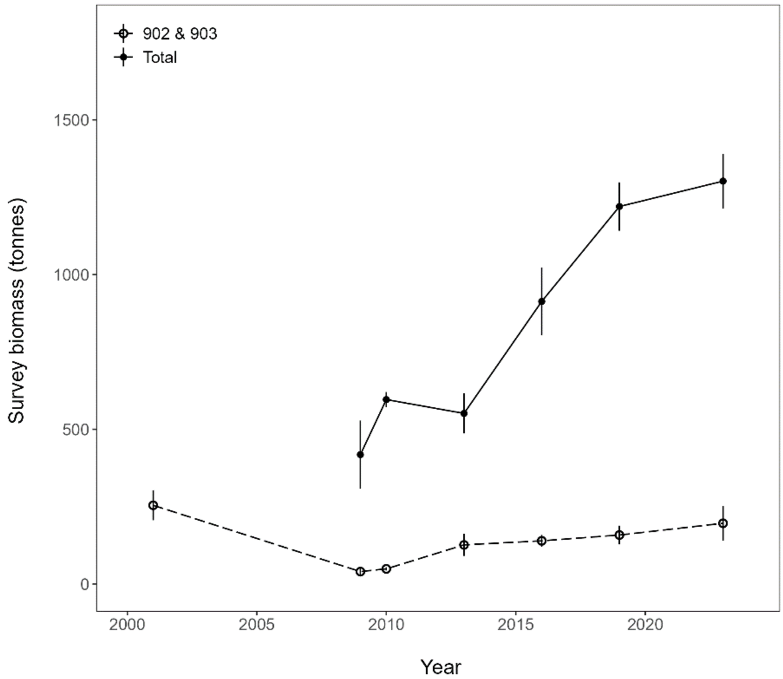

Figure 18: Plot of time series of SCI 3 trawl survey biomass estimates (± CV).

3.3 SCI 3 scampi tagging

In SCI 3, 5546 scampi were tagged with streamer tags and released from all trawl stations. The length distributions of the tagged scampi in SCI 3 are presented in Figure 19. Tagging did not target specific size ranges. While generally assumed to reflect the overall scampi size distribution, these distributions reflect sizes of lively scampi used for tagging. The sex ratio in catches from surveys prior to 2019 in SCI 3 at this time of year have been male dominated (Tuck et al. 2018), but were roughly even in 2019. During this 2023 survey males dominated the catch again (3510 males and 2036 females). Changes in sex ratio may reflect a slight change in the timing of moulting. Because females moult at this time of year in burrows, their availability to trawl gear may be reduced (Tuck 2019). Tagged scampi were released at 25 separate locations. No scampi were released while the vessel was fishing, and no recaptures were made during the survey.

The next scheduled survey in SCI 3 will be in 2026, and it is anticipated that all recoveries will come from commercial fishing activity. As of May 2024, no scampi tagged during the 2023 SCI 3 survey have been returned to NIWA by industry vessels. Tag recovery rates from SCI 6A have generally been higher than from other scampi fisheries where tagging has been undertaken. The same tagging approach has been applied across all areas, and the reason for differences in recovery rates remains unclear. One plausible explanation could be the colder surface waters in SCI 6A which may contribute to enhanced survival rates. Tagging mortality was not investigated during this voyage (following the recommendation of the Shellfish Working Group), but when examined previously, short-term (up to seven days) survival has been estimated at 88% in SCI 6A (Tuck et al. 2015a) and 76% in SCI 2 (Tuck et al. 2013). The higher release mortality in SCI 2 was assumed to be caused by warmer surface water temperatures. It is expected that the new tank cooling system will have increased chances of survival post-tagging which may yield higher returns during the coming season.

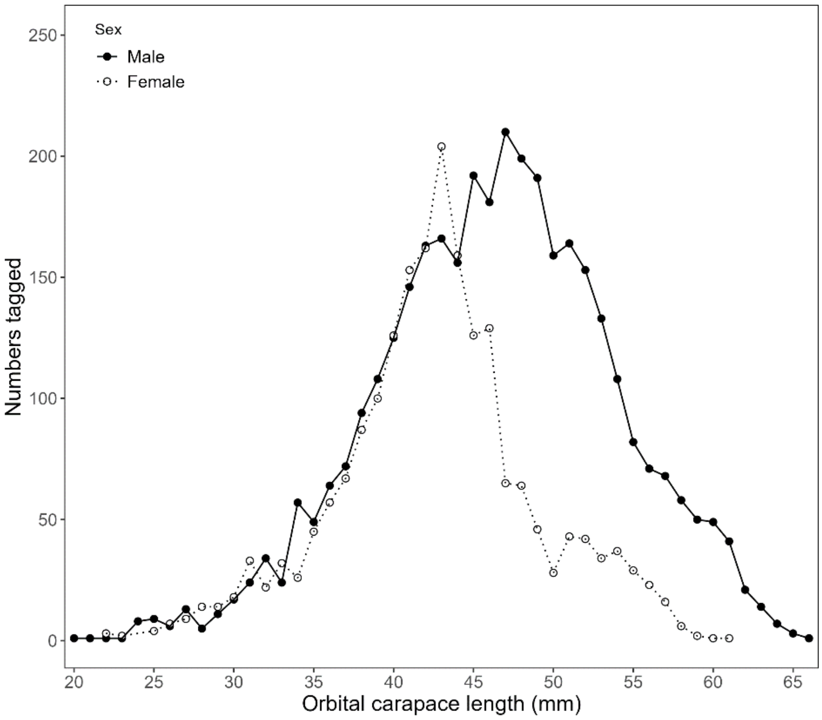

Figure 19: Length distribution of scampi tagged and released during the 2023 SCI 3 survey.

3.4 SCI 4A photographic survey

Visibility was generally fine at most sites and most photographs exposed in the critical area were of good quality. Over the whole SCI 4A survey, a total area of 3317 m^2 of seabed was photographed (acceptable quality images). An average of 37.6 (s.d. = 7.7) usable images were collected at each station and the average usable area of the seabed visible in each image was 6.31 m^2 (s.d. = 2.0 m^2) providing an average area viewed of 237.0 m^2 (s.d. = 65.5 m^2) at each station. This is the first year of surveys in SCI 4A.

3.4.1 SCI 4A major burrow counts

The locations of photographic stations and relative burrow densities are shown in Figure 20. The unadjusted burrow density estimates at the station level varied from 0.06 to 0.25 m^{-2} (mean density of 0.13 m^{-2}). Scaling the observed densities of major burrows to strata area resulted in a abundance estimate of 218.6 million burrows for the surveyed area, with a CV of 12% (Table 9), with the highest densities observed in the western strata (4AW; Table 9).

Table 9: Estimates of the density and abundance of major burrow openings from the 2023 SCI 4A survey, by stratum, based on unadjusted counts. Fishery estimates of density and abundance represent the combined stratum estimates.

Major burrows	4AE	4AW	Fishery
Area (km^2)	872	791	1 663
N. stations	7	7	14
Mean density (nmi^{-1})	0.12	0.14	0.13
CV (%)	15	20	12
Abundance (Millions)	94.3	124.3	218.6

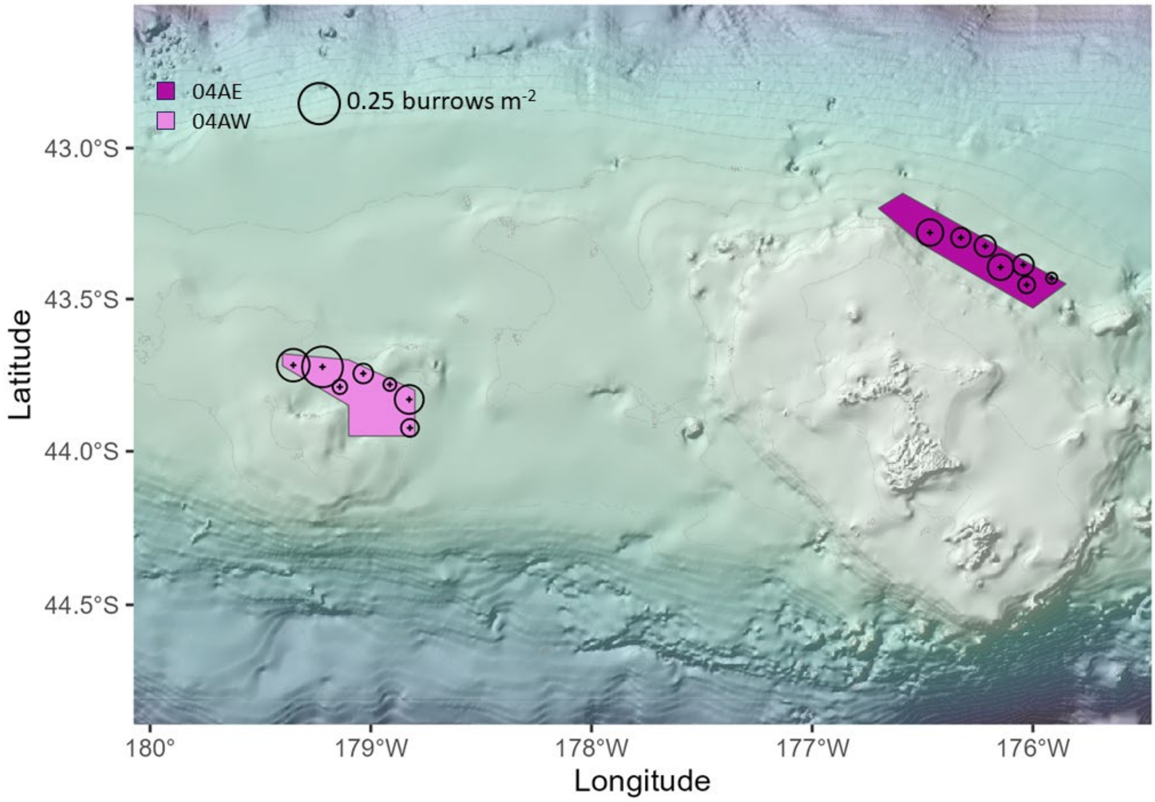

Figure 20: Distribution of burrow openings for the 2023 photographic SCI 4A survey. Area of symbol represents relative burrow density. Largest circle represents 0.25 burrows per m^2.

3.4.2 SCI 4A visible scampi

Densities of visible scampi ranged from 0.02 to 0.07 m^{-2}(Figure 21). Scaling the observed densities of visible scampi to strata area resulted in an abundance estimate of 44.2 million animals for the surveyed area, with a CV of 18% (Table 10, Table 4). Counting animals out of burrows and walking free on the bottom (which would be more vulnerable to trawling) were estimated at 9.0 million animals, with a CV of 27% (Table 11). Overall survey mean densities for the current survey in SCI 4A are provided in Table 12. Uncorrected and reference set read corrected major burrow and scampi density estimates for the SCI 4A survey, by stratum and for all strata combined, are presented in Table Appendix .

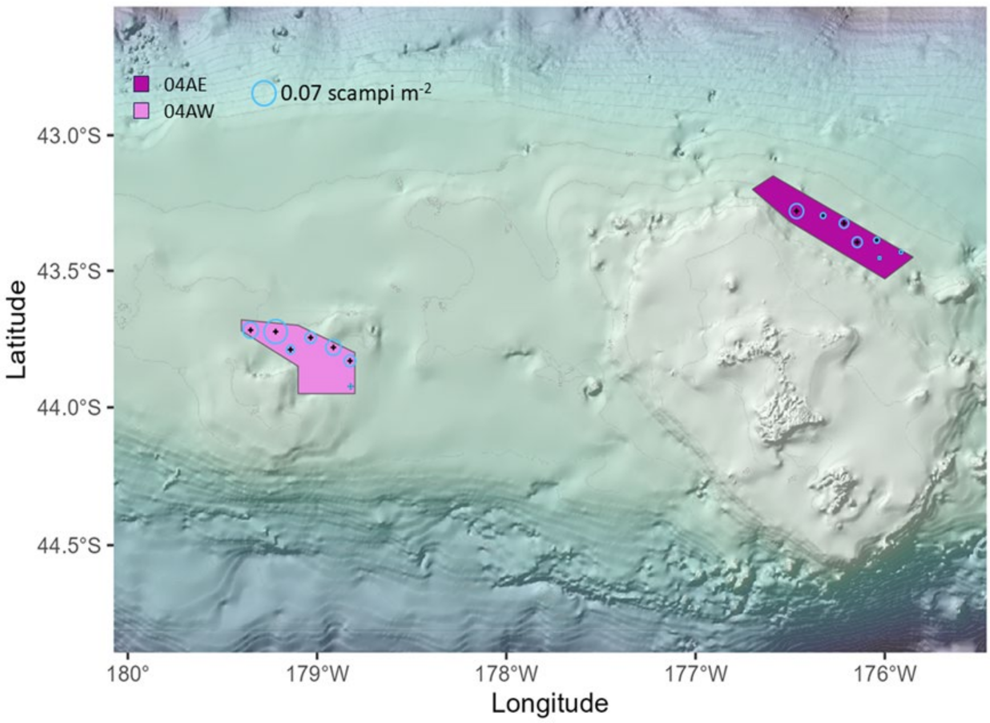

Figure 21: Distribution of scampi density for the 2023 SCI 4A photographic survey. Area of symbol represents relative visible scampi density. Largest circle represents 0.07 visible scampi per m^2.

Table 10: Estimates of the density and abundance of visible scampi from the 2023 SCI 4A survey by stratum. Fishery estimates of density and abundance represent the combined stratum estimates.

Visible scampi	4AE	4AW	Fishery
Area (km^2)	872	791	1 663
N. stations	7	7	14
Mean density (m^{-2})	0.02	0.04	0.03
CV (%)	28	22	18
Abundance (Millions)	13.71	30.53	44.23

Table 11: Estimates of the density and abundance of scampi out of burrows from the 2023 SCI 4A survey by stratum. Scampi "out" were defined as those for which the telson was not obscured by the burrow. Fishery estimates of density and abundance represent the combined stratum estimates.

Scampi out	4AE	4AW	Fishery
Area (km^2)	872	791	1 663
N. stations	7	7	14
Mean density (m^{-2})	0.008	0.003	0.006
CV (%)	28	49	27
Abundance (Millions)	6.1	2.9	9.0

Table 12: Overall survey mean densities (m^{-2}) of major burrow openings, visible scampi, and scampi out of burrows for the SCI 4A survey.

	Major opening	Visible scampi	Scampi "out"	Scampi as % of openings	% of visible scampi "out"
2023	0.131	0.026	0.006	19.5	21.3

3.5 SCI 4A trawl survey

The locations of the SCI 4A trawl survey stations and relative scampi catch rates are shown in Figure 22. Biomass estimates are provided by strata for the 2023 survey in Table 13. The trawl survey estimate was 214.4 t (28% CV) (Table 13) or 12.7 million individuals (9% CV).

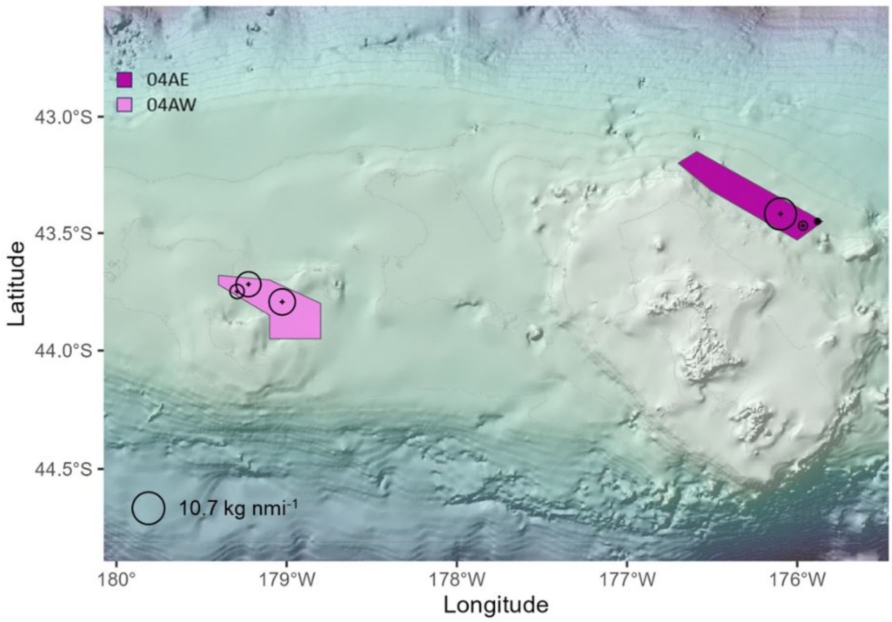

Figure 22: Distribution of scampi catch rates for the 2023 trawl survey of SCI 4A. Area of symbol represents relative scampi catch rate. Largest circle represents 10.7 kg nmi^{-1}.

Table 13: Trawl survey biomass estimates (tonnes) by stratum for SCI 4A. Mean values are expressed as kilograms per nautical mile.

	Stratum		
Strata	04AE	04AW	Total
Area (km2)	872	791	1 663
N. stations	3	3	6
Mean density (kg nmi^{-1})	4.9	7.1	6.0
CV (%)	59	19	28
Biomass (tonnes)	92.7	121.7	214.4

In SCI 4A, 109 kg of scampi were caught, accounting for 7.4% of the total catch (2611 kg). Scampi were the eleventh most abundant species. By weight, the most abundant species in the catch were dark ghost sharks (*Hydrolagus novaezealandiae,* 14.1%), Bollons' rattail (*Coelorinchus bollonsi,* 10.3%), hoki (*Macruronus novaezelandiae,* 9.4%), javelinfish (*Lepidorhynchus denticulatus,* 8.7%) and spiny dogfish (*Squalus acanthias,* 8.5%), with the remainder comprising a variety of other species of fish and invertebrates. Within commercial fishing activities, scampi make up a greater proportion of the total catch, as bycatch mitigation approaches reduce finfish catches.

3.6 SCI 4A scampi tagging

In SCI 4A, 1172 scampi were tagged with streamer tags and released from all trawl stations. The length distributions of the tagged scampi are presented in Figure 23. Tagging did not target specific size ranges and the length distribution of tagged animals was likely to reflect the size distribution of suitable animals from the catches. As in SCI 3, males dominated the catch (729 males and 443 females). Changes in sex ratio may reflect a slight change in the timing of moulting. Because females moult at this time of year in burrows, their availability to trawl gear may be reduced (Tuck 2019). Tagged scampi were released at 6 separate locations. No scampi were released while the vessel was fishing and no recaptures were made during the survey.

The next scheduled survey in SCI 4A will be in 2026, and it is anticipated that all recoveries will come from commercial fishing activity. As of May 2024, no scampi tagged during the SCI 4A survey have been returned to NIWA by industry vessels.

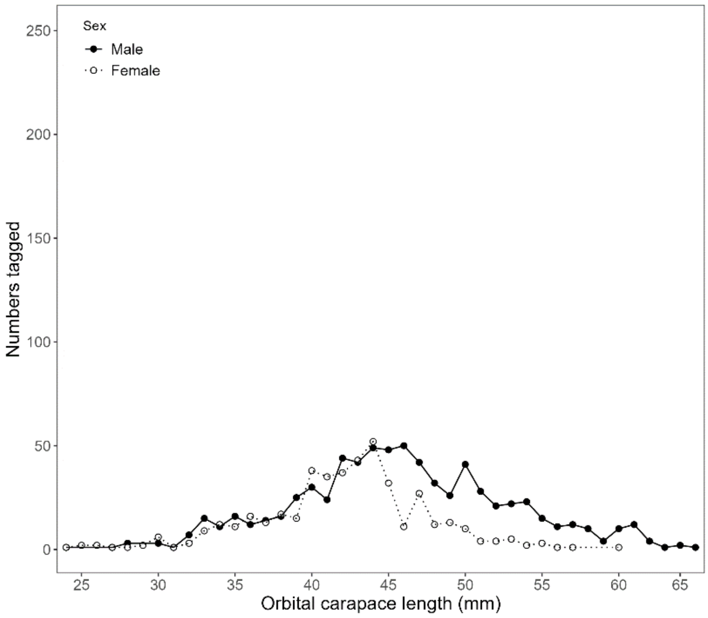

Figure 23: Length distribution of scampi tagged and released during the 2023 SCI 4A survey.

3.7 Other sampling

3.7.1 Microsporidian infection of scampi

This was the second survey in SCI 3 and the first in SCI 4A during which all measured scampi, including those obtained from extra tagging trawls, were formally examined for visual signs of infection. Estimated infection rates in SCI 3 ranged from 0–2.5% at each station and was 0.5% overall (Table 14). Despite using a more stringent classification scheme for scampi infection, the overall percentage of scampi that showed visible signs of infection was higher than recorded during the 2019 SCI 3 survey (0.2%). In SCI 4A no scampi were found to show visible signs of infection (Table 15).

Table 14: Details of scampi examined and those which showed visible signs of microsporidian infection in SCI 3.

Station	Stratum	Scampi examined	Infected	Not infected	% Infected
61	92A2	530	0	530	0.00
62	92A2	459	0	459	0.00
63	0092	759	0	759	0.00
64	0092	208	0	208	0.00
65	92A1	529	0	529	0.00
66	92A1	547	1	546	0.18
67	0092	321	0	321	0.00
68	093A	291	1	290	0.34
69	093A	308	1	307	0.33
70	92A1	462	0	462	0.00
71	0093	245	0	245	0.00
72	0093	164	0	164	0.00
73	92A2	423	1	422	0.24
74	92A2	126	0	126	0.00
75	093A	190	4	186	2.15
76	92B1	274	6	268	2.24
77	92B2	292	7	285	2.46
78	92B2	245	2	243	0.82
79	092C	320	0	320	0.00
80	092C	248	0	248	0.00
81	092C	413	1	412	0.24
82	92B1	200	2	198	1.01
83	92B2	438	8	430	1.86
84	92B2	204	3	201	1.49
85	92B1	348	8	340	2.35
86	093A	246	2	244	0.82
Total		9 076	48	9 028	0.53

Table 15: Details of scampi examined and those which showed visible signs of microsporidian infection in SCI 4A.

Station	Stratum	Scampi examined	Infected	Not infected	% Infected
17	04AE	84	0	84	0.00
18	04AE	149	0	149	0.00
19	04AE	258	0	258	0.00
20	04AW	402	0	402	0.00
21	04AW	332	0	332	0.00
22	04AW	173	0	173	0.00
Total		1 398	0	1 398	0.00

To improve the identification of diseased scampi, 19 individual scampi (13 which showed conspicuous signs of infection and 6 scampi which appeared healthy) were preserved in ethanol and are available for future pathological analysis.

3.7.2 CTD profiles

CTD profiles were collected from the 39 photographic stations in SCI 3 and the 14 photographic stations in SCI 4A. Data were downloaded at sea and have been uploaded to the MPI *ctd* database.

3.7.3 Sediment sampling

Sediment samples were collected at 15 survey stations. All sediment samples have been analysed for particle size and percentage of organic content. These data have been archived in NIWA's *Marine Sediments* database. A Shepard diagram of sand, silt, and clay content of the sediment from this and previous scampi surveys is provided in Figure 24. The diagram indicated that there was some variability between sites within regions, there were also some perceivable trends and differences between regions. Samples from SCI 3 collected during this survey were somewhat similar to samples collected during the 2019 SCI 3 survey but were found to contain more silt and sand than clay. This was the first time sediments were collected from the SCI 4A area and the substrate seemed mostly comprised of silty sand and sandy silt. In SCI 1 and 2, there was some variation between sites collected during the 2018 and 2021 survey, but in both regions, sediment types seemed to be more enriched in silt and contained less sand and clay than in the SCI 6A and SCI 3 regions. In SCI 6A the sediment is comprised of sand and sandy silt. Sandy substrates are less cohesive and can be linked to emergence rates with larger scampi being observed in trenches (Tuck et al. 2020).

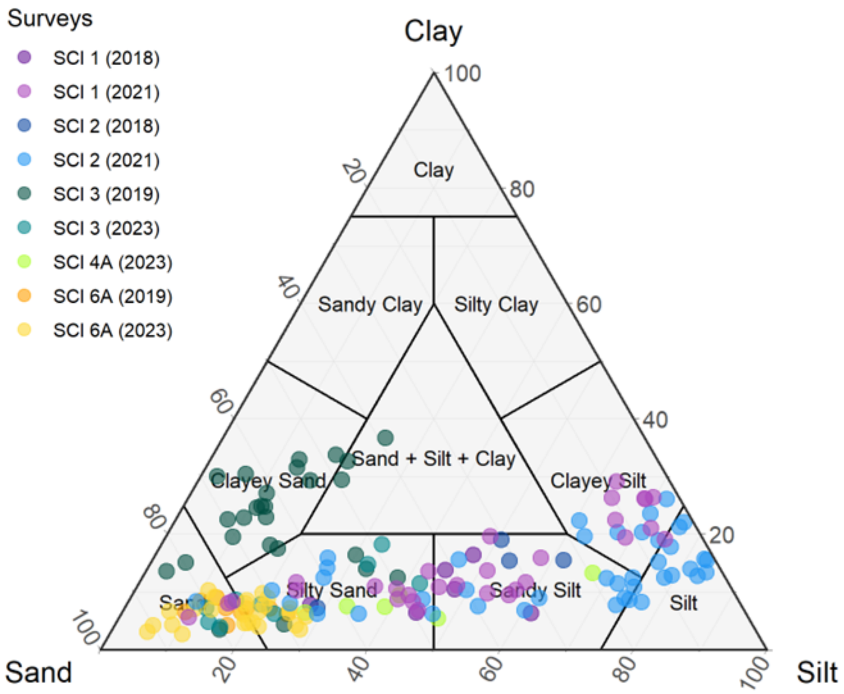

Figure 24: Shepard diagram of sediment composition (aggregated to sand, silt, and clay) from this and previous scampi surveys.

3.7.4 Acoustic data

Data from the vessel's ES60 echosounder were recorded throughout the voyage. These data have been archived for future analysis in the FNZ *acoustic* database.

3.7.5 Bycatch and predation on scampi

In SCI 3, 143 different species were recorded, and biological analyses, including stomach contents analyses, were carried out for 1641 individual fish (Table Appendix , Table 16). During stomach contents analyses, 832 stomachs were classed as empty or regurgitated and 782 as not empty. Eighty-five stomachs contained scampi with the main predators being bigeye sea perch (*Helicolenus barathri)*, ling (*Genypterus blacodes*) and ghost sharks (*Hydrolagus novaezealandiae, Hydrolagus bemisi*) (Table 16).

Table 16: Summary of stomach contents analysis by species in SCI 3.

Common name	Scientific name	Empty / regurgitated	Not empty	Total	Containing scampi	% of non-empty stomachs containing scampi
Bigeye sea perch	*Helicolenus barathri*	219	225	444	43	9.7
Ling	*Genypterus blacodes*	68	101	169	25	14.8
Dark ghost shark	*Hydrolagus novaezealandiae*	224	187	411	14	3.4
Giant stargazer	*Kathetostoma giganteum*	23	55	78	1	1.3
Pale ghost shark	*Hydrolagus bemisi*	4	8	12	1	8.3
Spiny dogfish	*Squalus acanthias*	135	106	241	1	0.4
Seal shark	*Dalatias licha*	1	0	1	0	0.0
Hake	*Merluccius australis*	28	4	32	0	0.0
Hoki	*Macruronus novaezelandiae*	130	96	226	0	0.0
Total		832	782	1 614	85	5.3

In SCI 4A, 65 different species were recorded, and biological analyses, including stomach contents analysis, were carried out for 304 individual fish (Table Appendix , Table 17). During stomach contents analysis, 203 stomachs were classed as empty or regurgitated and 101 as not empty. Six stomachs contained scampi with the main predators being identified as bigeye sea perch (*Helicolenus barathri)*, ling (*Genypterus blacodes*), and giant stargazers (*Kathetostoma giganteum*) (Table 17).

Table 17: Summary of stomach contents analysis by species in SCI 4A.

Common name	Scientific name	Empty / regurgitated	Not empty	Total	Containing scampi	% of non-empty stomachs containing scampi
Bigeye sea perch	*Helicolenus barathri*	60	28	88	3	3.4
Ling	*Genypterus blacodes*	31	22	53	2	3.8
Giant stargazer	*Kathetostoma giganteum*	18	14	32	1	3.1
Dark ghost shark	*Hydrolagus novaezealandiae*	14	6	20	0	0.0
Hoki	*Macruronus novaezelandiae*	6	14	20	0	0.0
Red cod	*Pseudophycis bachus*	21	2	23	0	0.0
Spiny dogfish	*Squalus acanthias*	52	15	67	0	0.0
Smooth skate	*Dipturus innominatus*	1	0	1	0	0.0
Total		203	101	304	6	2.0

4. FULFILLMENT OF BROADER OUTCOMES

As required under Government Procurement rules[1], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project. The broader outcomes specific to this project involved building capacity, capability, and diversity in the research sector. The future of fisheries independent photographic and trawl surveys to monitor the status of New Zealand's scampi stock relies upon the availability of staff with relevant skills and experience to undertake these surveys and carry out subsequent data analysis. For NIWA, succession planning is a key objective and there have been some recent and envisaged changes in staff availability. This is the second scampi project where early and mid-career scientists and technicians at NIWA have taken over survey and project leading roles, adding to the project with their own ideas and perspectives while building on their previous experiences.

This project was co-led by two female scientists and the first leg of the voyage was led by a female scientist, representing the still very few female staff participating in sea-going field work. One fourth of the staff members involved in the work identify as female.

5. CONCLUSIONS

A photographic and trawl survey of scampi in SCI 3 and SCI 4A was conducted in September and October 2023. This was the seventh time SCI 3 was surveyed and the first time SCI 4A was surveyed.

In SCI 3, the unadjusted photographic survey estimates for the whole survey area were 1264 million burrows and 438 million visible scampi which was an increase in both number of scampi burrows and visible scampi compared to the 2019 SCI 3 survey. The SCI 3 trawl survey estimate of 1302 t represents an increase in biomass from the SCI 3 2019 estimate of 1220 t. In SCI 4A, the unadjusted photographic survey estimates for the whole survey area were 219 million burrows and 43 million visible scampi. The SCI 4A trawl survey resulted in a biomass estimate of 214 t.

In SCI 3 and SCI 4A, 5546 and 1172 scampi were tagged and released respectively, as part of an investigation into growth. To date no tagged scampi have been recaptured by industry vessels. Data from anticipated returns during the following seasons is anticipated to be integrated into the existing tag recapture dataset, contributing to growth estimates within the stock assessment model.

A range of additional data were collected during the survey, including CTD profiles, acoustic data, sediment samples, bycatch, stomach contents analysis of potential scampi predators, visual assessment of microsporidian parasite infection rates in scampi, and sampling of scampi for microsporidian pathological analyses. Microsporidian infection rates in SCI 3 were recorded as 0.5% which was higher than in SCI 3 in 2019, despite a more conservative classification approach being applied. In SCI 4A no scampi were found to show visible signs of infection. Six species were observed to predate on scampi. Stomach contents provide a snapshot of recent diet and other methods, such as stable isotopes, might be a better indicator of predation and should be considered for future surveys. Sediment analysis of 15 collected samples indicated for a sandy and silty sand substrate in SCI 3 and silty sand and sandy silt substrate in SCI 4A.

6. ACKNOWLEDGEMENTS

This work would not have been possible and successful without the advice and cooperation of the skipper and the crew of the RV *Kaharoa*. Thank you to Pablo Escobar-Flores, Richard O'Driscoll, Jennifer Devine and Caroline Chin who have provided valuable advice and assistance with this work. We thank the EPA and the NIWA Activity Notifications team for their help in complying with the

[1] https://www.procurement.govt.nz/procurement/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

requirements of the Exclusive Economic Zone and Continental Shelf Regulations 2013, in relation to returning of tagged scampi. Scampi tag recoveries have been made and reported to NIWA by the fishing industry who have been a pleasure to work with. This report was reviewed by Darren Stevens. This work was funded by Fisheries New Zealand under research project SCI2022-02.

7. REFERENCES

Aguzzi, J.; Sarda, F.; Abello, P.; Company, J.B.; Rotllant, G. (2003). Diel and seasonal patterns of *Nephrops norvegicus* (Decapoda : Nephropidae) catchability in the western Mediterranean. *Marine Ecology Progress Series 258*: 201–211.

Aristegui, M.; Doyle, J.; Ryan, G.; Fitzgerald, R.; White, J.; O'Brien, S.; Tully, D.; Sullivan, M. (2021). Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2021 UWTV Survey Report and catch scenarios for 2022. Marine Institute UWTV Survey report, Galway, Ireland.

Bell, M.C.; Redant, F.; Tuck, I.D. (2006). *Nephrops* species. In: B. Phillips (Ed). *Lobsters: Biology, management, Aquaculture and Fisheries*. Blackwell Publishing, Oxford: 412–461.

Bian, R. (2021). SurvTools: R library as a part of the Fisheries Survey Analysis Project: A collection of manuals, methods, and software to undertake fisheries survey analyses. R package version 1.4, http://www.niwa.co.nz.

Bostock, H.; Jenkins, C.; Mackay, K.; Carter, L.; Nodder, S.; Orpin, A.; Pallentin, A.; Wysoczanski, R. (2018a). Distribution of surficial sediments in the ocean around New Zealand/Aotearoa. Part A: continental slope and deep ocean. *New Zealand Journal of Geology and Geophysics 62(1)*: 1–23.

Campbell, N.; Dobby, H.; Bailey, N. (2009). Investigating and mitigating uncertainties in the assessment of Scottish *Nephrops norvegicus* populations using simulated underwater television data. *ICES Journal of Marine Science 66(4)*: 646–655.

Cryer, M.; Downing, K.; Hartill, B.; Drury, J.; Armiger, H.J.; Middleton, C.; Smith, M.D. (2003). Digital photography as a stock assessment tool for *Metanephrops challengeri* on New Zealand's continental slope. *FAO fisheries proceedings; 3/1*, In: Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries. Part 1. Conference reports. 1–5 December 2003, Queenstown, New Zealand / edited by Ross Shotton.: 299–307.

Cryer, M.; Hartill, B.; Drury, J.; Tuck, I.D.; Cadenhead, H.J.; Smith, M.D.; Middleton, C. (2002). Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1, 1998-2002. (Unpublished Final Research Report for Ministry of Fisheries Research Projects SCI2000/02 & SCI2001/01 held by Fisheries New Zealand, Wellington.)

Cryer, M.; Stotter, D.R. (1997). Trawling and tagging of scampi off the Alderman Islands, western bay of Plenty, September 1995 (KAH9511). *New Zealand Fisheries Data Report.* 84 p.

Francis, R.I.C.C. (2006). Optimum allocation of stations to strata in trawl surveys. *New Zealand Fisheries Assessment Report 2006/23*. 50 p.

Froglia, C.; Atkinson, R.J.A.; Tuck, I.D.; Arneri, E. (1997). Underwater television survey, a tool to estimate *Nephrops* stock biomass in the Adriatic trawling grounds. *Proceedings of the Croatian Acadamy, Split 1995*: 657–666.

Horn, P.L.; Dunn, M.R. (2010). Inter-annual variability in the diets of hoki, hake and ling on the Chatham Rise from 1990 to 2009. *New Zealand Aquatic Environment and Biodiversity Report 54.* 57 p.

ICES (2007). Workshop on the Use of UWTV Surveys for Determining Abundance in *Nephrops* Stocks throughout European Waters. 17–21 April 2007, Heraklion, Crete, Greece. *ICES CM 2007/ACFM:14*. 198 p.

Marrs, S.J.; Atkinson, R.J.A.; Smith, C.J. (1998). The towed underwater TV technique for use in stock assessment of *Nephrops norvegicus. ICES Report of the Study Group on life histories of Nephrops norvegicus*, La Coruna, Spain.

Marrs, S.J.; Atkinson, R.J.A.; Smith, C.J.; Hills, J.M. (1996). Calibration of the towed underwater TV technique for the use in stock assessment of *Nephrops norvegicus*. Study project in support of the Common Fisheries Policy. 155 p.

McGregor, V.L. (2023). The 2022 stock assessment for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1) and Hawke Bay-Wairarapa (SCI 2) 1990–2022. *New Zealand Fisheries Assessment Report 2023/58*. 85 p.

McGregor, V.L.; Horn, P.L.; Fulton, E.A.; Dunn, M.R. (2019). From data compilation to model validation: a comprehensive analysis of a full deep-sea ecosystem model of the Chatham Rise. *PeerJ 7: e6517*. 10.7717/peerj.6517

Morello, E.B.; Froglia, C.; Atkinson, R. (2007). Underwater television as a fishery-independent method for stock assessment of Norway lobster (*Nephrops norvegicus*) in the central Adriatic Sea (Italy). *ICES Journal of Marine Science 64(6)*: 1116–1123.

Sardà, F.; Aguzzi, J. (2012). A review of burrow counting as an alternative to other typical methods of assessment of Norway lobster populations. *Reviews in Fish Biology and Fisheries 22(2):* 409–422.

Smith, R.S.M.; Marrs, S.J.; Atkinson, R.J.A.; Papadopoulou, K.N.; Hills, J.M. (2003). Underwater television for fisheries-independent stock assessment of *Nephrops norvegicus* from the Aegean (eastern Mediterranean) Sea. *Marine Ecology Progress Series 256*: 161–170.

Stentiford, G.D.; Bateman, K.S.; Small, H.J.; Moss, J.; Shields, J.D.; Reece, K.S.; Tuck, I. (2010). *Myospora metanephrops* (n. g., n. sp.) from marine lobsters and a proposal for erection of a new order and family (Crustaceacida; Myosporidae) in the Class Marinosporidia (Phylum Microsporidia). *International Journal for Parasitology 40(12)*: 1433–1446.

Stentiford, G.D.; Neil, D.M. (2011). Diseases of Nephrops and Metanephrops: A review. *Journal of Invertebrate Pathology 106(1): 92–109.*

Tuck, I.D. (2017) Characterisation and length-based population model for scampi (*Metanephrops challengeri*) at the Auckland Islands (SCI 6A). *New Zealand Fisheries Assessment Report 2017/56*. 180 p.

Tuck, I.D. (2019). Characterisation and a length-based assessment model for scampi (*Metanephrops challengeri*) on the Mernoo Bank (SCI 3). *New Zealand Fisheries Assessment Report 2019/61*. 248 p.

Tuck, I.D. (2020). Characterisation and CPUE standardisation of scampi in SCI 4A. *New Zealand Fisheries Assessment Report 2020/04*. 48 p.

Tuck, I.D.; Atkinson, R.J.A.; Chapman, C.J. (1994). The structure and seasonal variability in the spatial distribution of *Nephrops norvegicus* burrows. *Ophelia 40*: 13–25.

Tuck, I.D.; Chapman, C.J.; Atkinson, R.J.A. (1997a). Population biology of the Norway lobster, *Nephrops norvegicus* (L.) in the Firth of Clyde, Scotland. I. Growth and density. *ICES Journal of Marine Science 54*: 125–135.

Tuck, I.D.; Chapman, C.J.; Atkinson, R.J.A.; Bailey, N.; Smith, R.S.M. (1997b). A comparison of methods for the stock assessment of the Norway lobster, *Nephrops norvegicus* in the Firth of Clyde. *Fisheries Research 32*: 89–100.

Tuck, I.D.; Chapman, C.J.; Atkinson, R.J.A.; Bailey, N.; Smith, R.S.M. (1997c). A comparison of methods for the stock assessment of the Norway lobster, *Nephrops norvegicus* in the Firth of Clyde. *Fisheries Research 32*: 89–100.

Tuck, I.D.; Dunn, A. (2009). Length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1) and Wairarapa / Hawke Bay (SCI 2). (Unpublished Final Research Report for Ministry of Fisheries Research Projects SCI2006-01 & SCI2008-03W held by Fisheries New Zealand, Wellington.) 30 p.

Tuck, I.D.; Hartill, B.; Parkinson, D.; Harper, S.; Drury, J.; Smith, M.; Armiger, H. (2009). Estimating the abundance of scampi - Relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 1 and SCI 6A (2008). Final Research Report for Ministry of

Fisheries research project SCI2007-02. 26 p. (Unpublished report held by Fisheries New Zealand, Wellington.)

Tuck, I.D.; Hartill, B.; Parkinson, D.; Smith, M.; Armiger, H.: Rush, N.; Drury, J. (2011). Estimating the abundance of scampi – Relative abundance of scampi, *Metanephrops challengeri*, from photographic surveys in SCI 3 (2009 & 2010). Final Research Report for Ministry of Fisheries research project. 29 p.

Tuck, I.D.; Parkinson, D.; Armiger, H.; Smith, M.; Miller, A.; Rush, N.; Spong, K. (2015a). Estimating the abundance of scampi in SCI 6A (Auckland Islands) in 2013. *New Zealand Fisheries Assessment Report 2015/10*. 52 p.

Tuck, I.D.; Parkinson, D.; Armiger, H.; Smith, M.; Miller, A.; Rush, N.; Spong, K. (2018). Estimating the abundance of scampi in SCI 3 (Mernoo Bank) in 2016. *New Zealand Fisheries Assessment Report 2018/24*: 32 p.

Tuck, I.D.; Parkinson, D.; Armiger, H.; Smith, M.; Miller, A.; Drury, J.; Spong, K. (2020). Estimating the abundance of scampi in SCI 6A (Auckland Islands) in 2019. *New Zealand Fisheries Assessment Report 2020/13*. 50 p.

Tuck, I.D.; Parkinson, D.; Armiger, H.; Smith, M.; Miller, A.; Drury, J.; Spong, K. (2021). Estimating the abundance of scampi in SCI 3 (Mernoo Bank) in 2019. *New Zealand Fisheries Assessment Report 2021/17*. 42 p.

Tuck, I.D.; Parkinson, D.; Drury, J.; Armiger, H.; Miller, A.; Rush, N.; Smith, M.; Hartill, B. (2013). Estimating the abundance of scampi - Relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 1 and SCI 2 (2012). Final Research Report for Ministry of Fisheries research project SCI2010-02A. 54 p.

Tuck, I.D.; Parkinson, D.; Hartill, B.; Drury, J.; Smith, M.; Armiger, H. (2007). Estimating the abundance of scampi - relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 6A (2007). (Unpublished Final Research Report for Ministry of Fisheries Research Project SCI2006/02 held by Fisheries New Zealand, Wellington.) 29 p.

Tuck, I.D.; Parsons, D.M.; Hartill, B.W.; Chiswell, S.M. (2015b). Scampi (*Metanephrops challengeri*) emergence patterns and catchability. *ICES Journal of Marine Science 72 (Supplement 1)*: i199-i210.

Tuck, I.D.; Spong, K. (2013). Burrowing megafauna in SCI 3. *New Zealand Fisheries Assessment Report 2013/20.* 50 p.

van der Reis, A. (2021). The application of molecular genetic tools to examine diet and population structure in the New Zealand scampi, *Metanephrops challengeri*. PhD thesis. University of Auckland.

Wieczorek, A.M.; Underwood, M.J.; Evans, O.; Wood, B.; Hall, J.; Armiger, H.; Smith, M.; Hamill, J.; Drury, J.; Miller, A.; Lane, H.; Spong, K.; McGregor, V.; Holmes, S. (2024). Estimation of the abundance of scampi in SCI 6A using trawl and photographic surveys. *New Zealand Fisheries Assessment Report 2024/33. 39 p.*

APPENDIX 1: UNADJUSTED SURVEY ESTIMATES SCI 3

Table Appendix 1: Unadjusted scampi biomass and abundance estimates in SCI 3.

2001 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552								992
Stations	7	9								16
Burrows per m^2	0.133	0.333								0.245
CV	0.16	0.14								0.11
Millions	58.74	183.58								242.32
Scampi per m^2	0.021	0.080								0.054
CV	0.41	0.13								0.16
Millions	9.04	44.08								53.12
Emerged per m^2	0.000	0.005								0.003
CV	NA	0.56								0.59
Millions	0.00	2.53								2.53

2009 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	7	9	8	12	11	8	3	5	63	16
Burrows per m^2	0.053	0.046	0.038	0.060	0.057	0.053	0.045	0.047	0.051	0.049
CV	0.27	0.15	0.12	0.17	0.15	0.15	0.08	0.05	0.07	0.15
Millions	23.51	25.25	26.29	86.07	34.63	35.15	7.78	21.47	260.14	48.76
Scampi per m^2	0.018	0.018	0.013	0.039	0.027	0.023	0.017	0.009	0.023	0.018
CV	0.30	0.23	0.20	0.18	0.18	0.27	0.41	0.24	0.10	0.18
Millions	8.06	9.91	9.39	56.40	16.26	15.19	2.95	4.07	122.24	17.97
Emerged per m^2	0.001	0.001	0.001	0.005	0.008	0.006	0.001	0.002	0.004	0.001
CV	0.47	0.59	0.68	0.42	0.27	0.58	1.00	0.48	0.20	0.38
Millions	0.58	0.76	0.69	6.82	4.94	3.98	0.23	0.85	18.85	1.34

2010 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	6	9	10	9	11	9	3	5	62	15
Burrows per m^2	0.047	0.087	0.061	0.056	0.093	0.085	0.054	0.122	0.076	0.071
CV	0.25	0.11	0.14	0.16	0.11	0.08	0.24	0.09	0.06	0.12
Millions	20.56	47.79	42.57	79.82	56.37	55.99	9.37	55.79	368.26	68.35
Scampi per m^2	0.009	0.008	0.013	0.022	0.024	0.032	0.018	0.021	0.019	0.008
CV	0.36	0.26	0.22	0.24	0.23	0.16	0.55	0.35	0.11	0.21
Millions	3.98	4.24	8.93	31.12	14.35	21.29	3.08	9.53	96.52	8.22
Emerged per m^2	0.002	0.000	0.004	0.004	0.005	0.007	0.006	0.006	0.004	0.001
CV	0.50	1.00	0.42	0.39	0.40	0.35	0.61	0.38	0.17	0.48
Millions	1.09	0.25	3.13	5.91	3.18	4.60	0.96	2.90	22.04	1.34

2013 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	6	5	4	16	6	6	3	3	49	11
Burrows per m^2	0.109	0.206	0.060	0.088	0.206	0.193	0.163	0.163	0.137	0.153
CV	0.15	0.11	0.13	0.14	0.20	0.14	0.23	0.34	0.08	0.14
Millions	47.86	113.90	41.82	125.32	124.54	127.52	28.08	74.64	683.67	161.76
Scampi per m^2	0.020	0.021	0.014	0.016	0.042	0.050	0.044	0.021	0.026	0.020
CV	0.38	0.13	0.40	0.18	0.16	0.17	0.22	0.21	0.10	0.20
Millions	8.70	11.49	10.09	23.23	25.52	33.11	7.60	9.65	129.39	20.19
Emerged per m^2	0.003	0.002	0.006	0.004	0.011	0.008	0.007	0.007	0.005	0.002
CV	0.67	0.53	0.77	0.31	0.25	0.21	0.38	0.31	0.15	0.46
Millions	1.29	0.87	4.52	5.37	6.63	5.04	1.22	3.07	28.02	2.16

Table Appendix 1 (cont): Unadjusted scampi biomass and abundance estimates in SCI 3.

2016 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	3	6	3	7	3	11	11	6	50	9
Burrows per m^2	0.101	0.190	0.143	0.183	0.078	0.108	0.208	0.190	0.160	0.160
CV	0.28	0.11	0.01	0.13	0.44	0.15	0.14	0.11	0.07	0.13
Millions	44.61	104.79	24.63	84.16	54.65	155.36	125.86	125.68	719.73	149.41
Scampi per m^2	0.033	0.044	0.054	0.045	0.018	0.035	0.065	0.055	0.047	0.040
CV	0.34	0.20	0.06	0.17	0.46	0.32	0.18	0.11	0.09	0.17
Millions	14.38	24.25	9.30	20.82	12.86	49.97	39.37	36.67	207.61	38.63
Emerged per m^2	0.004	0.009	0.008	0.005	0.001	0.002	0.009	0.005	0.005	0.007
CV	1.00	0.37	0.23	0.42	1.00	0.39	0.27	0.26	0.16	0.35
Millions	1.66	4.80	1.33	2.07	0.64	3.08	5.45	3.13	22.17	6.47

2019 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	3	5	6	9	6	5	3	3	40	8
Burrows per m^2	0.317	0.216	0.209	0.151	0.365	0.294	0.297	0.284	0.251	0.254
CV	0.31	0.06	0.22	0.16	0.10	0.22	0.22	0.47	0.08	0.12
Millions	139.46	119.02	146.04	216.62	220.54	194.58	51.04	130.54	1217.84	258.48
Scampi per m^2	0.112	0.051	0.062	0.064	0.100	0.085	0.134	0.043	0.077	0.074
CV	0.39	0.08	0.24	0.13	0.18	0.19	0.33	0.58	0.10	0.20
Millions	49.39	28.25	43.30	91.75	60.29	56.26	23.00	19.84	372.07	77.64
Emerged per m^2	0.009	0.004	0.006	0.008	0.010	0.008	0.005	0.004	0.007	0.006
CV	0.51	0.61	0.64	0.19	0.23	0.37	0.18	1.00	0.13	0.38
Millions	3.77	2.09	3.92	12.17	5.80	5.25	0.81	1.61	35.42	5.86

2023 Survey										Unadjusted
Stratum	902	903	902a1	902a2	902b1	902b2	902c	903a	Fishery	902 & 903
Area (km^2)	440	552	700	1 432	605	661	172	459	5 023	992
Stations	5	3	6	8	4	7	3	3	39	8
Burrows per m^2	0.173	0.364	0.195	0.220	0.284	0.331	0.200	0.240	0.248	0.244
CV	0.32	0.16	0.24	0.12	0.32	0.05	0.16	0.18	0.08	0.19
Millions	76.14	200.69	136.84	315.54	171.74	218.72	34.33	110.17	1264.16	276.83
Scampi per m^2	0.076	0.120	0.068	0.099	0.057	0.112	0.061	0.062	0.085	0.093
CV	0.39	0.15	0.25	0.13	0.23	0.09	0.21	0.30	0.08	0.24
Millions	33.35	66.47	47.57	142.15	34.75	74.32	10.42	28.57	437.60	99.82
Emerged per m^2	0.008	0.005	0.009	0.010	0.012	0.013	0.021	0.011	0.011	0.007
CV	0.45	1.00	0.40	0.34	0.33	0.20	0.36	0.48	0.14	0.41
Millions	3.37	2.71	6.39	13.95	7.32	8.51	3.60	5.18	51.04	6.08

APPENDIX 2: UNADJUSTED SURVEY ESTIMATES SCI 4A

Table Appendix 2: Unadjusted scampi biomass and abundance estimates in SCI 4A.

2023 Survey		Unadjusted	
Stratum	4AE	4AW	Fishery
Area (km^2)	872	791	1 663
Stations	7	7	14
Burrows per m^2	0.119	0.143	0.131
CV	0.15	0.20	0.12
Millions	94.25	124.30	218.55
Scampi per m^2	0.017	0.034	0.026
CV	0.28	0.23	0.18
Millions	13.67	29.52	43.20
Emerged per m^2	0.008	0.003	0.005
CV	0.28	0.50	0.27
Millions	6.01	2.87	8.88

APPENDIX 3: CATCH COMPOSITION

Table Appendix 3: Catch composition from the 26 trawl survey stations in SCI 3.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
ACS	*Actinostolidae*	Smooth deepsea anemones	5.3	-	-
AER	*Aeneator recens*	*Aeneator recens*	0.8	-	-
APD	Aphroditidae	Seamice	0.6	-	-
API	*Alertichthys blacki*	Alert pigfish	0.1	-	-
ASC	Ascidiacea	Sea squirt	0.1	-	-
AWI	*Alcithoe wilsonae*	*Alcithoe wilsonae*	1.2	-	-
BAM	*Bathyplotes* spp.	*Bathyplotes* spp.	0.3	-	-
BBE	*Centriscops humerosus*	Banded bellowsfish	141.5	-	-
BER	*Typhlonarke* spp.	Numbfish	23.7	-	-
BNS	*Hyperoglyphe antarctica*	Bluenose	4.3	-	-
BOC	*Bolocera* spp.	Deepsea anemone	0.2	-	-
BPD	Brachiopoda	Lamp shells	0.2	-	-
BRG	Brisingida	Brisingida (Order)	0.1	-	-
BSH	*Dalatias licha*	Seal shark	10.1	1	1
BTA	*Brochiraja asperula*	Smooth deepsea skate	3.1	-	-
BTS	*Brochiraja spinifera*	Prickly deepsea skate	3.6	-	-
BYS	*Beryx splendens*	Alfonsino	5.6	-	-
BYX	*Beryx splendens* & *B. decadactylus*	Alfonsino & Long-finned beryx	0.5	-	-
CAM	*Camplyonotus rathbunae*	Sabre prawn	1.3	-	-
CAR	*Cephaloscyllium isabellum*	Carpet shark	15.8	-	-
CAS	*Coelorinchus aspercephalus*	Oblique banded rattail	68.2	-	-
CBB		Coral rubble	21.0	-	-
CBI	*Coelorinchus biclinozonalis*	Two saddle rattail	2.0	-	-
CBO	*Coelorinchus bollonsi*	Bollons rattail	741.6	-	-
CCX	*Coelorinchus parvifasciatus*	Small banded rattail	25.1	-	-
CDO	*Capromimus abbreviatus*	Capro dory	2.1	-	-
CHA	*Chauliodus sloani*	Viper fish	0.1	-	-
CJA	*Crossaster multispinus*	Sun star	0.4	-	-
CMR	*Coluzea mariae*	*Coluzea mariae*	1.0	-	-
COF	*Flabellum* spp.	Flabellum coral	0.6	-	-
COL	*Coelorinchus oliverianus*	Olivers rattail	61.6	-	-
COV	*Comitas onokeana vivens*	*Comitas onokeana vivens*	0.4	-	-
CRM	*Callyspongia* cf. *ramosa*	Airy finger sponge	0.2	-	-
CUC	*Paraulopus nigripinnis*	Cucumber fish	1.0	-	-
CVI	*Pycnoplax victoriensis*	Two-spined crab	2.2	-	-
DAP	*Dagnaudus petterdi*	Antlered crab	5.5	-	-
DCO	*Notophycis marginata*	Dwarf cod	1.3	-	-
DCS	*Bythaelurus dawsoni*	Dawson's catshark	0.2	-	-

Table Appendix 3 (cont.): Catch composition from the 26 trawl survey stations in SCI 3.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
DDA	*Diaphus danae*	Dana lanternfish	0.1	-	-
DDI	*Desmophyllum dianthus*	*Desmophyllum dianthus*	1.9	-	-
DIR	*Diacanthurus rubricatus*	Pagurid	0.9	-	-
DMG	*Dipsacaster magnificus*	*Dipsacaster magnificus*	6.6	-	-
EGA	*Euciroa galatheae*	*Euciroa galatheae*	1.4	-	-
EPD	*Epigonus denticulatus*	White cardinalfish	5.6	-	-
EPT	*Epigonus telescopus*	Deepsea cardinalfish	77.0	-	-
ETL	*Etmopterus lucifer*	Lucifer dogfish	15.4	-	-
EUC	*Euclichthys polynemus*	Eucla cod	0.1	-	-
EUN	*Eunice* spp.	Eunice sea-worm	0.2	-	-
FHD	*Hoplichthys haswelli*	Deepsea flathead	225.3	-	-
FMA	*Fusitriton magellanicus*	*Fusitriton magellanicus*	1.0	-	-
GAS	Gastropoda	Gastropods	0.5	-	-
GAT	*Gastroptychus* spp.	*Gastroptychus* spp.	0.1	-	-
GDU	*Goniocorella dumosa*	Bushy hard coral	9.6	-	-
GIZ	*Kathetostoma giganteum*	Giant stargazer	227.0	78	78
GMC	*Leptomithrax garricki*	Garrick's masking crab	0.3	-	-
GOR	*Gorgonocephalus* spp.	*Gorgonocephalus* spp.	23.2	-	-
GPA	*Goniocidaris parasol*	Sea urchin	0.2	-	-
GSH	*Hydrolagus novaezealandiae*	Dark ghost shark	898.1	411	411
GSP	*Hydrolagus bemisi*	Pale ghost shark	36.4	12	12
GVO	*Provocator mirabilis*	Golden volute	1.2	-	-
HAG	*Eptatretus cirrhatus*	Hagfish	2.4	-	-
HAK	*Merluccius australis*	Hake	136.6	32	32
HBA	*Helicolenus barathri*	Bigeye sea perch	2 091.6	444	444
HCO	*Bassanago hirsutus*	Hairy conger	23.7	-	-
HDR	Hydrozoa	Hydroid	0.5	-	-
HEX	*Hexanchus* griseus	Sixgill shark	19.1	-	-
HMT	Hormathiidae	Deepsea anemone	0.4	-	-
HOK	*Macruronus novaezelandiae*	Hoki	1 467.6	226	226
HSI	*Haliporoides sibogae*	Jackknife prawn	0.5	-	-
HTH	Holothurian unidentified	Sea cucumber	0.1	-	-
IRM	*Stoloteuthis maoria*	Bobtail squid	0.1	-	-
JAV	*Lepidorhynchus denticulatus*	Javelinfish	2 378.5	-	-
KWH	*Austrofucus glans*	Knobbed whelk	0.1	-	-
LAG	*Laetmogone* spp.	*Laetmogone* spp.	0.3	-	-
LBI	*Lissodendoryx bifacialis*	*Lissodendoryx bifacialis*	1.4	-	-
LCH	*Harriotta raleighana*	Long-nosed chimaera	33.8	-	-
LDO	*Cyttus traversi*	Lookdown dory	163.0	-	-
LHE	*Lampanyctodes hectoris*	Hector's lanternfish	0.1	-	-

Table Appendix 3 (cont.): Catch composition from the 26 trawl survey stations in SCI 3.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
LIN	*Genypterus blacodes*	Ling	409.5	169	169
LNV	*Lithosoma novaezelandiae*	Rock star	1.4	-	-
LSQ	*Lycoteuthis lorigera*	*Lycoteuthis lorigera*	0.1	-	-
MGA	*Munida gracilis*	*Munida gracilis*	2.1	-	-
MIQ	*Moroteuthopsis ingens*	Warty squid	1.2	-	-
MSL	*Mediaster sladeni*	Starfish	8.4	-	-
NMA	*Notopandalus magnoculus*	*Notopandalus magnoculus*	0.6	-	-
NOS	*Nototodarus sloanii*	NZ southern arrow squid	12.8	-	-
NUD	Nudibranchia	Nudibranchs	0.4	-	-
OCO	*Octopus* spp.	*Octopus* spp.	0.6	-	-
ODT	*Odontaster* spp.	Pentagonal tooth-star	0.1	-	-
ONG	Porifera	Sponges	1.3	-	-
OPA	*Hemerocoetes* spp.	Opalfish	0.2	-	-
OPE	*Lepidoperca aurantia*	Orange perch	32.9	-	-
PAG	Paguroidea	Pagurid	1.7	-	-
PCH	*Penion chathamensis*	*Penion chathamensis*	3.5	-	-
PDG	*Oxynotus bruniensis*	Prickly dogfish	8.8	-	-
PHO	*Phosichthys argenteus*	Lighthouse fish	0.1	-	-
PLU	*Physiculus luminosa*	Luminescent cod	0.6	-	-
PNE	*Proserpinaster neozelanicus*	*Proserpinaster neozelanicus*	2.0	-	-
POL	Polychaeta	Polychaete	0.4	-	-
PRU	*Pseudechinaster rubens*	*Pseudechinaster rubens*	0.6	-	-
PSI	*Psilaster acuminatus*	Geometric star	18.1	-	-
PYC	Pycnogonida	Sea spiders	0.1	-	-
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	0.4	-	-
RCO	*Pseudophycis bachus*	Red cod	29.0	-	-
RGR	*Radiaster gracilis*	*Radiaster gracilis*	0.1	-	-
RHY	*Paratrachichthys traill*i	Common roughy	4.7	-	-
RIB	*Mora moro*	Ribaldo	11.3	-	-
ROK	*Geological specimens*	Rocks stones	24.1	-	-
RSO	*Rexea solandri*	Gemfish	8.8	-	-
SAL		Salps	0.2	-	-
SBK	*Notacanthus sexspinis*	Spineback	15.2	-	-
SCH	*Galeorhinus galeus*	School shark	51.8	-	-
SCI	*Metanephrops challengeri*	Scampi	977.7	-	-
SCO	*Bassanago bulbiceps*	Swollenhead conger	1.6	-	-
SDF	*Azygopus pinnifasciatus*	Spotted flounder	1.7	-	-
SDM	*Sympagurus dimorphus*	Pagurid	0.2	-	-
SEO		Seaweed	1.4	-	-

Table Appendix 3 (cont.): Catch composition from the 26 trawl survey stations in SCI 3.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
SIP	Sipuncula	Unsegmented worms	0.2	-	-
SKA	Rajidae Arhynchobatidae (Families)	Skate	0.1	-	-
SMK	*Teratomaia richardsoni*	Spiny masking crab	2.1	-	-
SMO	*Sclerasterias mollis*	Cross-fish	0.4	-	-
SPD	*Squalus acanthias*	Spiny dogfish	503.3	241	241
SPH	Scaphopoda	Tusk shells	1.1	-	-
SPN		Sea pen	3.9	-	-
SPT	*Spatangus multispinus*	Heart urchin	4.6	-	-
SRH	*Hoplostethus mediterraneus*	Silver roughy	76.3	-	-
SSI	*Argentina elongata*	Silverside	116.2	-	-
SSK	*Dipturus innominatus*	Smooth skate	131.4	-	-
SSQ	*Sepioloidea* spp.	Bobtail squid	1.7	-	-
SUA	*Suberites affinis*	Fleshy club sponge	0.3	-	-
SWA	*Seriolella punctata*	Silver warehou	1 672.0	-	-
TAM	Echinothuriidae & Phormosomatidae	Tam O shanter urchin	0.1	-	-
TFA	*Trichopeltarion fantasticum*	Frilled crab	1.7	-	-
THO	*Thouarella* spp.	Bottlebrush coral	0.3	-	-
TOP	*Ambophthalmos angustus*	Pale toadfish	7.4	-	-
UNI		Unidentified	0.7	-	-
URP	*Uroptychus* spp.	*Uroptychus* spp.	0.1	-	-
VNI	*Lucigadus nigromaculatus*	Blackspot rattail	0.9	-	-
WIT	*Arnoglossus scapha*	Witch	6.0	-	-
WOD	Wood	Wood	27.8	-	-
WWA	*Seriolella caerulea*	White warehou	39.8	-	-
ZOR	*Zoroaster* spp.	Rat-tail star	2.6	-	-
ZVA	*Thetys vagina*	*Thetys vagina*	5.7	-	-

Table Appendix 4: Catch composition from the 6 trawl survey stations in SCI 4A.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
API	*Alertichthys blacki*	Alert pigfish	0.2	-	-
BAR	*Thyrsites atun*	Barracouta	5.6	-	-
BBE	*Centriscops humerosus*	Banded bellowsfish	13.9	-	-
BNS	*Hyperoglyphe antarctica*	Bluenose	5.7	-	-
BTA	*Brochiraja asperula*	Smooth deepsea skate	1.6	-	-
BYS	*Beryx splendens*	Alfonsino	0.2	-	-
CAR	*Cephaloscyllium isabellum*	Carpet shark	9.3	-	-
CAS	*Coelorinchus aspercephalus*	Oblique banded rattail	8.8	-	-
CBI	*Coelorinchus biclinozonalis*	Two saddle rattail	16.8	-	-
CBO	*Coelorinchus bollonsi*	Bollons rattail	268.2	-	-
CCX	*Coelorinchus parvifasciatus*	Small banded rattail	2.2	-	-
CDO	*Capromimus abbreviatus*	Capro dory	112.7	-	-
CMR	*Coluzea mariae*	*Coluzea mariae*	0.1	-	-
COL	*Coelorinchus oliverianus*	Olivers rattail	0.5	-	-
CVI	*Pycnoplax victoriensis*	Two-spined crab	0.3	-	-
DAP	*Dagnaudus petterdi*	Antlered crab	2.5	-	-
DCO	*Notophycis marginata*	Dwarf cod	0.1	-	-
DCS	*Bythaelurus dawsoni*	Dawson's catshark	1.4	-	-
DIR	*Diacanthurus rubricatus*	Pagurid	0.7	-	-
DMG	*Dipsacaster magnificus*	*Dipsacaster magnificus*	0.3	-	-
ETL	*Etmopterus lucifer*	Lucifer dogfish	0.4	-	-
EUC	*Euclichthys polynemus*	Eucla cod	0.2	-	-
FHD	*Hoplichthys haswelli*	Deepsea flathead	28.4	-	-
FMA	*Fusitriton magellanicus*	*Fusitriton magellanicus*	1.6	-	-
FQU	*Funiculina quadrangularis*	Rope-like sea pen	5.4	-	-
GIZ	*Kathetostoma giganteum*	Giant stargazer	119.9	32	32
GSH	*Hydrolagus novaezealandiae*	Ghost shark	368.5	20	20
GVO	*Provocator mirabilis*	Golden volute	0.1	-	-
HBA	*Helicolenus barathri*	Bigeye sea perch	180.4	88	88
HCO	*Bassanago hirsutus*	Hairy conger	2.5	-	-
HOK	*Macruronus novaezelandiae*	Hoki	244.6	20	20
JAV	*Lepidorhynchus denticulatus*	Javelinfish	226.8	-	-
LDO	*Cyttus traversi*	Lookdown dory	63.1	-	-
LIN	*Genypterus blacodes*	Ling	178.3	53	53
LNV	*Lithosoma novaezelandiae*	Rock star	0.2	-	-
LSO	*Pelotretis flavilatus*	Lemon sole	1.6	-	-
MNI	*Munida* spp.	Munida unidentified	0.5	-	-

Table Appendix 4 (cont.): Catch composition from the 6 trawl survey stations in SCI 4A.

Species code	Scientific name	Common name	Catch weight (kg)	Number measured	Number weighed
MSL	*Mediaster sladeni*	Starfish	14	-	-
NOS	*Nototodarus sloanii*	NZ southern arrow squid	11.1	-	-
NSD	*Squalus griffini*	Northern spiny dogfish	16.5	-	-
OCP		Octopod	0.1	-	-
OPI	*Opisthoteuthis* spp.	Umbrella octopus	0.5	-	-
PSI	*Psilaster acuminatus*	Geometric star	3.9	-	-
PYR	*Pyrosoma atlanticum*	*Pyrosoma atlanticum*	0.3	-	-
RCO	*Pseudophycis bachus*	Red cod	28.5	23	23
RHY	*Paratrachichthys trailli*	Common roughy	0.6	-	-
SAL		Salps	3.4	-	-
SCI	*Metanephrops challengeri*	Scampi	109	-	-
SCO	*Bassanago bulbiceps*	Swollenhead conger	3.4	-	-
SDF	*Azygopus pinnifasciatus*	Spotted flounder	1.5	-	-
SDO	*Cyttus novaezealandiae*	Silver dory	12.5	-	-
SPD	*Squalus acanthias*	Spiny dogfish	222.8	67	67
SPT	*Spatangus multispinus*	Heart urchin	158.6	-	-
SRB	*Brama australis*	Southern Ray's bream	1	-	-
SRH	*Hoplostethus mediterraneus*	Silver roughy	0.8	-	-
SSI	*Argentina elongata*	Silverside	45.4	-	-
SSK	*Dipturus innominatus*	Smooth skate	37.4	1	1
SSQ	*Sepioloidea* spp.	Bobtail squid	0.5	-	-
SWA	*Seriolella punctata*	Silver warehou	45.8	-	-
TAM	Echinothuriidae & Phormosomatidae	Tam O'Shanter urchin	0.3	-	-
TOP	*Ambophthalmos angustus*	Pale toadfish	5.8	-	-
VNI	*Lucigadus nigromaculatus*	Blackspot rattail	0.1	-	-
WIT	*Arnoglossus scapha*	Witch	2.2	-	-
WWA	*Seriolella caerulea*	White warehou	11.6	-	-
ZOR	*Zoroaster* spp.	Rat-tail star	0.3	-	-