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Tini a Tangaroa

Estimating the abundance of scampi in SCI 1 (Bay of Plenty) and SCI 2 (Wairarapa / Hawke Bay) in 2018

New Zealand Fisheries Assessment Report 2019/18

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Photographic and trawl surveys of scampi in SCI 1 and SCI 2 were conducted in February and March 2018 from the RV *Kaharoa*. These areas were last surveyed in 2015. On each voyage, the photographic survey component was completed first, followed by the trawl survey component. For SCI 1, the photographic survey suggests an increase in abundance since 2015, while the trawl survey suggests a more stable situation, where biomass has remained relatively stable since the early 2000s. Current estimates from the trawl survey are 188 tonnes (or 4 million individuals). Current estimates from the photographic survey are 217 million burrows, and 56 million visible scampi. For SCI 2, the photographic survey suggested a decrease in abundance from 2015, to an estimate of 166 million burrows (and 49 million visible scampi), at a level still well above estimates from the mid-2000s. The trawl survey suggests biomass has remained stable since 2012 (2018 estimate of 183 tonnes, or 3 million individuals), and as with the photographic data, estimates are well above those from the mid 2000s. Given that scampi live in burrows and are only available to trawl gear when they emerge on the seabed, trawl survey estimates are likely to be considerable underestimates of the stock biomass or abundance.

Over 6600 scampi were tagged and released, as part of an investigation into growth, with releases distributed across the fishing grounds. To date, a small number of tagged scampi have been recaptured.

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 2016/17 were 1054 t (limit 1244 t). The landings for scampi in SCI 1 were 129 t (TACC 120 t) in 2016/17, consistent with the average over recent years, while landings for scampi in SCI 2 were 150 t (TACC 153 t), maintaining the higher level recorded since the TACC was increased in October 2013. The other major fisheries are SCI 3 (TACC 340 t), SCI 4A (TACC 120 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 bottom sediment. The main fisheries are in waters 300 – 500 m deep, although the range is slightly deeper in the SCI 6A region (350 – 550 m). Little is known about the growth rate and maximum age of scampi.

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. 2015b). 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. Eight previous surveys have been conducted in SCI 1 (1998, 2000, 2001, 2002, 2003, 2008, 2012 and 2015) (Cryer et al. 2003b; Tuck et al. 2009b; Tuck et al. 2013; Tuck et al. 2016), and six previous surveys have been conducted in SCI 2 (2003 to 2006, 2012 and 2015) (Tuck et al. 2006; Tuck et al. 2013; Tuck et al. 2016). Photographic survey series are also available for SCI 3 (2001 – 2016, six surveys) and SCI 6A (2007 – 2015, five surveys).

These photographic surveys provide two abundance indices: the density of visible scampi (as an index of minimum absolute abundance), and the density of major burrow openings. The index of major burrow openings has been used as an abundance index in recent stock assessments for SCI 1 and SCI 2 (Tuck & Dunn 2012; Tuck 2014), although the relationship between scampi and burrows may be different in SCI 6A (Tuck et al. 2007; Tuck & Dunn 2009).

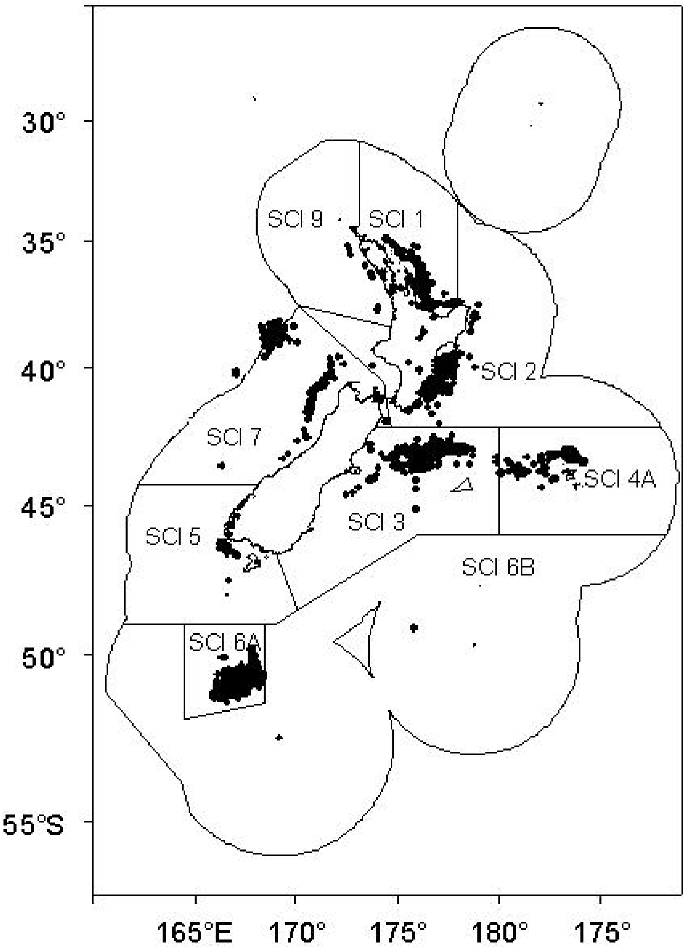

Figure 1: Spatial distribution of the scampi fishery since 1988–89 (ungroomed data). Each dot shows the mid-point of one or more tows recorded on TCEPR with scampi as the target species.

OVERALL OBJECTIVE: To estimate the abundance of scampi (*Metanephrops challengeri*) in SCI 1 and SCI 2.

OBJECTIVES:
1. To estimate the relative abundance of scampi using photographic techniques and trawl survey information.
2. To estimate growth of scampi from tagging.

2. METHODS

The survey design was presented to the Shellfish Assessment Working Group and included in the Voyage Programme document submitted to MPI in December 2017. The design for the survey largely followed that of the previous surveys in these areas (2015), with a random stratified design and stratification on the basis of depth (the main fishery areas having been divided into 300 – 400 m and 400 – 500 m depth bands) and general region, and stations allocated to strata so as to minimise the overall CV on the basis of the 2015 survey estimates of scampi burrow densities. However, previous surveys have focussed on the photographic component, often to the cost of precision within the trawl component. Given that both surveys provide indices for the stock assessment, the Working Group agreed with proposals to reduce the overall level of photographic sampling from previous designs (from 100 to 80 stations) to allow an additional 10 trawl stations (from 30 to 40) within the same survey duration. Survey strata for both areas are shown in Figure 2. The survey coverage for both trawl and photographic surveys in SCI 2 have remained consistent over the time series (survey strata 702, 703, 802, 803), but for SCI 1, the earliest (trawl only) surveys covered a large area (survey strata 202, 203, 302, 303, 402, 403) which was reduced (excluding strata 202 and 203) in 1998 when photographic surveys were introduced. Given the proportion of the fishery taking place within strata 202 and 203, these were reintroduced to the survey coverage in 2012 (Tuck et al. 2012).

Stations were allocated to strata on the basis of burrow abundance data from the 2015 surveys using the *allocate* package (Francis 2006), minimising the CV across the combined SCI 1 and SCI 2 area for a fixed number of stations. Random locations for photographic stations were generated within each stratum using the Random Stations package (Doonan & Rasmussen 2012), constrained to keep all stations at least 2 nautical miles apart. Trawl stations were then selected as the appropriate number of photographic stations that first appeared on the station list for each stratum, with minimum distance between each trawl station checked, and a station dropped and the next on the list selected if the distance was less than 4 nautical miles. Numbers of stations allocated to each stratum are provided in Table 1 and Figure 3.

Table 1: Details of strata and number of stations planned for SCI 1 and SCI 2 survey in 2018.

Area	Stratum	Depth (m)	Area (km^2)	Photo stations	Trawl stations
SCI 1	202	300–400	306.69	5	3
SCI 1	203	400–500	311.20	6	3
SCI 1	302	300–400	261.95	4	3
SCI 1	303	400–500	266.36	4	3
SCI 1	402	300–400	379.74	9	4
SCI 1	403	400–500	290.31	5	4
SCI 2	702	300–400	321.41	8	7
SCI 2	703	400–500	543.59	21	4
SCI 2	802	300–400	386.11	10	5
SCI 2	803	400–500	230.54	8	4

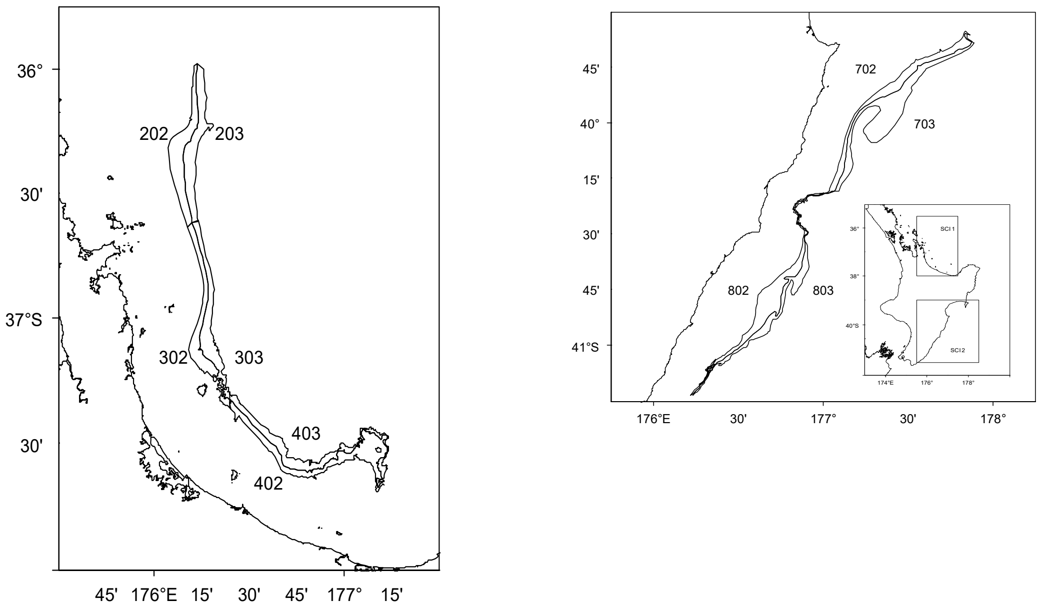

Figure 2: Survey strata for the 2018 photographic survey of SCI 1 (left) and SCI 2 (right).

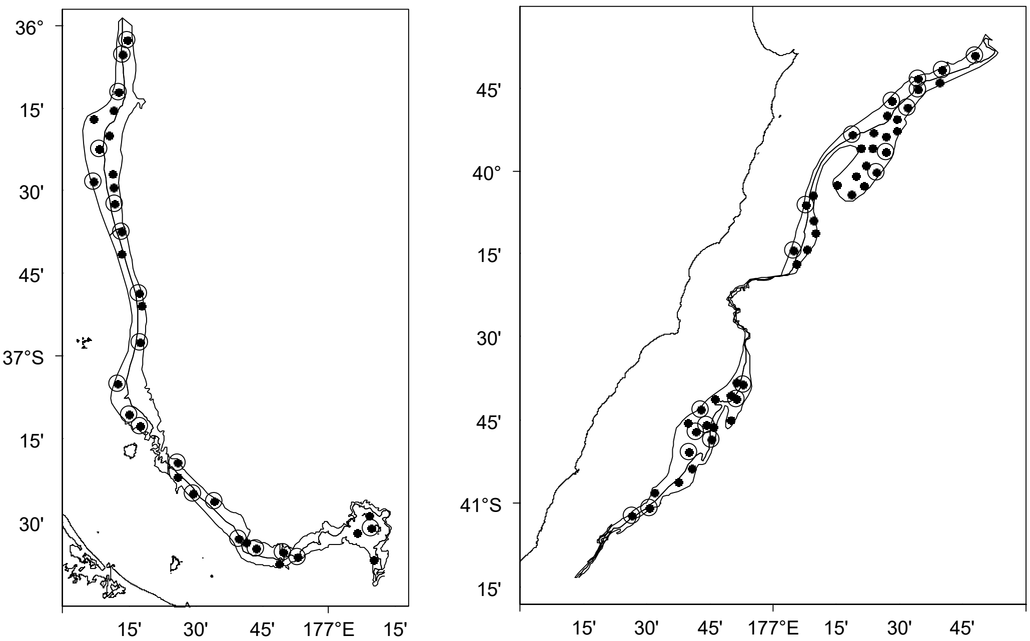

Figure 3: Station locations for the 2018 photographic survey of SCI 1 (left) and SCI 2 (right) (black dots indicating the station midpoints). Open circles represent stations also sampled by trawling.

In February/March 2018 we undertook stratified random photographic surveys of scampi burrows within SCI 1 (Bay of Plenty, 300–500 m depth) and SCI 2 (Hawke Bay / Wairarapa, 300–500 m depth), from the NIWA research vessel *RV Kaharoa*, using the survey design as discussed with and approved by the MPI Shellfish Working Group. These were the ninth and seventh photographic surveys of the SCI 1 and SCI 2 areas respectively. The survey was stratified on the basis of depth (100 m bands) and region (Figure 2). The survey coverage accounts for about 99% (SCI 1) and 98% (SCI 2) of landings from the fisheries over their history.

2.1 Photographic survey

As discussed above, a target of 33 (SCI 1) and 47 (SCI 2) photographic stations was set, on the basis of survey duration, and these were allocated to strata using the *allocate* package in R (so as to minimise the overall expected survey CV), on the basis of burrow densities observed in the 2015 surveys. Photographic sampling was undertaken between about 0600 and 1800 NZST to coincide with the period of maximum trawl catchability of scampi. Although the time of day should have no direct effect on the counting of scampi burrows and their constituent openings, sampling at a time when the greatest number of scampi are likely to be out of their burrows has two main advantages. First, a larger number of individuals can be measured for a photographic length frequency distribution, and second, the presence of scampi at or near burrow openings is an excellent aid to the identification of certain burrow types as belonging to scampi.

We used NIWA's deepwater digital camera system, with an automatic flash exposure providing almost instantaneous triggering and exposure. Images were stored on 1 GB "flash" cards in the camera, allowing us to save images in raw format. After the completion of each station, the images were downloaded from the camera via USB cable (avoiding the need to open the camera housing after each station), and the images were saved to the hard drives of a dedicated PC, and backed up on a portable hard drive.

The camera was triggered using a combination of a time-delay switch and a micro ranger, as its cage was held in the critical area 2–4 m off the seabed using a modified Furuno CN22 acoustic headline monitor displaying distance off-bottom in "real time" on the bridge. The micro ranger triggered the camera to take a picture in the critical altitude range, while the timer triggered the camera to also take a picture, once the time limit was reached. Our target was to expose 30 – 40 frames per station as the ship drifted, using a time delay sufficient to ensure that adjacent photographs did not overlap. Visibility was good at most sites, except where substantial swell meant that maintenance of the critical altitude off the bottom was difficult, and run duration was extended to allow for images lost to over and under exposure. Also, when visibility was poor, some stations were repeated later in the trip. Almost all of the photographs exposed in the critical area were of good or excellent quality.

Image selection and scoring

Images were examined and scored using a standardised protocol (developed under MPI project SCI2000/02) (Cryer et al. 2002) applied by a team of six trained readers. For each image, the main criteria of usability were the ability to discern fine seabed detail, and the visibility of more than 50% of the frame (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 is clearly and sharply visible was estimated and marked using polygons in NICAMS (NIWA Image Capture and Manipulation System, developed using the ImageJ software). Each reader then assessed the number of burrow openings using the standardized protocol (Cryer et al. 2002). We defined "major" and "minor" burrow openings which were, respectively, the type of opening at which scampi are usually observed, and the "rear" openings associated respectively with most burrows. Based on our examination of a large number of images of scampi associated with burrows, "major" and "minor" openings each have their own characteristics and should be scored separately (Figure 4). We classified each opening (whether major or minor) as "highly characteristic" or "probable", based on the extent to which each is characteristic of burrows observed to be used by New Zealand scampi. An investigation into mud burrowing megafauna in scampi grounds concluded that it is unlikely that other species present would generate burrows that would be confused with those generated by scampi (Tuck & Spong 2013). Burrows and holes which could conceivably be used by scampi, but which are not "characteristic" are not counted. Our counts of burrow openings may, therefore, be conservative. Many ICES stock assessments of the related *Nephrops norvegicus* are conducted using relative abundance indices based on counts of "burrow systems" (rather than burrow openings) (Tuck et al. 1994; Tuck et al. 1997). We counted burrow openings rather than assumed burrow systems because systems are relatively large compared with the quadrat (photograph) size and accepting all burrows totally or partly within each photograph is positively biased by edge effects (Marrs et al. 1996; Marrs et al. 1998).

The criteria used by readers to judge whether or not a burrow should be scored are, of necessity, partially subjective as we cannot be certain that any particular burrow belongs to a *M. challengeri* and is currently inhabited unless the individual is photographed in the burrow. However, after viewing large numbers of scampi associated with burrows, we have developed a set of descriptors that guide our decisions (Cryer et al. 2002). Using these descriptors as a guideline, each reader assesses each potential burrow opening (paying more attention to attributes with a high ranking such as surface tracks, sediment fans, and a shallow descent angle) and scores it only if it is "probably" a scampi burrow. Scores were saved within a database within the NICAMS system, for later compilation into an ACCESS database containing all scampi image data. Within NICAMS, features counted by each reader were individually identifiable within each image, providing an audit trail.

Once the images from any particular stratum or survey had been scored by three readers, any images for which the greatest difference between readers in the counts of major openings (combined for "highly characteristic" and "probable") is more than 1 were re-examined by all readers (who may or may not change their score, in the light of observations from other readers). All images where there was any difference between readers on the count of visible scampi (even a difference of interpretation as to whether a scampi is "in" or "out" of a burrow) were re-examined by all readers. During the second reading process, each reader had access to the score and annotated files of all other readers and, after re-assessing their own interpretation against the original image, were encouraged to compare their readings with the interpretations of other readers. Thus, the re-reading process was a means of maintaining consistency among readers as well as refining the counts for a given image.

To enable comparison of the 2018 survey data with previous surveys, the reference sets for SCI 1 (initially generated in 2008, and including images from 1998 to 2003)(Tuck et al. 2009b), and subsequently augmented with images from successive surveys (Tuck et al. 2013; Tuck et al. 2016) and SCI 2 (generated in 2012, and including images from 2003 to 2006)(Tuck et al. 2013) were augmented with images from 2012 and 2015 (Tuck et al. 2016), and reread in 2018 (at the same time as the 2018 survey images), with each image in each reference set being read by all six readers, using the standard image scoring and re-reading procedure.

Data analysis

Burrow and scampi counts from photographs were analysed using methods analogous to those in the *SurvCalc* Analysis Program (Francis & Fu 2012) for trawl surveys, as previously described to the Shellfish Fishery Assessment Working Group (SFAWG). To exclude a possible image size effect (burrows perhaps being more or less likely to be accepted as the number of pixels making up their image decreases), the approach adopted has been that images with a very small (less than 2 m^2) or very large (more than 16 m^2) readable area have been excluded. The mean density of burrow openings at a given station was estimated as the sum of all counts (major or minor openings) divided by the sum of all readable areas. For any given stratum, the mean density of openings and its associated variance were estimated using standard parametric methods, giving each station an equal weighting. The total number of openings in each stratum was estimated by multiplying the mean density by the estimated area of the stratum. The overall mean density of openings in the survey area was estimated as the weighted average mean density, and the variance for this overall mean was derived using the formula for strata of unequal sizes (Snedecor & Cochran 1989):

For the overall mean, $\bar{x}_{(y)} = \sum W_i . \bar{x}_i$

and its variance, $s^2{}_{(y)} = \sum W_i{}^2 . S_i{}^2 . (1 - \phi_i) / n_i$

where $s^2_{(y)}$ is the variance of the overall mean density, $\bar{x}_{(y)}$, of burrow openings in the surveyed area, W_i is the relative size of stratum i, and S_i^2 and n_i are the sample variance and the number of samples respectively from that stratum. The finite correction term, $(1 - \phi_i)$, was set to unity because all sampling fractions were less than 0.01.

Separate indices were calculated for major and minor openings, for all visible scampi, and for scampi "out" of their burrows (i.e., walking free on the sediment surface). Only indices for major burrow openings and for visible scampi are presented here because the SFAWG has agreed that these are likely to be the most reliable indices. The minor sensitivity of the indices to the reader "bias" identified for SCI 1 (Cryer et al. 2002) was investigated with *reader_year* "correction factors" calculated for each reader in each survey, and a "corrected" density index for major burrow openings is also provided. Confidence in the estimates was examined through a bootstrapping procedure, resampling stations (with replacement) within strata, selecting one reader (from three) within station.

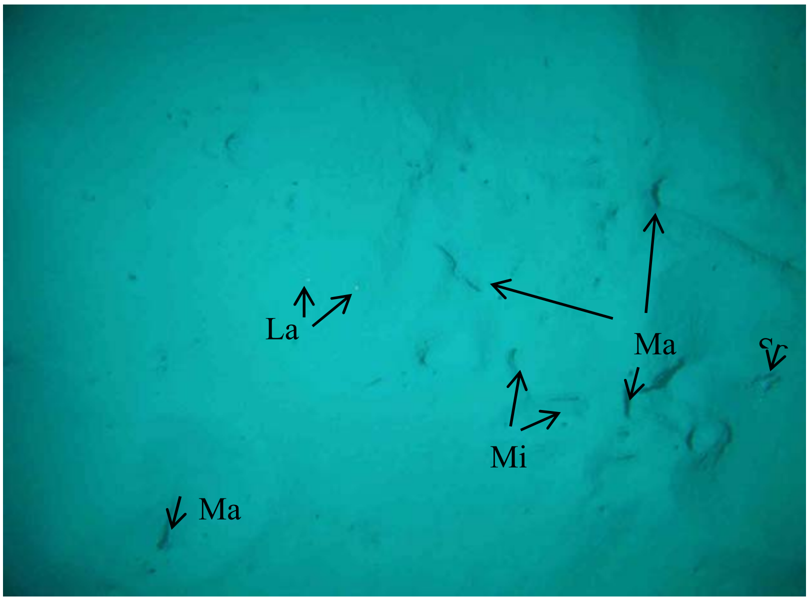

Figure 4: Example image from March 2006 survey in SCI 2 showing laser scaling dots, several characteristic scampi burrows and one large visible scampi.

2.2 Trawl survey

Trawl survey sampling was undertaken between roughly 0600 and 1800 NZST, during the second half of each component of the voyage, after the photographic survey had been completed. Trawling was conducted with the *RV Kaharoa* scampi trawl, as with previous scampi surveys from this vessel (Cryer et al. 2003c; Tuck et al. 2011).

Scampi tagging

The second objective of the voyage was to tag and release scampi to investigate growth. When time allowed, all scampi caught on each tow that were considered to be in good health were tagged and released. All scampi were rapidly sorted from the catch, and stored in darkened non-draining bins of well aerated, chilled seawater. Any animals with carapace punctures were excluded, and any damaged or missing limbs were recorded. Animals were tagged between the carapace and cuticle of the first abdominal segment through the musculature of the abdomen (Figure 5) with sequentially numbered streamer tags (Hallprint type 4S), Hallprint T-bar tags, or both. The streamer tags have been used successfully in previous scampi studies (Cryer & Stotter 1997; Cryer & Stotter 1999; Tuck & Dunn 2012), although tag return data suggest that some tag loss may be occurring at the moult, and therefore the T-bar tag approach has also been examined. Tag recovery rates from previous tagging investigations of these fisheries were poor, and a chilled water recirculating system was employed to hold animals at bottom water temperature (8–12 ºC) rather than ambient surface water temperature (18–21 ºC), in an attempt to improve survival. The next scheduled research sampling in SCI 1 and SCI 2 will be in 2021, and so it is anticipated that recoveries will be from commercial fishing activity. At the request of MPI and the Shellfish Working Group, no tag mortality component was included in the survey, as it was considered very unlikely that tag recapture data would be used to estimate stock size for this fishery.

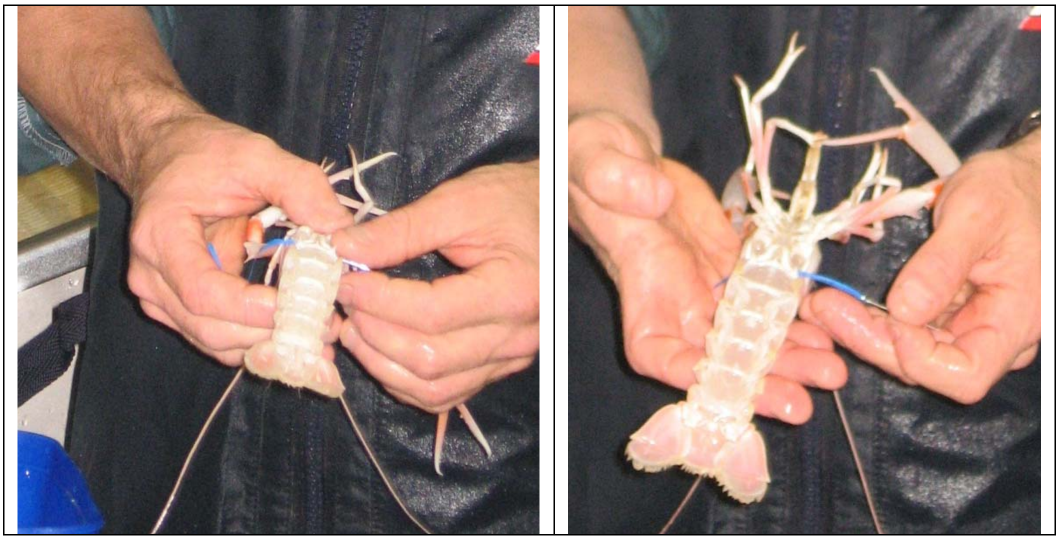

Figure 5: Photographs showing location of streamer tag in scampi.

3. RESULTS

The voyage was completed successfully between 12th February and 23rd March 2018. All photographic trawl stations were completed, despite some poor weather during some parts of the voyage.

3.1 SCI 1 Photographic survey

Visibility was generally good at most sites, and almost all of the photographs exposed were of good or better quality. Over the whole SCI 1 survey, a total area of 5199 m^2 of seabed was viewed (acceptable quality images), with an average of 36.3 images at each station, an average seabed area viewed by each image of 4.33 m^2, providing an average area viewed of 157.54 m^2 at each station. All planned photographic stations were achieved (Table 2).

Following suggestions from the Shellfish Working Group, calibration across years and between readers was conducted in a single analysis, rather than the two stage process implemented previously (Tuck et al. 2009a). All the image count data (including reference set counts) were combined into a single dataset. Terms were created for *reader_year* (combination of reader and the year in which the image was read), *stratum_year* (combination of survey stratum and year the image was recorded in) and *station_year* (combination of station number and survey year). Burrow count data from individual images were aggregated to station level and examined within a generalised linear mixed modelling framework, with *strata_year*, *reader_year* and readable area (offset) as explanatory variables, and image and *station_year* as random effects, and a negative binomial error distribution. Models were run with the `glmer.nb` function within the *lme4* package in R. The significance of effects were tested by sequentially adding terms to a model testing the null hypotheses that there were no *stratum_year* or *reader_year* differences between burrow counts over time. These null hypotheses were rejected as the model detected highly significant effects (both considered as factors) (Table 3). Diagnostic plots for the model are presented in Figure 6.

Table 2: Details of strata and number of photo stations completed for SCI 1 survey in 2018.

			Photo stations	
Stratum	Area (km^2)	Depth (m)	Planned	Completed
202	306.69	300–400	5	5
203	311.20	400–500	6	6
302	261.95	300–400	4	4
303	266.36	400–500	4	4
402	379.74	300–400	9	9
403	290.31	400–500	5	5

Table 3: Analysis of deviance for a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *strata_year*, and readable area for SCI 1.

	Df	Sum sq	Mean Sq	F value	P
Stratum_year	41	156.90	3.8269	3. 8269	<0.0001
Reader_year	30	431.56	14.3855	14. 3855	<0.0001

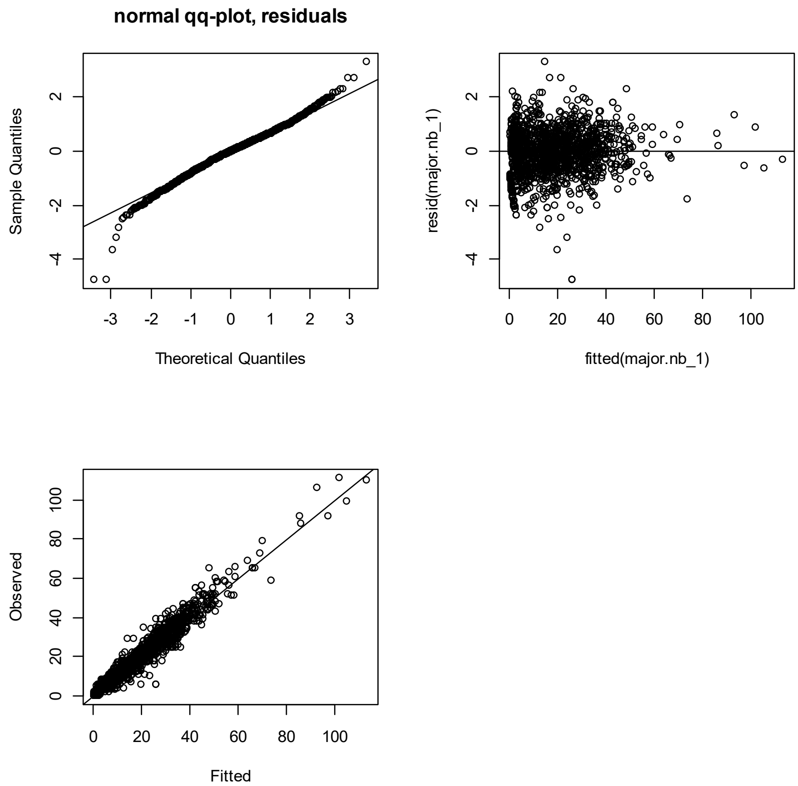

Figure 6: Diagnostic plots for generalised linear mixed effects model to estimate reader_year coefficients for SCI 1.

Canonical indices of the *reader_year* terms are presented in Table 4 and plotted in Figure 7. These were calculated from the GLMM indices and covariance matrix (Francis 1999).

The correction factor (Table 4) for each *reader_year* (C_i) is defined as follows

$$C_i = \frac{\bar{c}}{c_i}$$

where c_i is the index of the *i*th *reader_year*, and $\bar{c}$ is the average of the *reader_year* indices. These correction factors were applied to the individual reader reads for the analysis of the image data, estimating overall abundance.

Table 4: Canonical indices (and variance, CV and upper and lower 95% CI) for *reader_year* terms from a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *strata_year*, and readable area for SCI 1.

Reader_Year	Indices	Variance	CVs	Upper 95%	Lower 95%	Correction factor
AM_2012	1.14	0.006285	0.069808	1.294261	0.977139	0.892332
AM_2015	1.28	0.016999	0.102225	1.536173	1.014658	0.794582
AM_2018	1.40	0.017007	0.092857	1.665233	1.143596	0.721597
BH_2003	0.94	0.008633	0.098898	1.125304	0.753654	1.078706
BH_2008	0.91	0.007048	0.092683	1.073723	0.737909	1.118794
BH_2012	0.84	0.007071	0.099837	1.010418	0.674070	1.203240
CM_2003	1.13	0.012698	0.099952	1.352760	0.902018	0.898910
DP_2008	1.18	0.011621	0.091549	1.393099	0.961903	0.860655
DP_2012	0.78	0.003421	0.075265	0.894119	0.660154	1.304045
DP_2015	1.26	0.016469	0.101917	1.515837	1.002510	0.804831
DP_2018	1.22	0.013529	0.095637	1.448811	0.983560	0.833279
HA_2003	0.92	0.008485	0.099646	1.108640	0.740186	1.096287
HA_2008	0.94	0.007646	0.093315	1.111901	0.762147	1.081532
HA_2012	0.83	0.003994	0.075880	0.959268	0.706475	1.216780
HA_2015	1.15	0.013821	0.102266	1.384698	0.914447	0.881564
HA_2018	1.00	0.009390	0.097087	1.191896	0.804290	1.015358
IT_2008	0.88	0.006649	0.092411	1.045486	0.719312	1.148485
IT_2012	0.93	0.004889	0.075058	1.071407	0.791722	1.087870
IT_2015	1.10	0.012589	0.102269	1.321507	0.872708	0.923721
IT_2018	0.97	0.008849	0.097262	1.155321	0.779041	1.047810
JD_2003	0.90	0.008213	0.100994	1.078564	0.716070	1.129391
JD_2008	0.72	0.004713	0.095368	0.857194	0.582578	1.407754
MC_2003	1.09	0.011479	0.098009	1.307460	0.878895	0.927042
MS_2003	1.13	0.012639	0.099223	1.357873	0.908184	0.894436
MS_2008	0.96	0.008109	0.093459	1.143602	0.783410	1.051806
MS_2012	1.11	0.006724	0.074086	1.270862	0.942851	0.915585
MS_2015	1.13	0.013536	0.102700	1.365558	0.900177	0.894563
MS_2018	1.11	0.011094	0.095280	1.316094	0.894787	0.916758
NR_2012	0.74	0.003231	0.076393	0.857733	0.630370	1.362031
NR_2015	0.87	0.008107	0.103764	1.047830	0.687665	1.167876
NR_2018	0.87	0.007754	0.101036	1.047618	0.695402	1.162835

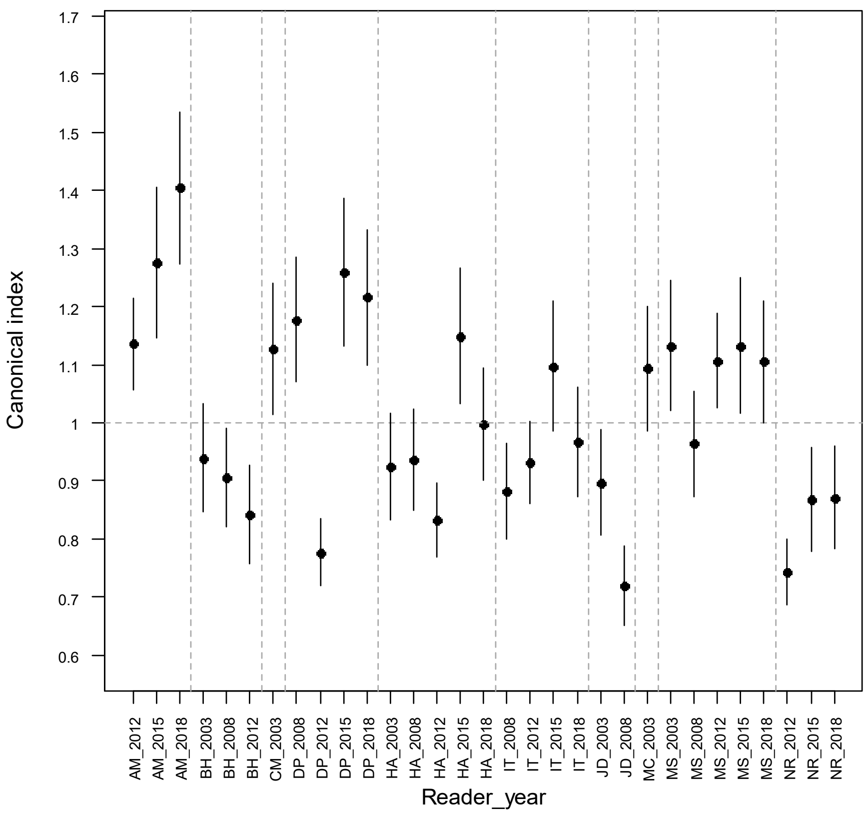

Figure 7: Canonical indices (and CV) for *reader_year* terms from a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *strata_year*, and readable area for SCI 1.

Reader_year effects were also tested for counts of visible scampi in the same way, but were not found to be significant, supporting our previous observation that identification and counting of scampi is far less subjective than burrow openings.

The number of completed stations by strata are provided in Table 2. The locations of photographic stations, and relative burrow densities, are shown in Figure 8. The uncorrected burrow density estimates varied from 0.03 – 0.23 m^{-2}, and reader correction factors led to a slight reduction in overall density estimates. Densities of all scampi, and scampi out of their burrows ranged from 0 to 0.1 (Figure 9) and 0.03 m^{-2}, respectively. Scaling the densities to the combined area of the strata (1816 km^{2}) leads to abundance estimates from 217 million burrows or, assuming 100% occupancy, a maximum abundance estimate of the same number of animals (Table 5). Analysis of all SCI 1 surveys (with and without *reader_year* corrections) are presented in Appendix 1.

Overall, the density of major scampi burrow openings was estimated to be 0.12 m^{-2}. The density was higher in the deeper strata (203, 303 and 403) and the southern shallower stratum (402). The CVs from the bootstrapped estimates (bootstrapping of the *reader_year* corrected estimates, resampling stations with replacement within strata, and selecting one of the three readers for each station) were very similar to those of the corrected estimates (Table 5).

The estimated mean density of all visible scampi was 0.03 m^{-2}, with the highest density observed in the deeper and southern strata. Scaling the observed densities of visible scampi to strata area leads to a minimum abundance estimate of 56 million animals for the surveyed area (Table 6). Counting animals out of burrows and walking free on the surface reduced this estimate to 11 million animals (Table 7). The CVs for visible scampi and scampi out of burrows from the bootstrapped estimates were comparable with those of the original estimates.

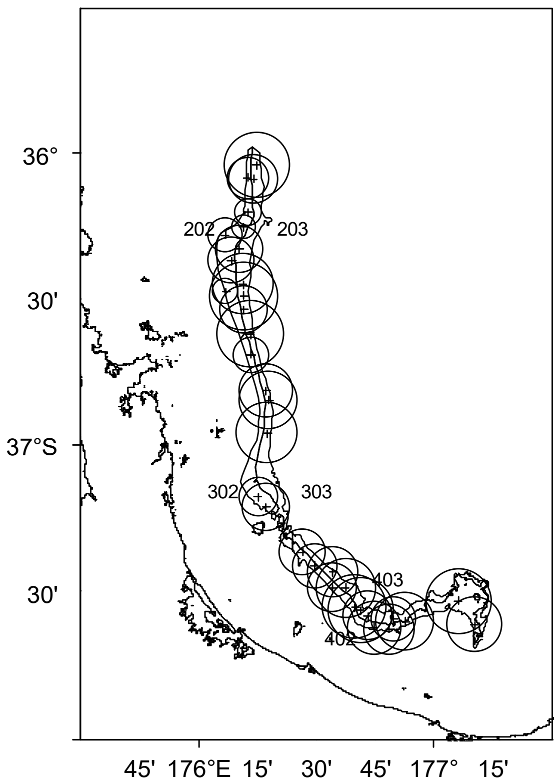

Figure 8: Station locations for the 2018 photographic survey of SCI 1 (area of symbol represents relative burrow density). Largest circle represents 0.23 burrows .m^{-2} (uncorrected for *reader_year*). The scale is the same between Figure 8 and Figure 20.

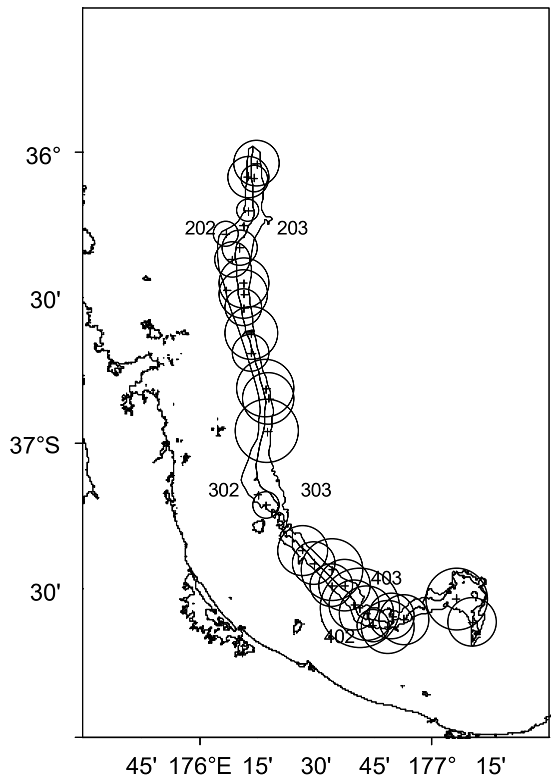

Figure 9: Station locations for the 2018 photographic survey of SCI 1 (area of symbol represents relative visible scampi density). Largest circle represents 0.095 visible scampi .m^{-2}. The scale is the same between Figure 9 and Figure 21.

Table 5: Estimates of the density and abundance of major burrow openings from the SCI 1 survey for 2018. Counts by each reader have been scaled by correction factors for *reader_year*. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Major burrows	202	203	302	303	402	403	Fishery	Bootstrap
Area (km^2)	306.69	311.20	261.95	266.36	379.74	290.31	1816	
Stations	5	6	4	4	9	5	33	
Mean density (.m^{-2})	0.0488	0.1524	0.0814	0.1585	0.1349	0.1385	0.1196	
CV	0.24	0.14	0.13	0.10	0.09	0.15	0.05	0.05
Abundance (millions)	14.97	47.39	21.33	42.17	51.00	40.17	217.03	217.18

Table 6: Estimates of the density and abundance of visible scampi from the SCI 1 survey for 2018. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Visible scampi	202	203	302	303	402	403	Fishery	Bootstrap
Area (km^2)	306.69	311.20	261.95	266.36	379.74	290.31	1816	
Stations	5	6	4	4	9	5	33	
Mean density (.m^{-2})	0.0077	0.0269	0.0147	0.0490	0.0340	0.0538	0.0309	
CV	0.51	0.17	0.40	0.10	0.14	0.18	0.08	0.07
Abundance (millions)	2.35	8.37	3.84	13.05	12.84	15.59	56.05	55.92

Table 7: Estimates of the density and abundance of scampi out of burrows from the SCI 1 survey for 2018. Scampi "out" were defined as those for which the telson was not obscured by the burrow. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Scampi out	202	203	302	303	402	403	Fishery	Bootstrap
Area (km^2)	306.69	311.20	261.95	266.36	379.74	290.31	1816	
Stations	5	6	4	4	9	5	33	
Mean density (.m^{-2})	0.0026	0.0027	0.0071	0.0112	0.0078	0.0061	0.0062	
CV	1.00	0.92	0.36	0.26	0.48	1.00	0.24	0.22
Abundance (millions)	0.81	0.83	1.85	2.97	2.96	1.76	11.19	11.07

The trend in abundance in major burrow openings is shown in Figure 10 (for individual strata) and Figure 11 (for larger areas). For the consistently surveyed area (surveyed since 1998), the abundance shows a decline in the early 2000s, and remained very stable until the most recent survey, which shows an increase in abundance to levels comparable with 1998. Estimated abundance for the current survey extent (encompassing over 98% of scampi targeted fishing in the SCI 1 management area) suggests a stable abundance between 2012 and 2015, and a similar increase to the consistently surveyed area between 2015 and 2018. The survey estimates uncorrected for *reader_year* effect (Appendix 1) are similar to the corrected estimates and show a similar overall pattern. The indices of scampi abundance (visible scampi, and scampi out of burrows) are presented in Figure 12. These show a similar decline in the early 2000s, but with visible scampi increasing between 2008 and 2012, declining by 2015, and increasing markedly by 2018 (to over twice the 2015 estimate). Estimates of scampi out of burrows are far lower, and show less temporal pattern, after the initial decline in the early part of the series, although they also suggest an increase in 2018.

Overall survey mean densities for the current and previous surveys in SCI 1 are provided in Table 8. The count of visible scampi as a percentage of burrows (which could be considered a minimum estimate of occupancy) was 29% in 2018 but has previously been lower for this stock (average 17%). The range observed is comparable with other SCI survey data (Tuck et al. 2013). The proportion of scampi seen out of their burrows (scampi out as a proportion of all visible scampi) was 21% in 2018, which is comparable with recent other surveys in SCI 1, SCI 2 and SCI 3 (Tuck et al. 2013), but lower than observed in SCI 6A (Tuck et al. 2015a).

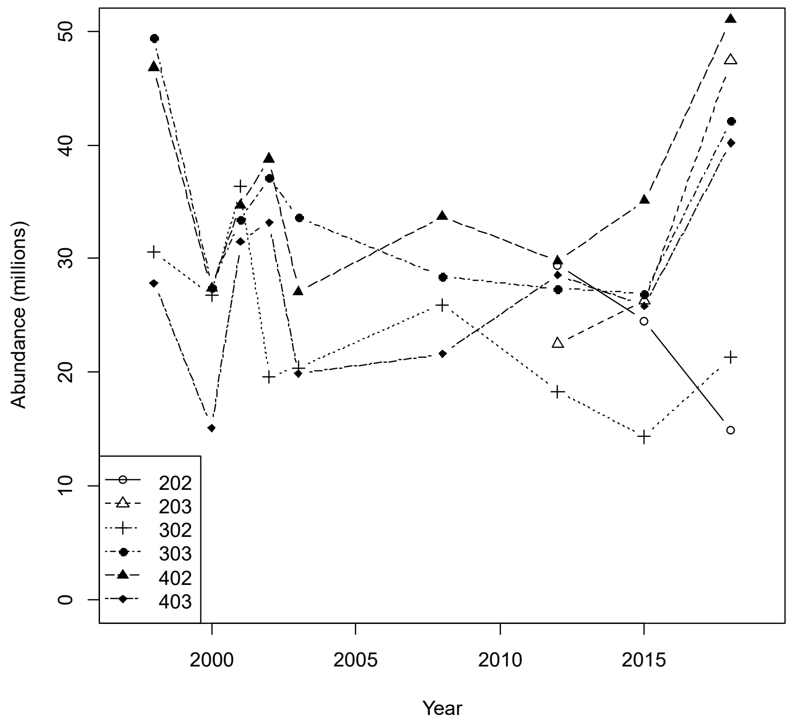

Figure 10: Estimated abundance of major scampi burrow openings for SCI 1 by strata.

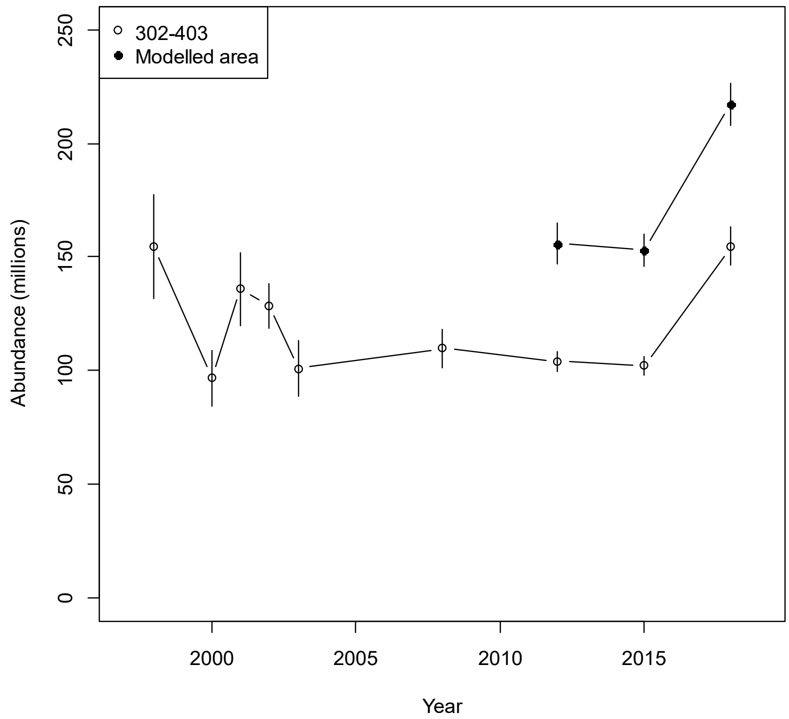

Figure 11: Estimated abundance of major scampi burrow openings (± CV) for SCI 1 for combined 302, 303, 402 and 403 strata (which have been covered by all photographic surveys), and whole SCI 1 survey area (only covered since 2012).

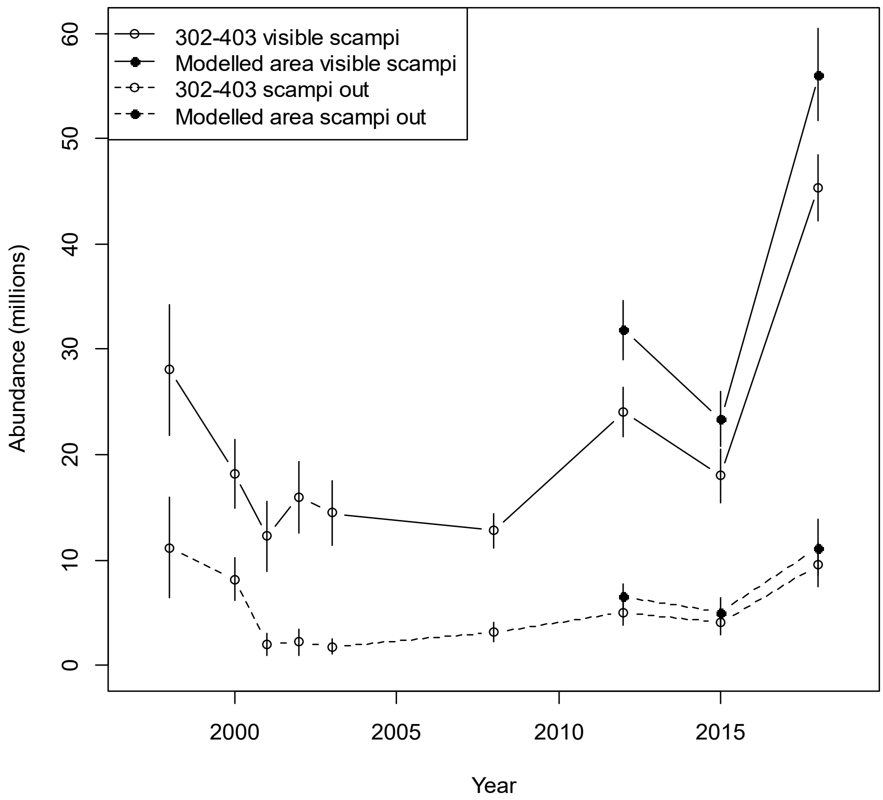

Figure 12: Estimated abundance of scampi (± CV) for SCI 1 for combined 302, 303, 402 and 403 strata (which have been covered by all photographic surveys), and whole SCI 1 survey area (only covered since 2012).

Table 8. Overall survey mean densities (m^{-2}) of major burrow openings, visible scampi and scampi out of burrows, for the series of SCI 1 surveys (data for the combined 302, 303, 402 & 403 strata and the current survey coverage presented in separate blocks).

	Major opening	Visible scampi	Scampi "out"	Scampi as % of openings	% of visible scampi "out"
302–403					
1998	0.1293	0.0235	0.0093	0.18	0.40
2000	0.0810	0.0152	0.0068	0.19	0.45
2001	0.1137	0.0103	0.0016	0.09	0.16
2002	0.1076	0.0133	0.0018	0.12	0.14
2003	0.0844	0.0121	0.0015	0.14	0.12
2008	0.0918	0.0107	0.0026	0.12	0.25
2012	0.0870	0.0201	0.0042	0.23	0.21
2015	0.0855	0.0150	0.0034	0.18	0.23
2018	0.1293	0.0379	0.0080	0.29	0.21
SCI 1					
2012	0.0859	0.0175	0.0036	0.20	0.20
2015	0.0843	0.0129	0.0028	0.15	0.22
2018	0.1195	0.0309	0.0062	0.26	0.20

3.2 SCI 1 Trawl survey

The locations of trawl survey stations, and relative scampi catch rates, are shown in Figure 13. Biomass estimates are provided by strata for the 2018 survey in Table 9, and are compared with previous surveys estimated over the same strata in Table 11. Equivalent abundance estimates are provided for the 2018 survey in Table 10, and are compared with previous surveys in Table 12.

Table 9: Trawl survey estimates by strata for SCI 1. Mean values expressed as kg.nautical mile^{-1} with the *RV Kaharoa* scampi trawl gear.

	Stratum						
Area (km^2)	202	203	302	303	402	403	Total
N. stations	307	311	262	266	378	290	1814
Mean (kg.mile^{-1})	3	3	3	3	4	4	18
CV	2.23	1.18	2.34	3.08	7.70	11.52	4.82
Biomass (tonnes)	0.96	0.39	0.35	0.08	0.50	0.27	0.21
Area (km^2)	14.79	7.92	13.27	17.68	62.86	72.13	188.64

Table 10: Trawl survey estimates (abundance) by survey and stratum for SCI 1. Mean values expressed as numbers mile^{-1} with the *RV Kaharoa* scampi trawl gear.

	Stratum						
Strata	202	203	302	303	402	403	Total
Area (km^2)	307	311	262	266	378	290	1814
No. of stations	3	3	3	3	4	4	18
Mean (No. mile^{-1})	39.98	25.56	60.95	75.67	183.98	216.64	104.02
CV	0.96	0.42	0.46	0.14	0.48	0.28	0.21
Abundance (millions)	0.26	0.17	0.34	0.43	1.50	1.36	4.08

The overall raised trawl survey estimate was 188 tonnes (21% CV) (Table 9), or 4.1 million individuals (21% CV) (Table 10). Given that scampi live in burrows and are only available to trawl gear when they emerge on the seabed, this is likely to be a considerable underestimate of the stock biomass. This is comparable with the 2012 and 2015 estimates (186 t, 21% CV, and 170 7, 13% CV), but a decline on the peak biomass estimates of the mid 1990s (Table 11, Figure 14 and Figure 15). The trends in scampi abundance (in numbers) estimated from the trawl surveys follow very similar patterns to those shown by biomass (Table 12).

Table 11: Time series of raised trawl survey scampi stock estimates (tonnes) by survey strata for SCI 1. Time step relates to assessment model (see Tuck 2014), with surveys in December – January allocated to step 1, and those in February – April allocated to step 2.

	202	203	302	303	402	403	Total	3/402 & 3/403	Time step
1993	22.01	32.34	71.63	37.14	80.71	27.79	271.61	217.26	1
1994	51.37	24.45	48.46	42.88	130.23	66.64	364.03	288.21	1
1995	58.81	59.95	132.84	98.01	134.10	26.65	510.37	391.61	1
1996			52.53	63.91					2
1998			71.70	19.29	71.74	11.25		173.98	1
2000	34.61	9.17	57.08	57.16	54.19	12.90	225.10	181.33	2
2001			21.45	39.40	70.99	47.69		179.52	1
2002			33.05	24.66	44.22	28.69		130.62	2
2008			24.63	57.34	67.52	62.42		211.91	2
2012	8.30	28.28	14.22	49.59	55.27	30.89	186.55	149.97	2
2015	10.71	41.37	1.89	32.46	22.21	61.96	170.59	118.52	2
2018	14.79	7.92	13.27	17.68	62.86	72.13	188.64	165.94	2

Table 12: Time series of raised trawl survey scampi stock estimates (millions) by survey strata for SCI 1. Time step relates to assessment model (see Tuck 2014), with surveys in December – January allocated to step 1, and those in February – April allocated to step 2.

	202	203	302	303	402	403	Total	3/402 & 3/403	Time step
1993	0.36	0.54	1.47	0.89	2.17	0.75	6.18	5.28	1
1994	0.89	0.47	0.91	0.85	2.82	1.21	7.14	5.78	1
1995	1.03	1.05	2.39	1.77	2.69	0.34	9.28	7.20	1
1996			0.88	1.22					2
1998			0.69	0.58	1.76	0.16		3.19	1
2000	0.64	0.14	0.95	0.92	1.35	0.24	4.23	3.45	2
2001			0.31	0.57	1.16	0.67		2.72	1
2002			0.15	0.71	0.98	0.55		2.39	2
2008			0.45	0.93	1.86	1.24		4.47	2
2012	0.18	0.56	0.25	1.05	0.66	0.50	3.20	2.46	2
2015	0.19	0.60	0.04	0.54	0.48	1.24	3.08	2.30	2
2018	0.26	0.17	0.34	0.43	1.50	1.36	4.08	3.64	2

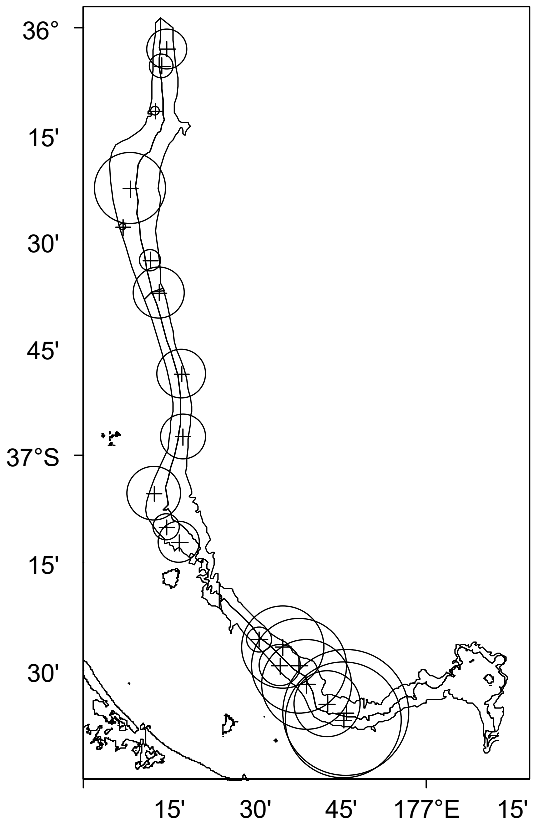

Figure 13: Trawl station locations for the 2018 survey of SCI 1 (size of symbol represents relative scampi catch rate). Largest circle represents 20.1 kg.mile^{-1}. The scale is the same between Figure 13 and Figure 25.

Over the whole SCI 1 trawl survey, 388 kg of scampi were caught, accounting for about 5.7% of the total catch (6850 kg), with scampi being the fourth most abundant species. By weight, the most predominant species caught were sea perch (16.9%), hoki (14.7%), silver roughy (6.7%), scampi (5.7%), javelin fish (5.6%), and ling (5.6%). In commercial fishing activities, scampi forms a greater proportion of the total catch, as bycatch mitigation approaches reduce fish catch.

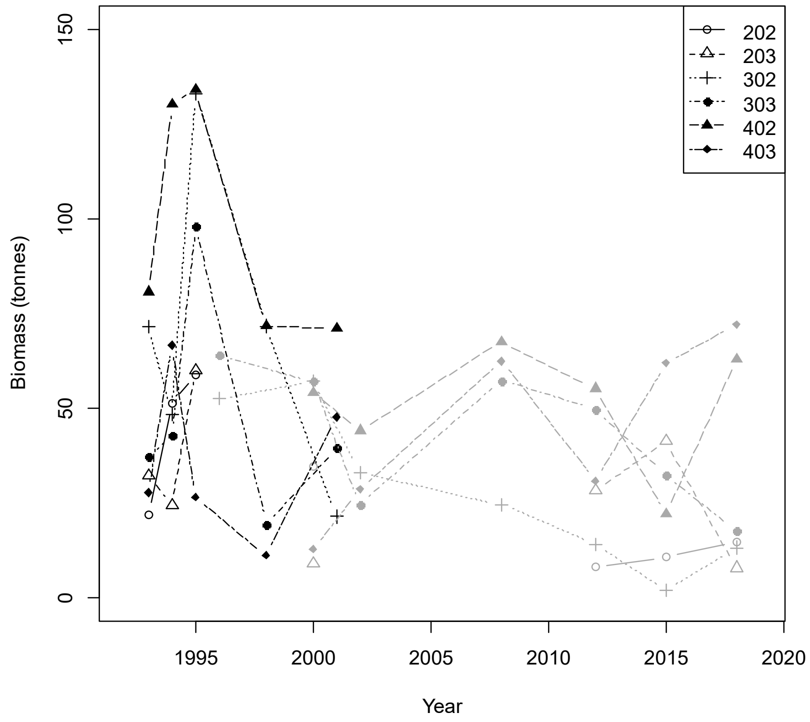

Figure 14: Plot of time series of trawl survey biomass estimates for SCI 1 by survey strata.

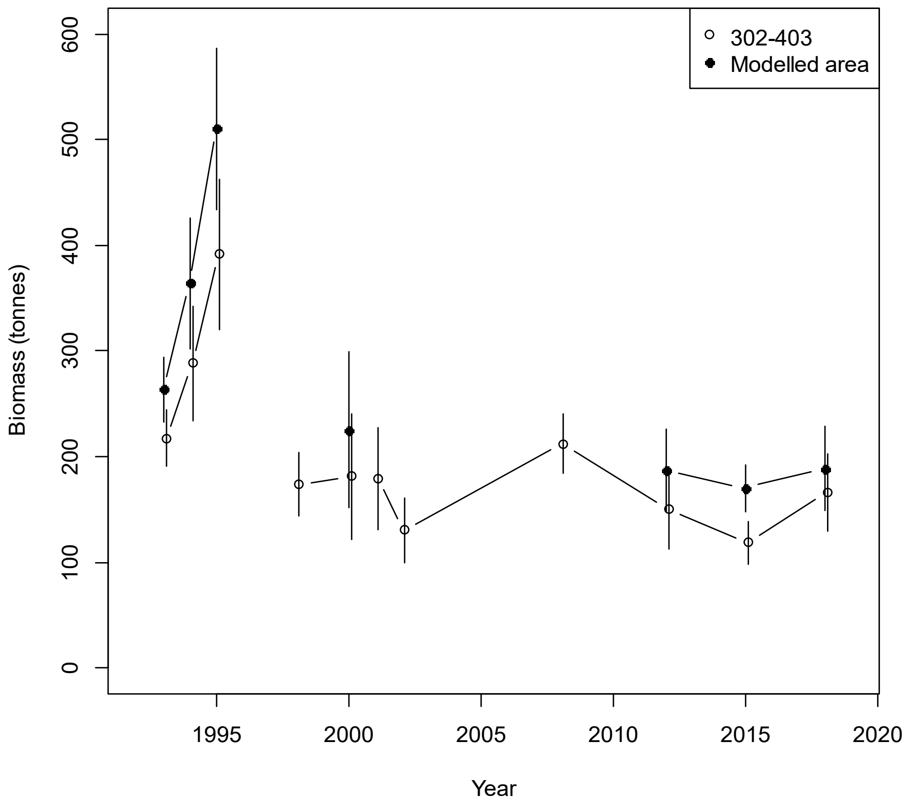

Figure 15: Plot of time series of trawl survey biomass estimates (± CV) for SCI 1 for combined 302, 303, 402 and 403 strata (which have been covered by all photographic surveys), and whole SCI 1 survey area (only covered since 2012).

3.3 SCI 1 Tagging

Undamaged active scampi were tagged from each trawl catch, and released for the growth investigation. The next scheduled research sampling in SCI 1 will be in 2021, and so it is anticipated that recoveries will be from commercial fishing activity. Over the SCI 1 component of the survey, almost 3700 scampi were tagged with either streamer (2531) or T-bar (1167) tags, which were then released. Tagging did not target specific size ranges, and the length distribution of tagged animals reflects the size distribution of suitable animals from the catches. The length distributions of the tagged scampi are presented in Figure 16. The sex ratio of scampi tagged (and the catches) was more even than in previous surveys in this region at this time of year, when males have dominated catches (Tuck et al. 2016). The tagged scampi were released at 23 separate locations (Figure 17). No scampi were released while the vessel was fishing, and no recaptures were made by the RV *Kaharoa* during the survey. Tagging mortality was not investigated during this voyage (following recommendations of the Shellfish Assessment Working Group), but when examined elsewhere, short term (up to seven days) survival has been estimated at 76% in SCI 2 (Tuck et al. 2013) and 88% in SCI 6A (Tuck et al. 2015a), the difference assumed to be related to warmer surface water temperatures in SCI 2.

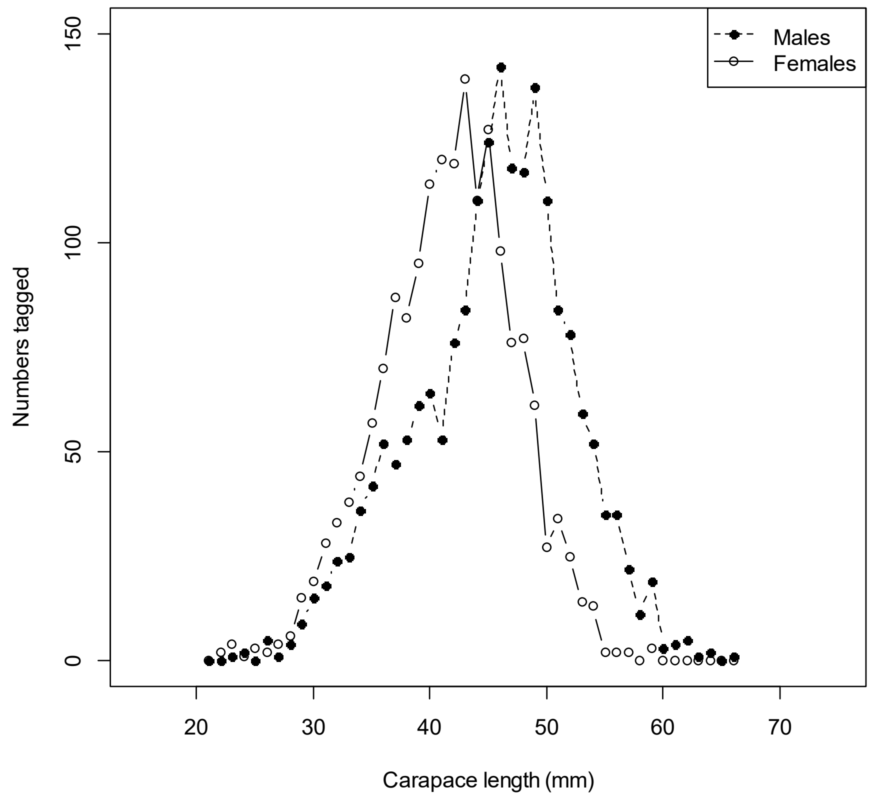

Figure 16: Length distribution of scampi tagged and released in SCI 1 during the 2018 voyage.

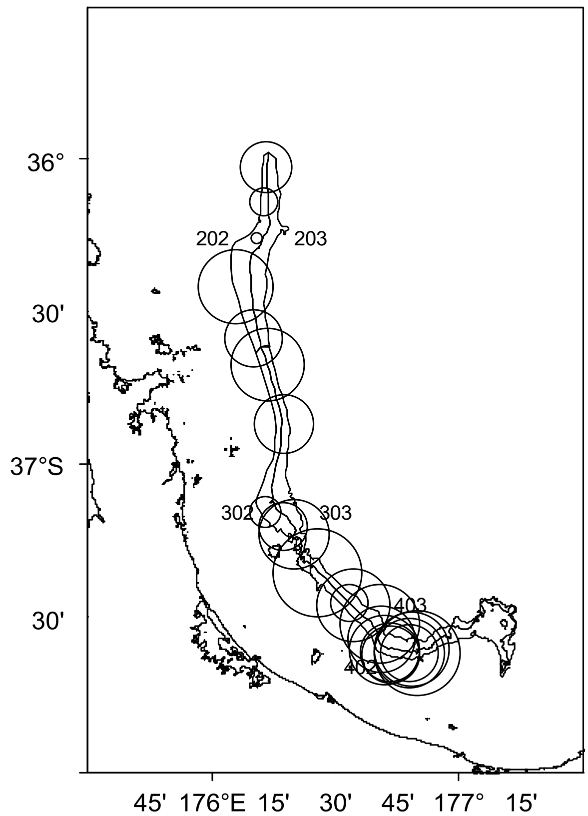

Figure 17: Map showing distribution of 2018 scampi release locations in SCI 1, and relative numbers released at each location. Largest circles represent 317 animals. The smallest release batch was 6 animals, and the average release batch was 160 animals

To date (January 2017) two recoveries have been reported to NIWA from SCI 1. Tag recoveries have generally been low from SCI 1 and SCI 2, compared to SCI 6A. The same tagging approach is used in all areas, and it is unclear why recovery rates are so different, although the colder surface waters in SCI 6A may contribute to increased survival.

3.4 SCI 2 Photographic survey

As with the SCI 1 component of the survey, visibility was generally good, and almost all of the photographs exposed in the critical area were of good or better quality. Over the whole SCI 2 survey, a total area of 7008 m^2 of seabed was viewed (acceptable quality images), with an average of 33.9 images at each station, an average seabed area viewed by each image of 4.39 m^2, providing an average area viewed of 149.10 m^2 at each station. All planned photographic stations were successfully surveyed (Table 13).

Following the approach described for SCI 1 (Section 3.1), calibration across years and between readers was conducted in a single analysis. The significance of effects was tested by sequentially adding terms, and a model testing the null hypotheses that there were no *stratum_year* or *reader_year* differences between burrow counts over time. These null hypotheses was rejected as the model detected highly significant effects (both considered as factors) (Table 14). Diagnostic plots for the model are presented in Figure 18. *Reader_year* indices are presented in Table 15 and plotted in Figure 19.

Table 13: Details of strata and number of photo stations completed for SCI 2 survey in 2018.

			Photo stations	
Stratum	Area (km^2)	Depth (m)	Planned	Completed
702	321.41	300–400	8	8
703	543.59	400–500	21	21
802	386.11	300–400	10	10
803	230.54	400–500	8	8

Table 14: Analysis of deviance for a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *stratum_year*, and readable area for SCI 2.

	Df	Sum sq	Mean Sq	F value	P
Stratum_year	27	93.36	3.4578	3.4578	<0.0001
Reader_year	42	1189.72	28.3266	28.3266	<0.0001

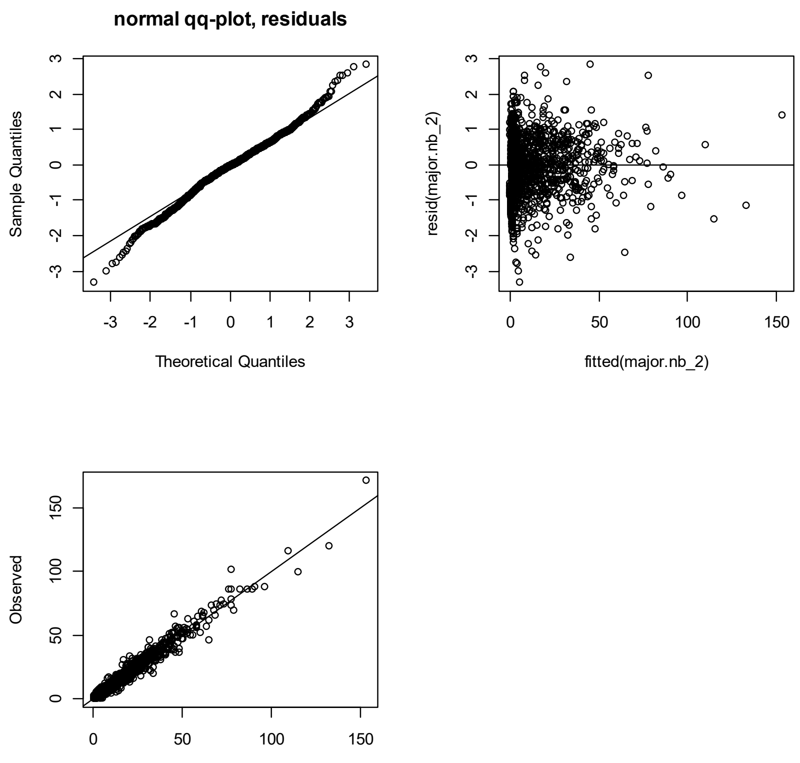

Figure 18: Diagnostic plots for generalised linear mixed effects model to estimate *reader_year* coefficients for SCI 2.

Table 15: Canonical indices (and variance, CV and upper and lower 95% CI) for *reader_year* terms from a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *strata_year*, and readable area for SCI 2.

Reader_Year	Indices	Variance	CVs	Upper 95%	Lower 95%	Correction factor
AM_2012	1.83	0.028843	0.092801	2.169740	1.490407	0.583381
AM_2015	1.40	0.017692	0.095304	1.661686	1.129637	0.764964
AM_2018	1.62	0.033210	0.112256	1.987857	1.258915	0.657657
BH_2003	1.21	0.062173	0.205723	1.710730	0.713352	0.880853
BH_2004	1.03	0.054886	0.226922	1.500973	0.563862	1.034107
BH_2005	0.96	0.032523	0.187724	1.321357	0.599992	1.111334
BH_2006	0.91	0.025626	0.176223	1.228573	0.588244	1.175276
BH_2012	0.74	0.010850	0.139847	0.953182	0.536521	1.433346
CM_2003	1.88	0.120950	0.184646	2.579044	1.187930	0.566837
CM_2004	1.64	0.139462	0.227465	2.388660	0.894878	0.650293
DP_2005	0.95	0.055682	0.248566	1.421273	0.477388	1.124614
DP_2006	0.87	0.026104	0.186105	1.191288	0.545017	1.229773
DP_2012	0.78	0.006213	0.101060	0.937598	0.622309	1.368838
DP_2015	1.17	0.012684	0.096417	1.393309	0.942824	0.914015
DP_2018	1.62	0.032379	0.110814	1.983699	1.263932	0.657483
HA_2003	1.27	0.059630	0.192481	1.757047	0.780274	0.841541
HA_2004	0.88	0.028727	0.192642	1.218790	0.540834	1.213475
HA_2005	1.21	0.054237	0.192979	1.672586	0.741030	0.884673
HA_2006	1.00	0.031025	0.175883	1.353739	0.649181	1.066074
HA_2012	0.78	0.005924	0.099035	0.931081	0.623219	1.373776
HA_2015	0.89	0.007685	0.098611	1.064315	0.713658	1.200952
HA_2018	1.18	0.017756	0.113000	1.445711	0.912708	0.905378
IT_2006	1.16	0.039744	0.171584	1.560586	0.763153	0.918890
IT_2012	0.77	0.006002	0.100761	0.923783	0.613904	1.388618
IT_2015	1.04	0.010257	0.097431	1.242007	0.836906	1.027104
IT_2018	1.17	0.017712	0.113280	1.441011	0.908669	0.908745
JD_2003	0.65	0.014796	0.188381	0.888973	0.402424	1.653450
JD_2004	0.36	0.007460	0.236871	0.537362	0.191887	2.928026
JD_2005	0.33	0.005857	0.230201	0.485513	0.179390	3.211390
JD_2006	0.32	0.003661	0.192061	0.436063	0.194030	3.388801
MC_2003	1.34	0.072759	0.200859	1.882403	0.803449	0.795003
MC_2004	0.95	0.030628	0.185035	1.295836	0.595799	1.128791
MC_2005	1.01	0.038226	0.192692	1.405681	0.623620	1.052215
MS_2003	1.41	0.069014	0.186011	1.937714	0.886895	0.755949
MS_2004	0.97	0.030601	0.180095	1.321201	0.621471	1.099136
MS_2005	1.41	0.071080	0.188829	1.945117	0.878684	0.756166
MS_2006	0.90	0.027101	0.182585	1.230886	0.572386	1.184103
MS_2012	1.15	0.012321	0.096551	1.371654	0.927654	0.928654
MS_2015	1.00	0.009499	0.097695	1.192528	0.802684	1.070192
MS_2018	1.40	0.024632	0.112434	1.709775	1.081996	0.764841
NR_2012	0.79	0.006379	0.101038	0.950259	0.630772	1.350550
NR_2015	0.86	0.007098	0.098348	1.025139	0.688143	1.246299
NR_2018	1.09	0.015760	0.115148	1.341302	0.839151	0.979274

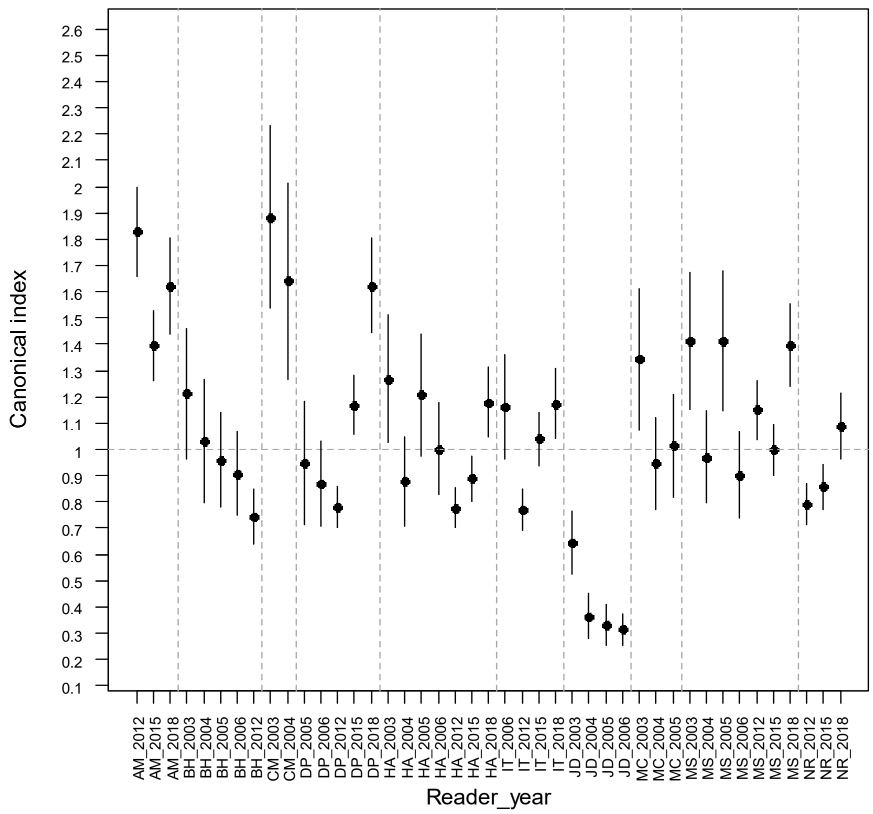

Figure 19: Canonical indices (and CV) for *reader_year* terms from a generalised linear mixed model relating the count of major burrow openings to *reader_year*, *strata_year*, and readable area for SCI 2.

As with SCI 1, *reader_year* effects were also tested for scampi counts in the same way, but were not found to be significant, supporting our previously assumed (but untested) view that identification and counting of scampi is far less subjective than burrow openings.

The number of completed stations by stratum are provided in Table 13. The locations of photographic stations, and relative burrow densities, are shown in Figure 20. The uncorrected burrow density estimates varied from 0 – 0.34 m^{-2}, and correction factors reduced overall density estimates slightly. Densities of all scampi, and scampi out of their burrows ranged from 0 to 0.10 (Figure 21) and 0.03 m^{-2}, respectively. Scaling the densities to the combined area of the strata (1482 km^2) leads to abundance estimates from 166 million burrows or, assuming 100% occupancy, a maximum abundance estimate of the same number of animals (Table 16). Analysis of all SCI 2 surveys (with and without *reader_year* corrections) are presented in Appendix 2.

Overall, the density of scampi major burrow openings was estimated to be 0.11 m^{-2}. The density was highest in stratum 803. The CVs from the bootstrapped estimates (bootstrapping of the *reader_year* corrected estimates, resampling stations with replacement within strata, and selecting one of the three readers for each station) were very similar to those of the original corrected estimates (Table 16).

The estimated mean density of all visible scampi was 0.03 m^{-2}, with the highest densities observed in the strata 702 and 802. Scaling the observed densities of visible scampi to stratum area leads to a minimum abundance estimate of 49 million animals for the surveyed area (Table 17). Counting animals out of burrows and walking free on the surface reduced this estimate to 5 million animals (Table 18). The CVs for visible scampi and scampi out of burrows from the bootstrapped estimates were comparable with those of the original estimates.

The trend in abundance in major burrow openings is shown in Figure 22 (for individual strata) and Figure 23 (for the whole survey). The strata show a relatively consistent pattern (reflected in the whole area) of an increase in abundance in 2004, followed by lower and comparable abundance estimates in 2005, 2006 and 2012. Abundance increased markedly by 2015, and while the estimate has declined for 2018, it remains higher than estimates prior to 2015. Over the whole survey area, estimated abundance of major burrow openings almost doubled between 2005 and 2015 and remains one and a half times the 2005 estimate in 2018. The survey estimates uncorrected for *reader_year* effect (Appendix 2) show a generally similar pattern. The indices of scampi abundance (visible scampi, and scampi out of burrows) are presented in Figure 24. The visible scampi estimate shows a consistent increase in abundance since 2006, while the scampi out of burrows shows a pattern more consistent with the major burrow index.

Overall survey mean densities for the current and previous surveys in SCI 2 are provided in Table 19. The count of visible scampi as a percentage of burrows (which could be considered a minimum estimate of occupancy) was 29% in 2018 (as it was for SCI 1). This is the highest value observed for SCI 2, but is within the bounds of other SCI survey data (Tuck 2014). The proportion of scampi seen out of their burrows (scampi out as a proportion of all visible scampi) was 11% in 2018, which is lower than that observed in SCI 1 in 2018, but comparable with recent other surveys in SCI 1, SCI 2 and SCI 3 (Tuck et al. 2016), and lower than observed in SCI 6A (Tuck et al. 2015a).

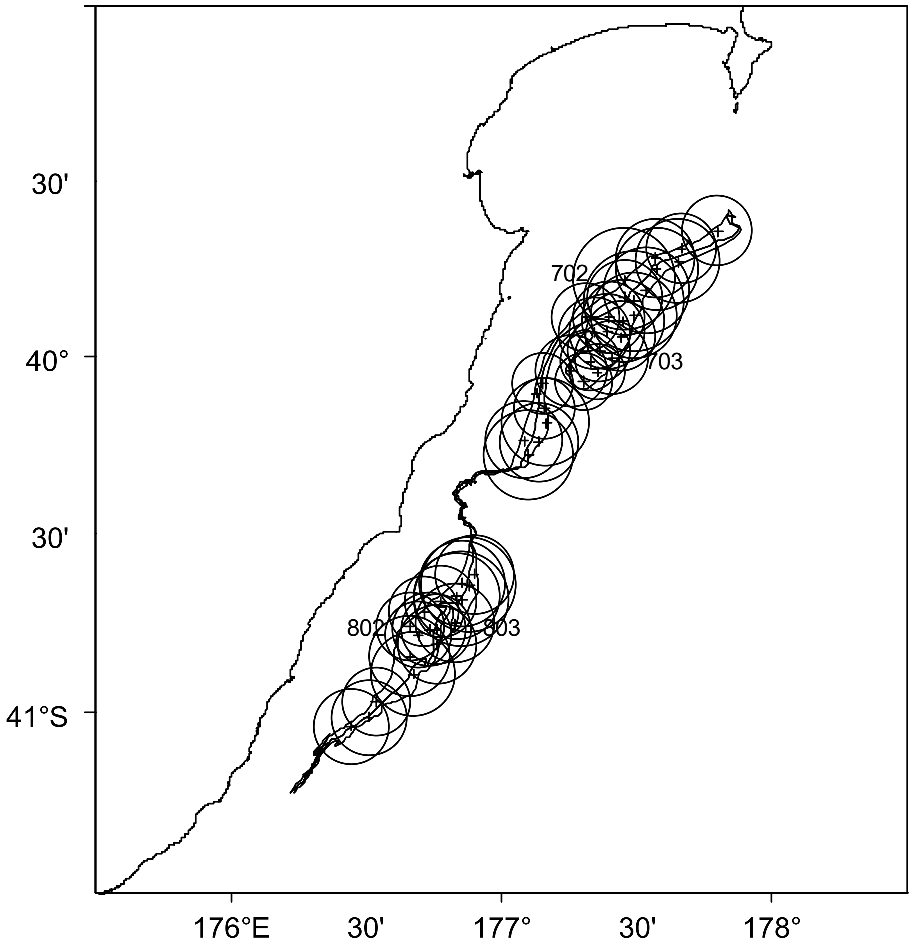

Figure 20: Station locations for the 2018 photographic survey of SCI 2 (area of symbol represents relative burrow density). Largest circle represents 0.34 burrows .m^{-2} (uncorrected for *reader_year*). The scale is the same between Figure 8 and Figure 20.

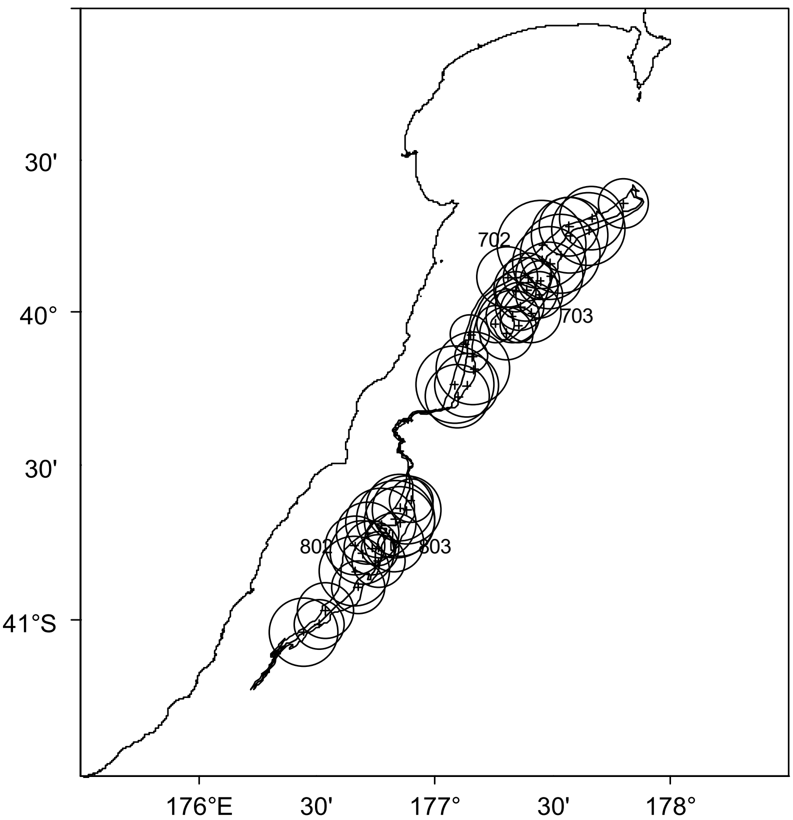

Figure 21: Station locations for the 2018 photographic survey of SCI 2 (area of symbol represents relative visible scampi density). Largest circle represents 0.03 visible scampi .m^{-2}. The scale is the same between Figure 9 and Figure 21.

Table 16: Estimates of the density and abundance of major burrow openings from the SCI 2 survey for 2018. Counts by each reader have been scaled by correction factors for *reader_year*. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Major burrows	702	703	802	803	Fishery	Bootstrap
Area (km^2)	321.41	543.59	386.11	230.54	1482	
Stations	8	21	10	8	47	
Mean density (.m^{-2})	0.1046	0.1085	0.1054	0.1467	0.1128	
CV	0.24	0.12	0.11	0.13	0.07	0.07
Abundance (millions)	33.58	59.05	40.68	33.90	167.21	166.19

Table 17: Estimates of the density and abundance of visible scampi from the SCI 2 survey for 2018. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Visible scampi	702	703	802	803	Fishery	Bootstrap
Area (km^2)	321.41	543.59	386.11	230.54	1482	
Stations	8	21	10	8	47	
Mean density (.m^{-2})	0.0365	0.0296	0.0398	0.0248	0.0330	
CV	0.33	0.17	0.12	0.24	0.11	0.10
Abundance (millions)	11.71	16.12	15.38	5.73	48.94	48.75

Table 18: Estimates of the density and abundance of scampi out of burrows from the SCI 2 survey for 2018. Scampi "out" were defined as those for which the telson was not obscured by the burrow. Bootstrap estimates of density and abundance (for the whole survey) based on median of 1000 sets of resampling stations within strata and reader within station.

Scampi out	702	703	802	803	Fishery	Bootstrap
Area (km^2)	321.41	543.59	386.11	230.54	1482	
Stations	8	21	10	8	47	
Mean density (.m^{-2})	0.0080	0.0022	0.0037	0.0019	0.0038	
CV	0.53	0.45	0.45	0.69	0.29	0.28
Abundance (millions)	2.57	1.18	1.42	0.44	5.61	5.61

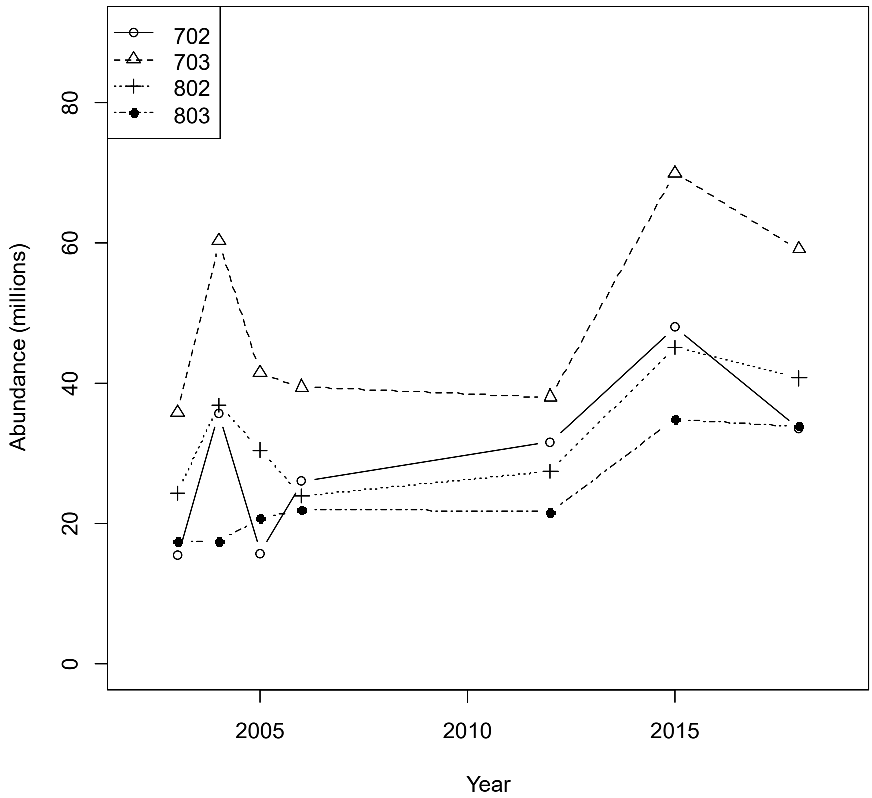

Figure 22: Estimated abundance of major scampi burrow openings for SCI 2 by strata.

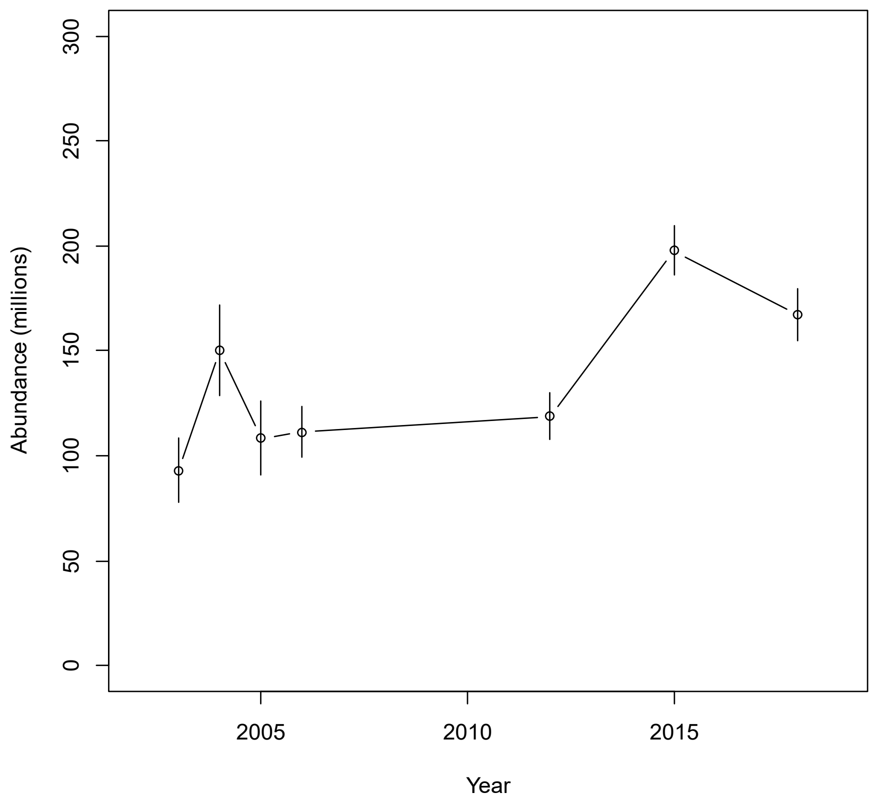

Figure 23: Estimated abundance of major scampi burrow openings (± CV) for SCI 2.

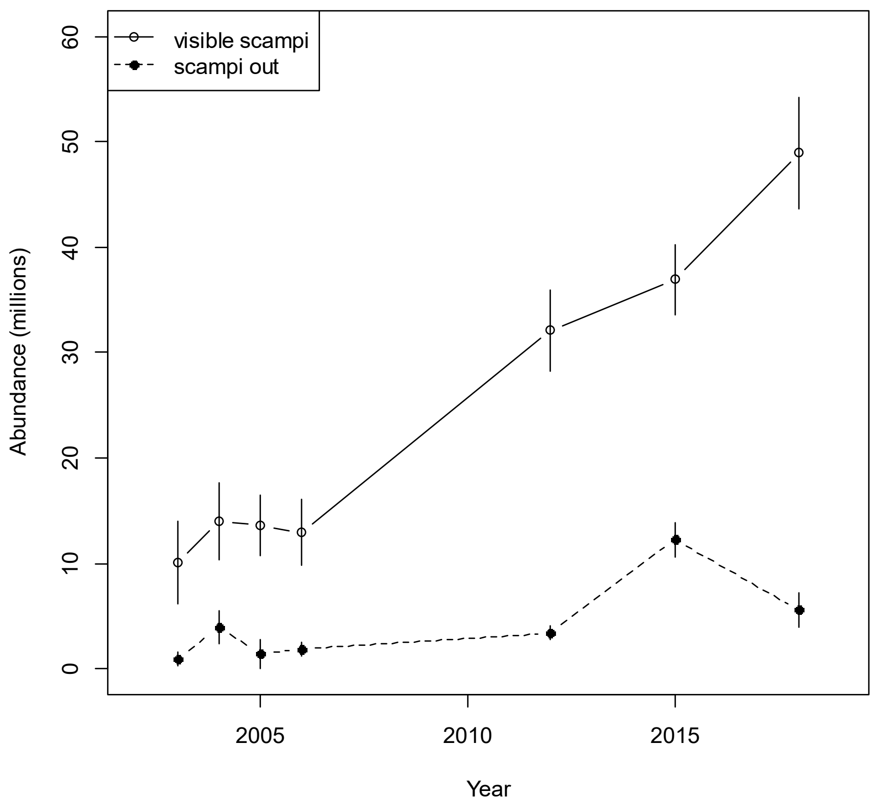

Figure 24: Estimated abundance of scampi (± CV) for SCI 2.

Table 19. Overall survey mean densities (m^{-2}) of major burrow openings, visible scampi and scampi out of burrows, for the series of SCI 2.

	Major opening	Visible scampi	Scampi "out"	Scampi as % of openings	% of visible scampi "out"
2003	0.0628	0.0068	0.0006	0.11	0.09
2004	0.1014	0.0094	0.0027	0.09	0.28
2005	0.0732	0.0092	0.0010	0.13	0.10
2006	0.0751	0.0087	0.0012	0.12	0.14
2012	0.0801	0.0217	0.0023	0.27	0.11
2015	0.1335	0.0249	0.0083	0.19	0.33
2018	0.1128	0.0330	0.0038	0.29	0.11

3.5 SCI 2 Trawl survey

The locations of trawl survey stations, and relative scampi catch rates, are shown in Figure 25. Biomass estimates are provided by strata for the 2018 survey in Table 20, and are compared with previous surveys estimated over the same strata in Table 22. Equivalent abundance estimates are provided for the 2018 survey in Table 21, and are compared with previous surveys in Table 23.

Table 20: Trawl survey estimates by strata for SCI 2. Mean values expressed as kg.nautical mile^{-1} with the *RV Kaharoa* scampi trawl gear.

	Stratum				
Strata	702	703	802	803	Total
Area (km^2)	321	544	386	231	1482
N. stations	7	4	5	4	20
Mean (kg.mile^{-1})	7.33	4.85	8.24	1.36	5.73
CV	0.25	0.51	0.61	0.18	0.29
Biomass (tonnes)	50.83	57.00	68.69	6.77	183.3

Table 21: Trawl survey estimates (abundance) by survey and stratum for SCI 2. Mean values expressed as numbers mile^{-1} with the *RV Kaharoa* scampi trawl gear.

	Stratum				
Strata	702	703	802	803	Total
Area (km^2)	321	544	386	231	1482
No. of stations	7	4	5	4	20
Mean (No. mile^{-1})	162.29	60.78	120.85	24.70	92.79
CV	0.24	0.45	0.54	0.19	0.23
Abundance (millions)	1.13	071	1.01	0.12	2.97

The overall raised trawl survey estimate was 183 tonnes (29% CV) (Table 20), or 3.0 million individuals (23% CV) (Table 21, Figure 27). Given that scampi live in burrows and are only available to trawl gear when they emerge on the seabed, this is likely to be a considerable underestimate of the stock biomass. This is a decrease (although not significantly) from the 2015 estimate (224 t, 19%

CV), and is also comparable with the 2012 estimate (164 t, 28% CV) and with the peak biomass estimates of the early to mid-1990s (Table 22 and Figure 26), and is significantly higher than the series of low biomass estimates observed in the mid-2000s. The trends in scampi abundance (in numbers) estimated from the trawl surveys follow very similar patterns to those shown by biomass (Table 23).

Over the whole SCI 2 trawl survey, 353 kg of scampi were caught, accounting for 3.7% of the total catch (9557 kg), with scampi being the seventh most abundant species. By weight, the predominant species caught were sea perch (27.0%), javelin fish (14.7%), hoki (10.2%), ling (6.1%), banded bellowsfish (4.2%), silver roughy (3.8%), and scampi (3.7%). As with SCI 1, within commercial fishing activities, scampi forms a greater proportion of the total catch, as bycatch mitigation approaches reduce finfish bycatch.

Table 22: Time series of raised trawl survey scampi stock estimates (tonnes) by survey strata for SCI 2. Time step relates to assessment model (see Tuck 2014), with surveys in December – January allocated to step 1, and those in February – April allocated to step 2.

	702	703	802	803	Total	Time step
1993	93.85	24.96	113.00	6.37	238.18	1
1994	83.19	40.20	44.89	1.77	170.05	1
1995	85.26	67.13	59.40	4.41	216.19	1
2000			36.23	49.29		1
2000			33.35	4.49		2
2003	3.72	8.25	8.65	7.42	28.05	2
2004	18.14	5.44	19.21	4.08	46.88	1
2005	9.93	17.23	19.21	4.41	50.78	2
2006	2.99	5.06	6.96	7.87	22.88	2
2012	83.53	18.47	52.75	9.39	164.15	2
2015	125.31	16.51	69.85	12.79	224.46	2
2018	50.83	57.00	68.69	6.77	183.3	2

Table 23: Time series of raised trawl survey scampi stock estimates (millions) by survey strata for SCI 2. Time step relates to assessment model (see Tuck 2014), with surveys in December – January allocated to step 1, and those in February – April allocated to step 2.

	702	703	802	803	Total	Time step
1993	1.89	0.70	2.28	0.11	4.97	1
1994	1.88	0.72	0.88	0.02	3.50	1
1995	1.46	1.13	1.02	0.15	3.75	1
2000			0.48	0.64		1
2000			0.80	0.13		2
2003	0.06	0.15	0.22	0.11	0.54	2
2004	0.42	0.08	0.49	0.08	1.06	1
2005	0.26	0.26	0.44	0.11	1.08	2
2006	0.20	0.24	0.17	0.15	0.76	2
2012	1.82	0.36	0.94	0.14	3.26	2
2015	2.40	0.22	0.90	0.16	3.68	2
2018	1.13	071	1.01	0.12	2.97	2

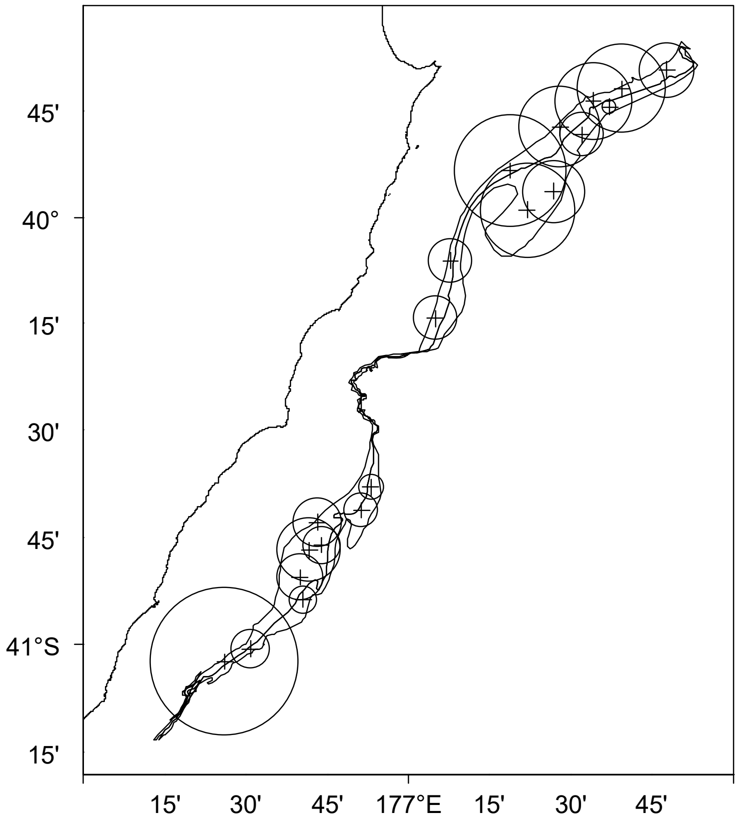

Figure 25: Trawl station locations for the 2018 survey of SCI 2 (size of symbol represents relative scampi catch rate). Largest circle represents 28.1 kg.mile^{-1}. The scale is the same between Figure 13 and Figure 25.

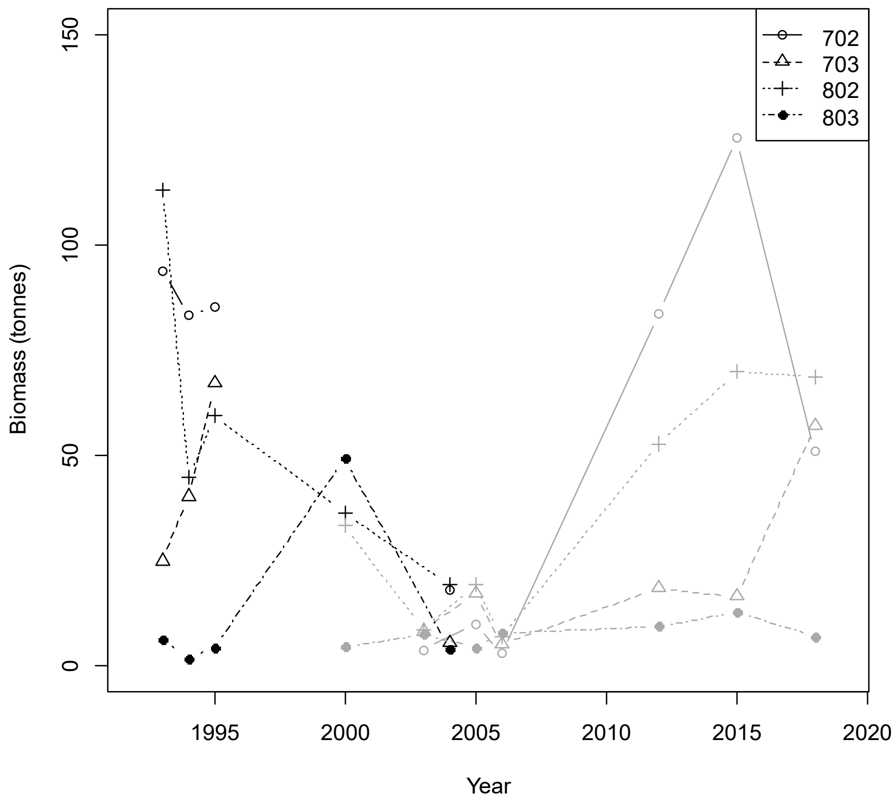

Figure 26: Plot of time series of trawl survey biomass estimates for SCI 2.

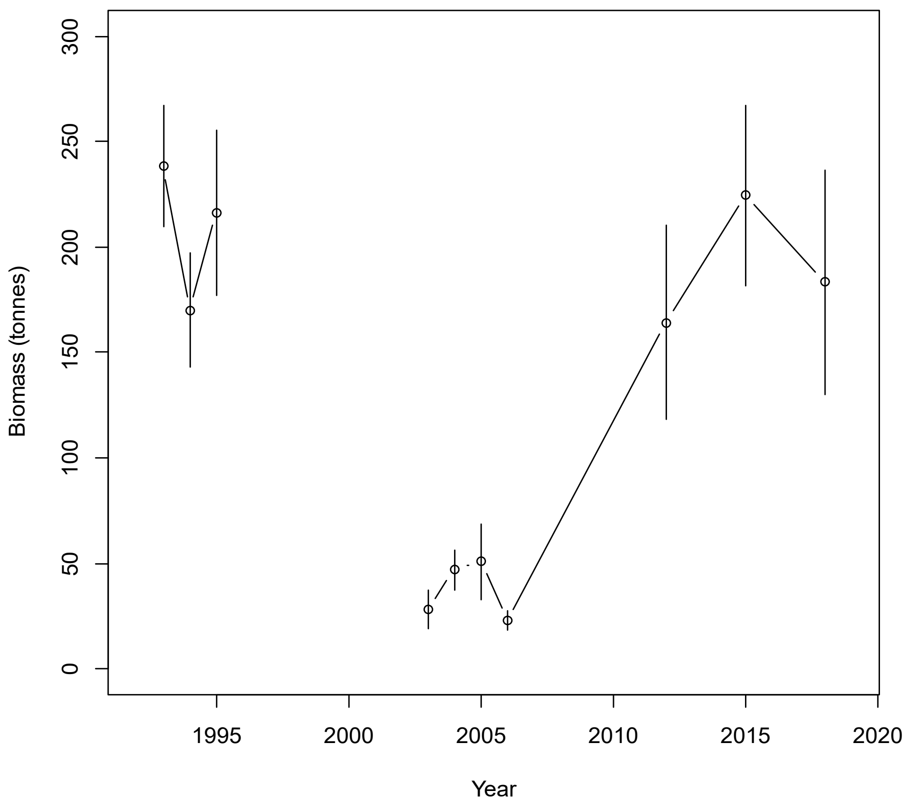

Figure 27: Plot of time series of trawl survey biomass estimates (± CV) for SCI 2.

3.6 SCI 2 Tagging

Undamaged active scampi were tagged from each trawl catch, and released for the growth investigation. The next scheduled research sampling in SCI 2 will be in 2021, and so it is anticipated that recoveries will be from commercial fishing activity. Over the SCI 2 component of the survey, just over 2950 scampi were tagged with either streamer (2285) or T-bar (666) tags, and were then released. Tagging did not target specific size ranges, and the length distribution of tagged animals reflects the size distribution of suitable animals from the catches. The length distributions of the tagged scampi are presented in Figure 28. As with SCI 1, the sex ratio of tagged scampi (and catches) was more even than previous surveys. The tagged scampi were released at 24 separate locations (Figure 29). No scampi were released while the vessel was fishing, and no recaptures were made by the *RV Kaharoa* during the survey. Tagging mortality was not investigated during this voyage (see Section 3.3).

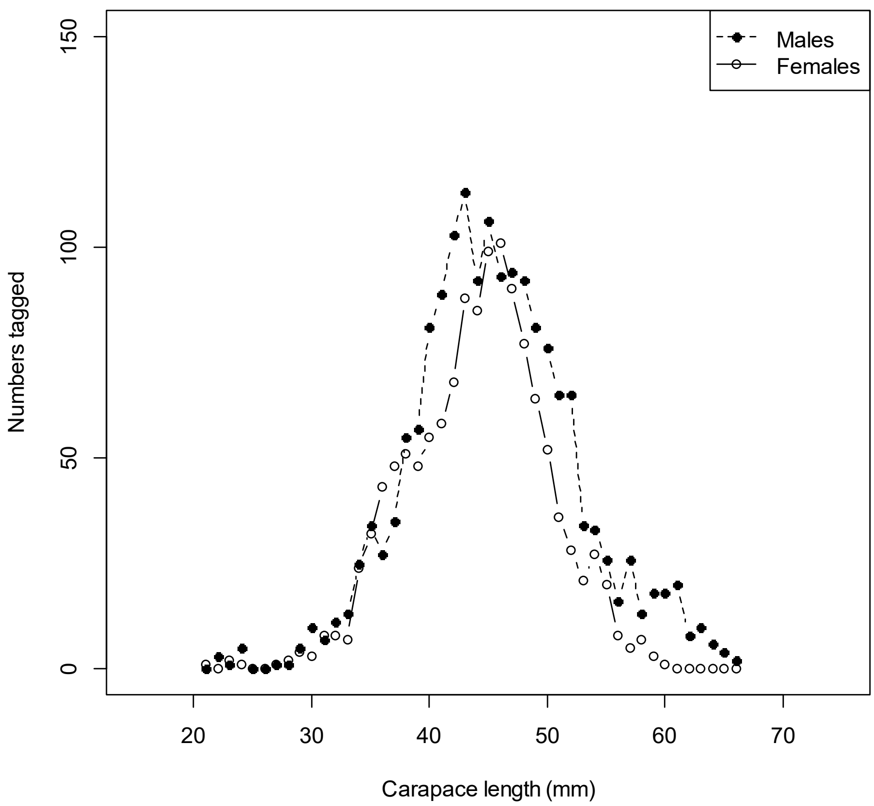

Figure 28: Length distribution of scampi tagged and released in SCI 2 during the 2018 voyage.

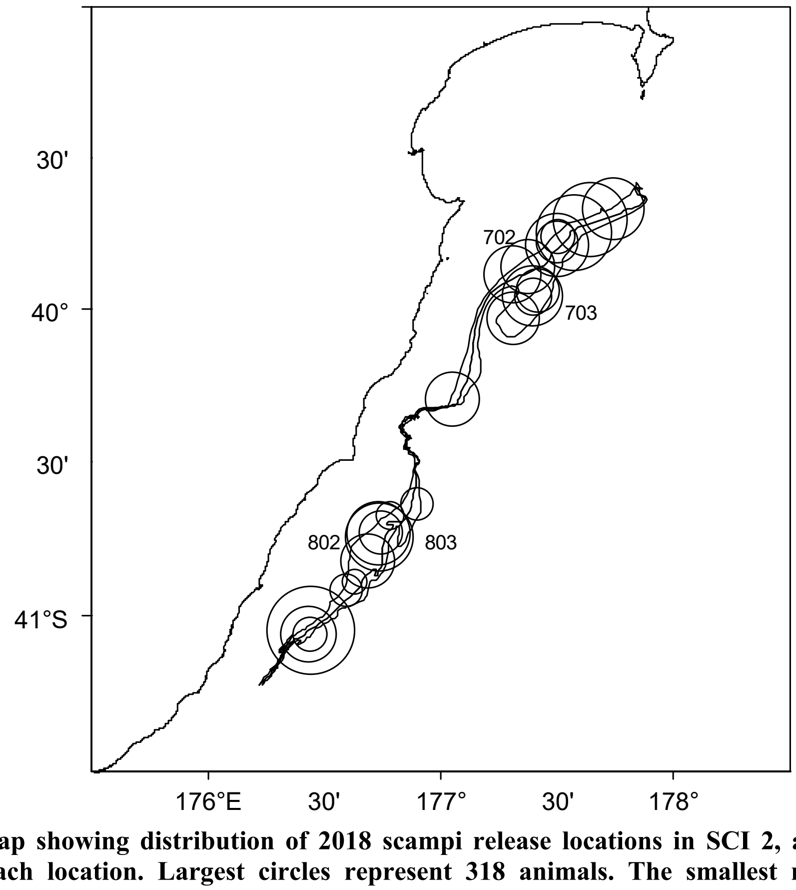

Figure 29: Map showing distribution of 2018 scampi release locations in SCI 2, and relative numbers released at each location. Largest circles represent 318 animals. The smallest release batch was 27 animals, and the average release batch was 123 animals

To date (January 2017) no recoveries have been reported to NIWA from SCI 2. The tag recovery rate from SCI 1 and SCI 2 has generally been low. The same tagging approach is used in all areas, and it is unclear why recovery rates are so different, although the colder surface waters in SCI 6A may contribute to increased survival.

4. CONCLUSIONS

A photographic and trawl survey of scampi in SCI 1 and SCI 2 was conducted in February and March 2018, replicating the coverage of the 2012 surveys, but with greater emphasis on the trawl component, and an increase in sampling effort in SCI 2 (in an attempt to minimise the CV across the combined survey area). For SCI 1, the photographic survey estimated a scampi burrow abundance of 217 million over the whole area, an increase from what appears to have been a relatively stable abundance from 2004 to 2015 (~150 million). Trawl survey catch rates in SCI 1 have remained relatively stable since the early 2000s, and the 2018 biomass estimate was 188 tonnes (21% CV). For SCI 2, the photographic survey estimated a scampi burrow abundance of 166 million over the whole area, declining from the largest estimate in the series in 2015 (197 million), but remaining above estimates prior to 2015. Trawl survey catch rates in SCI 2 remain comparable with the 2012 and 2015 estimates, and estimates in the mid-1990s, and are significantly greater than estimates from the mid-2000s. Scampi biomass over the whole SCI 2 survey area was 183 tonnes (29% CV) in 2018. Given that scampi live in burrows and are only available to trawl gear when they emerge on the seabed, these are likely to be considerable underestimates of the stock biomass.

Over the two surveys over 6600 scampi were tagged and released, as part of an investigation into growth, but to date, only two scampi have been recaptured.

5. ACKNOWLEDGEMENTS

This work would not have been possible without the advice and cooperation of the skipper and the crew of the *RV Kaharoa*. Derrick Parkinson led the voyage. We thank the EPA for their help in complying with the requirements of the Exclusive Economic Zone and Continental Shelf Regulations 2013. Scampi tag recoveries have been made and reported to NIWA by the fishing industry. The voyage was funded within Fisheries New Zealand project SCI2017-01. This report was reviewed by Bruce Hartill.

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7. APPENDIX 1: SCI 1 Summary of photo survey workup

Uncorrected analysis

1998

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.1116	0.1784	0.1276	0.0992	0.1285
CV	0.35	0.29	0.29	0.18	0.15
Millions	29.24	47.46	48.51	28.77	153.97
Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0280	0.0247	0.0278	0.0124	0.0234
CV	0.57	0.24	0.30	0.49	0.22
Millions	7.33	6.58	10.56	3.59	28.05
Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0212	0.0093	0.0073	0.0012	0.0093
CV	0.75	0.43	0.49	Div 0	0.43
Millions	5.55	2.48	2.77	0.36	11.16

Uncorrected analysis

2000

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	4	5	5	5	19
Mean (/sq m)	0.0984	0.0995	0.0708	0.0517	0.0786
CV	0.25	0.23	0.25	0.24	0.12
Millions	25.78	26.46	26.92	14.98	94.13
Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	4	5	5	5	19
Mean (/sq m)	0.0212	0.0142	0.0177	0.0074	0.0152
CV	0.28	0.23	0.38	0.50	0.18
Millions	5.54	3.79	6.74	2.15	18.22
Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	4	5	5	5	19
Mean (/sq m)	0.0071	0.0096	0.0077	0.0028	0.0068
CV	0.40	0.41	0.52	0.61	0.25
Millions	1.87	2.55	2.92	0.81	8.14

Uncorrected analysis

2001

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.1347	0.1209	0.0902	0.1061	0.1106
CV	0.29	0.15	0.31	0.07	0.12
Millions	35.30	32.17	34.27	30.76	132.50
Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0152	0.0066	0.0099	0.0096	0.0102
CV	0.39	0.21	0.36	0.92	0.27
Millions	3.98	1.76	3.75	2.78	12.27
Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0036	0.0005	0.0000	0.0030	0.0016
CV	0.64	0	0	1.00	0.55
Millions	0.95	0.14	0.00	0.86	1.95

Uncorrected analysis

2002

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	8	7	7	5	27
Mean (/sq m)	0.0787	0.1452	0.1076	0.1262	0.1141
CV	0.12	0.09	0.16	0.18	0.08
Millions	20.63	38.62	40.90	36.60	136.74

Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	8	7	7	5	27
Mean (/sq m)	0.0075	0.0182	0.0163	0.0102	0.0133
CV	0.28	0.27	0.43	0.53	0.21
Millions	1.96	4.85	6.19	2.96	15.96

Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	8	7	7	5	27
Mean (/sq m)	0.0010	0.0016	0.0039	0.0002	0.0018
CV	0.68	0.54	0.84	Div 0	0.57
Millions	0.25	0.42	1.47	0.06	2.20

Uncorrected analysis

2003

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0764	0.1318	0.0702	0.0704	0.0853
CV	0.30	0.17	0.19	0.38	0.12
Millions	20.03	35.05	26.67	20.42	102.16

Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0174	0.0130	0.0088	0.0107	0.0121
CV	0.39	0.38	0.42	0.50	0.21
Millions	4.55	3.45	3.36	3.10	14.46

Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0010	0.0023	0.0018	0.0006	0.0015
CV	1.00	0.71	0.67	1.00	0.41
Millions	0.27	0.62	0.67	0.19	1.75

Uncorrected analysis

2008

Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	10	9	10	10	39
Mean (/sq m)	0.0898	0.0935	0.0826	0.0698	0.0835
CV	0.13	0.16	0.15	0.15	0.08
Millions	23.53	24.87	31.39	20.23	100.02

Scampi	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	10	9	10	10	39
Mean (/sq m)	0.0132	0.0164	0.0080	0.0066	0.0107
CV	0.27	0.16	0.37	0.27	0.13
Millions	3.47	4.35	3.04	1.90	12.76

Out	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	10	9	10	10	39
Mean (/sq m)	0.0016	0.0055	0.0027	0.0007	0.0026
CV	0.91	0.31	0.67	0.89	0.30
Millions	0.42	1.47	1.04	0.21	3.15

Uncorrected analysis

2012

Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	9	11	10	10	11	9	40	60
Mean (/sq m)	0.0828	0.0654	0.0654	0.0943	0.0711	0.0882	0.0791	0.0774
CV	0.16	0.17	0.17	0.11	0.11	0.16	0.07	0.06
Millions	25.42	20.33	17.12	25.08	27.02	25.57	94.80	140.55
Scampi	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	9	11	10	10	11	9	40	60
Mean (/sq m)	0.0105	0.0146	0.0149	0.0149	0.0238	0.0246	0.0201	0.0175
CV	0.35	0.21	0.23	0.18	0.14	0.22	0.10	0.09
Millions	3.22	4.55	3.90	3.97	9.05	7.12	24.05	31.82
Out	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	9	11	10	10	11	9	40	60
Mean (/sq m)	0.0013	0.0035	0.0027	0.0027	0.0079	0.0018	0.0042	0.0036
CV	0.61	0.45	0.58	0.44	0.33	0.60	0.24	0.20
Millions	0.41	1.09	0.71	0.72	3.02	0.54	4.98	6.49

Uncorrected analysis

2015

Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	11	12	9	7	10	11	37	60
Mean (/sq m)	0.0882	0.0942	0.0605	0.1140	0.1034	0.0995	0.0954	0.0940
CV	0.10	0.07	0.11	0.05	0.16	0.08	0.06	0.05
Millions	27.08	29.29	15.85	30.32	39.28	28.87	114.31	170.69
Scampi	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	11	12	9	7	10	11	37	60
Mean (/sq m)	0.0059	0.0116	0.0101	0.0117	0.0172	0.0195	0.0150	0.0129
CV	0.21	0.17	0.33	0.22	0.26	0.24	0.14	0.11
Millions	1.81	3.60	2.64	3.12	6.55	5.67	17.98	23.39
Out	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	11	12	9	7	10	11	37	60
Mean (/sq m)	0.0008	0.0022	0.0011	0.0014	0.0049	0.0055	0.0034	0.0028
CV	0.57	0.48	0.52	0.67	0.53	0.42	0.30	0.26
Millions	0.25	0.68	0.29	0.37	1.87	1.59	4.12	5.05

Uncorrected analysis

2018

Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	5	6	4	4	9	5	22	33
Mean (/sq m)	0.0537	0.1626	0.0858	0.1797	0.1470	0.1453	0.1404	0.1295
CV	0.27	0.15	0.14	0.10	0.10	0.17	0.04	0.06
Millions	16.50	50.56	22.47	47.79	55.55	42.13	167.94	234.99
Scampi	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	5	6	4	4	9	5	22	33
Mean (/sq m)	0.0077	0.0269	0.0147	0.0490	0.0340	0.0538	0.0379	0.0309
CV	0.51	0.17	0.40	0.10	0.14	0.18	0.06	0.08
Millions	2.35	8.37	3.84	13.05	12.84	15.59	45.32	56.05
Out	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	5	6	4	4	9	5	22	33
Mean (/sq m)	0.0026	0.0027	0.0071	0.0112	0.0078	0.0061	0.0080	0.0062
CV	1.00	0.92	0.36	0.26	0.48	1.00	0.17	0.24
Millions	0.81	0.83	1.85	2.97	2.96	1.76	9.54	11.19

Reader_year corrected analysis

1998					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.1167	0.1857	0.1238	0.0960	0.1293
CV	0.35	0.29	0.29	0.18	0.15
Millions	30.58	49.41	46.80	27.84	154.63

Reader_year corrected analysis

2000					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	4	5	5	5	19
Mean (/sq m)	0.1024	0.1033	0.0725	0.0522	0.0810
CV	0.25	0.23	0.25	0.24	0.13
Millions	26.83	27.47	27.39	15.13	96.83

Reader_year corrected analysis

2001					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.1387	0.1256	0.0918	0.1086	0.1137
CV	0.29	0.15	0.31	0.07	0.12
Millions	36.33	33.42	34.71	31.49	135.95

Reader_year corrected analysis

2002					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	8	7	7	5	27
Mean (/sq m)	0.0748	0.1397	0.1025	0.1145	0.1076
CV	0.12	0.09	0.16	0.18	0.08
Millions	19.61	37.15	38.76	33.19	128.71

Reader_year corrected analysis

2003					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	5	5	5	5	20
Mean (/sq m)	0.0779	0.1263	0.0717	0.0686	0.0844
CV	0.30	0.17	0.19	0.38	0.12
Millions	20.41	33.58	27.09	19.88	100.97

Reader_year corrected analysis

2008					
Major	302	303	402	403	Fishery
Area (sq km)	262	266	380	290	1198
Count (stations)	10	9	10	10	39
Mean (/sq m)	0.0991	0.1070	0.0892	0.0747	0.0918
CV	0.14	0.17	0.14	0.15	0.08
Millions	25.95	28.45	33.73	21.65	109.79

Reader_year corrected analysis

2012								
Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	9	11	10	10	11	9	40	60
Mean (/sq m)	0.0957	0.0724	0.0698	0.1029	0.0789	0.0985	0.0870	0.0859
CV	0.16	0.17	0.16	0.10	0.11	0.14	0.04	0.06
Millions	29.37	22.52	18.29	27.36	29.81	28.56	104.02	155.91

Reader_year corrected analysis

2015

Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	11	12	9	7	10	11	37	60
Mean (/sq m)	0.0799	0.0845	0.0547	0.1012	0.0929	0.0891	0.0855	0.0844
CV	0.11	0.07	0.12	0.05	0.16	0.07	0.04	0.05
Millions	24.54	26.28	14.33	26.93	35.10	25.84	102.21	153.02

Reader_year corrected analysis

2018

Major	202	203	302	303	402	403	302-403	Fishery
Area (sq km)	307	311	262	266	380	290	1198	1816
Count (stations)	5	6	4	4	9	5	22	33
Mean (/sq m)	0.0488	0.1524	0.0814	0.1585	0.1349	0.1385	0.1293	0.1196
CV	0.24	0.14	0.13	0.10	0.09	0.15	0.04	0.05
Millions	14.97	47.39	21.33	42.17	51.00	40.17	154.67	217.03

8. APPENDIX 2: SCI 2 Summary of photo survey workup

Uncorrected analysis

2003					
Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	5	5	4	5	19
Mean (/sq m)	0.0543	0.0733	0.0857	0.0939	0.0756
CV	0.36	0.31	0.27	0.28	0.16
Millions	17.42	39.87	33.09	21.69	112.07
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	5	5	4	5	19
Mean (/sq m)	0.0054	0.0074	0.0074	0.0061	0.0068
CV	0.42	0.88	0.44	0.35	0.39
Millions	1.74	4.05	2.84	1.41	10.04
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	5	5	4	5	19
Mean (/sq m)	0.0000	0.0012	0.0000	0.0014	0.0006
CV	0.00	1.00	0.00	1.00	0.74
Millions	0.00	0.63	0.00	0.32	0.95

Uncorrected analysis

2004					
Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	8	11	5	32
Mean (/sq m)	0.0989	0.0966	0.0774	0.0558	0.0857
CV	0.21	0.19	0.37	0.41	0.13
Millions	31.74	52.54	29.88	12.89	127.05
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	8	11	5	32
Mean (/sq m)	0.0127	0.0151	0.0035	0.0015	0.0094
CV	0.41	0.38	0.64	1.00	0.26
Millions	4.06	8.23	1.34	0.35	13.99
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	8	11	5	32
Mean (/sq m)	0.0040	0.0034	0.0022	0.0000	0.0027
CV	0.71	0.50	1.00	0.00	0.39
Millions	1.28	1.83	0.83	0.00	3.94

Uncorrected analysis

2005					
Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0488	0.0530	0.0880	0.0826	0.0658
CV	0.21	0.36	0.23	0.20	0.14
Millions	15.68	28.82	33.97	19.08	97.54
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0071	0.0136	0.0081	0.0034	0.0092
CV	0.20	0.33	0.37	0.65	0.21
Millions	2.28	7.38	3.11	0.80	13.57
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0000	0.0026	0.0000	0.0000	0.0010
CV	0.00	1.00	0.00	0.00	1.00
Millions	0.00	1.41	0.00	0.00	1.41

Uncorrected analysis

2006

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0763	0.0542	0.0524	0.0698	0.0610
CV	0.21	0.14	0.25	0.30	0.10
Millions	24.51	29.49	20.21	16.12	90.33
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0122	0.0060	0.0075	0.0124	0.0087
CV	0.61	0.31	0.27	0.53	0.24
Millions	3.92	3.29	2.89	2.86	12.95
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0018	0.0008	0.0013	0.0012	0.0012
CV	0.55	0.67	0.57	1.00	0.33
Millions	0.59	0.45	0.52	0.28	1.84

Uncorrected analysis

2012

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	14	15	6	43
Mean (/sq m)	0.0807	0.0706	0.0654	0.0889	0.0743
CV	0.16	0.23	0.16	0.22	0.11
Millions	25.91	38.42	25.24	20.53	110.09
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	14	15	6	43
Mean (/sq m)	0.0258	0.0185	0.0221	0.0228	0.0217
CV	0.21	0.26	0.21	0.23	0.12
Millions	8.28	10.05	8.52	5.27	32.11
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	14	15	6	43
Mean (/sq m)	0.0020	0.0018	0.0030	0.0027	0.0023
CV	0.40	0.42	0.28	0.58	0.20
Millions	0.64	0.95	1.17	0.63	3.39

Uncorrected analysis

2015

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	18	9	5	39
Mean (/sq m)	0.1468	0.1289	0.1162	0.1563	0.1338
CV	0.09	0.11	0.11	0.25	0.07
Millions	47.13	70.15	44.87	36.11	198.25
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	18	9	5	39
Mean (/sq m)	0.0422	0.0120	0.0297	0.0235	0.0249
CV	0.13	0.17	0.14	0.37	0.09
Millions	13.55	6.51	11.46	5.43	36.96
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	18	9	5	39
Mean (/sq m)	0.0205	0.0025	0.0098	0.0023	0.0083
CV	0.20	0.34	0.20	0.44	0.13
Millions	6.59	1.34	3.79	0.53	12.24

Uncorrected analysis

2018					
Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	21	10	8	47
Mean (/sq m)	0.1333	0.1381	0.1310	0.1819	0.1420
CV	0.26	0.12	0.11	0.14	0.08
Millions	42.78	75.12	50.58	42.02	210.50
Scampi	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	21	10	8	47
Mean (/sq m)	0.0365	0.0296	0.0398	0.0248	0.0330
CV	0.33	0.17	0.12	0.24	0.11
Millions	11.71	16.12	15.38	5.73	48.94
Out	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	21	10	8	47
Mean (/sq m)	0.0080	0.0022	0.0037	0.0019	0.0038
CV	0.53	0.45	0.45	0.69	0.29
Millions	2.57	1.18	1.42	0.44	5.61

Reader_year corrected analysis

2003

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	5	5	4	5	19
Mean (/sq m)	0.0485	0.0657	0.0631	0.0755	0.0628
CV	0.36	0.31	0.27	0.28	0.16
Millions	15.55	35.75	24.34	17.45	93.09

Reader_year corrected analysis

2004

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	8	11	5	32
Mean (/sq m)	0.1109	0.1108	0.0956	0.0757	0.1014
CV	0.21	0.19	0.37	0.41	0.14
Millions	35.61	60.25	36.90	17.48	150.25

Reader_year corrected analysis

2005

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0490	0.0763	0.0789	0.0898	0.0732
CV	0.21	0.36	0.23	0.20	0.16
Millions	15.74	41.50	30.47	20.74	108.46

Reader_year corrected analysis

2006

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	9	7	6	29
Mean (/sq m)	0.0811	0.0724	0.0619	0.0952	0.0751
CV	0.21	0.14	0.24	0.30	0.11
Millions	26.04	39.39	23.88	21.99	111.29

Reader_year corrected analysis

2012

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	14	15	6	43
Mean (/sq m)	0.0984	0.0699	0.0711	0.0938	0.0801
CV	0.18	0.20	0.15	0.17	0.09
Millions	31.58	38.03	27.45	21.67	118.73

Reader_year corrected analysis

2015

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	7	18	9	5	39
Mean (/sq m)	0.1494	0.1284	0.1169	0.1510	0.1335
CV	0.07	0.10	0.09	0.23	0.06
Millions	47.96	69.85	45.11	34.89	197.82

Reader_year corrected analysis

2018

Major	702	703	802	803	Fishery
Area (sq km)	321	544	386	231	1482
Count (stations)	8	21	10	8	47
Mean (/sq m)	0.1046	0.1085	0.1054	0.1467	0.1128
CV	0.24	0.12	0.11	0.13	0.07
Millions	33.58	59.05	40.68	33.90	167.21