Ministry for Primary Industries
Manatū Ahu Matua

Estimating the abundance of scampi in SCI 6A (Auckland Islands) in 2016

New Zealand Fisheries Assessment Report 2017/06

I.D. Tuck,
D. Parkinson,
H. Armiger,
M. Smith
A. Miller
N. Rush,
K. Spong

ISSN 1179-5352 (online)
ISBN 978-1-77665-477-2 (online)

January 2017

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

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

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Tuck, I.D.; Parkinson, D.; Armiger, H.; Smith, M.; Miller, A.; Rush, N.; Spong, K. (2017). Estimating the abundance of scampi in SCI 6A (Auckland Islands) in 2016.

***New Zealand Fisheries Assessment Report 2017/06.* 36 p.**

Photographic and trawl surveys of scampi in SCI 6A was conducted in February and March 2016 from the RV *Kaharoa*. This area was last surveyed in 2013. The photographic survey component was completed first, followed by the trawl survey component. The photographic survey estimated a scampi burrow abundance of 145 million over the whole area; a slight increase on the 2013 estimate. The photographic survey of visible scampi also showed an increase on the 2013 estimate. The trawl survey estimate of 593 tonnes (or 8.2 million individuals) reflects a marked reduction from the 2013 estimate, but it is unclear how comparable the 2016 estimates are with the previous series, owing to an unavoidable vessel and gear change. 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.

Almost 3900 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 2014/15 were 875 t (limit 1231 t). The landings for scampi in SCI 6A were 102 t in 2014/15, and have been markedly below the 306 t TACC since 2009/10. The other major fisheries are SCI 1 (TACC 120 t), SCI 2 (TACC 133 t), SCI 3 (TACC 340 t), and SCI 4A (TACC 120 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 they emerge 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). 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. Four previous surveys have been conducted in SCI 6A (2007 – 2009, and 2013) (Tuck et al. 2007; Tuck et al. 2009a; Tuck et al. 2009b; Tuck et al. 2015). Longer survey series are available for SCI 1 (1998 – 2015, eight surveys), SCI 2 (2003 – 2015, six surveys), and SCI 3 (2001 – 2013, 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, SCI 2, and SCI 3 (Tuck & Dunn 2012; Tuck 2014; 2016), although the relationship between scampi and burrows may be different in SCI 6A (Tuck et al. 2007; Tuck & Dunn 2009), and the index of visible scampi was used in the most recent (unaccepted) assessment for SCI 6A (Tuck 2015).

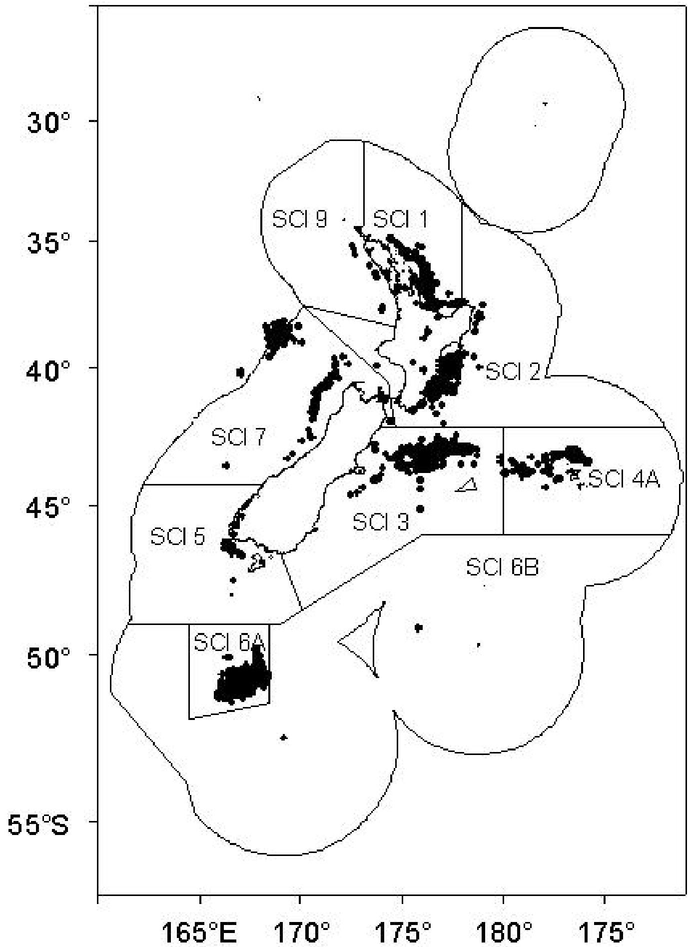


Figure 1: Spatial distribution of the scampi fishery since 1988–89 (ungroomed data). Each dot shows the mid-point of one or more tows recorded on TCEPR with scampi as the target species.

OVERALL OBJECTIVE: To estimate the abundance of scampi (*Metanephrops challengeri*) in SCI 6A.

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 MPI Shellfish Working Group and submitted to MPI in early 2016, and follows the design of the 2013 survey. The survey coverage for both trawl and photographic surveys in SCI 6A have remained consistent over the time series (except for an additional area to the north east that was only surveyed in 2007), but stratification has changed within this overall coverage as improved bathymetric data have become available. The present survey coverage accounts for over 90% of scampi landings from SCI 6A over the history of the fishery, and almost 100% in more recent years. The survey was undertaken from the NIWA research vessel *Kaharoa* in February–April 2016. Previous surveys have been undertaken from the Sanford Ltd scampi trawler *San Tongariro*, but this vessel is no longer available. There should be no effect on the photographic survey component of the work (the photographic data is independent of the platform the system is deployed from), but the trawling component of the survey is likely to be affected by the vessel and trawl change. Net diagrams and other comparisons of the *San Tongariro* and *Kaharoa* trawl gears (as used on scampi surveys) are provided in Appendix 1.

Following previous survey designs, a random stratified survey was conducted, with stratification on the basis of depth (50 m bands) and general region. Survey coverage and strata are shown in Figure 2.

Stations were allocated to strata on the basis of burrow abundance data from the 2013 surveys using the *allocate* package (Francis 2006), minimising the CV 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. The first three random photographic stations from each stratum were taken as trawl stations, with the minimum distance between each trawl station checked, and a station dropped as a trawl station and the next on the list selected if the distance was less than 4 nautical miles. Numbers of stations allocated to each stratum and planned station locations are provided in Table 1 and Figure 3.

Table 1: Details of strata and number of stations planned for SCI 6A in 2016.

Stratum	Depth (m)	Area (km^2)	Photo stations	Trawl stations
350	350–400	278	3	3
400N	400–450	789	5	3
400S	400–450	752	4	3
450N	450–500	1216	12	3
450S	450–500	1348	13	3
500	500–550	514	3	3

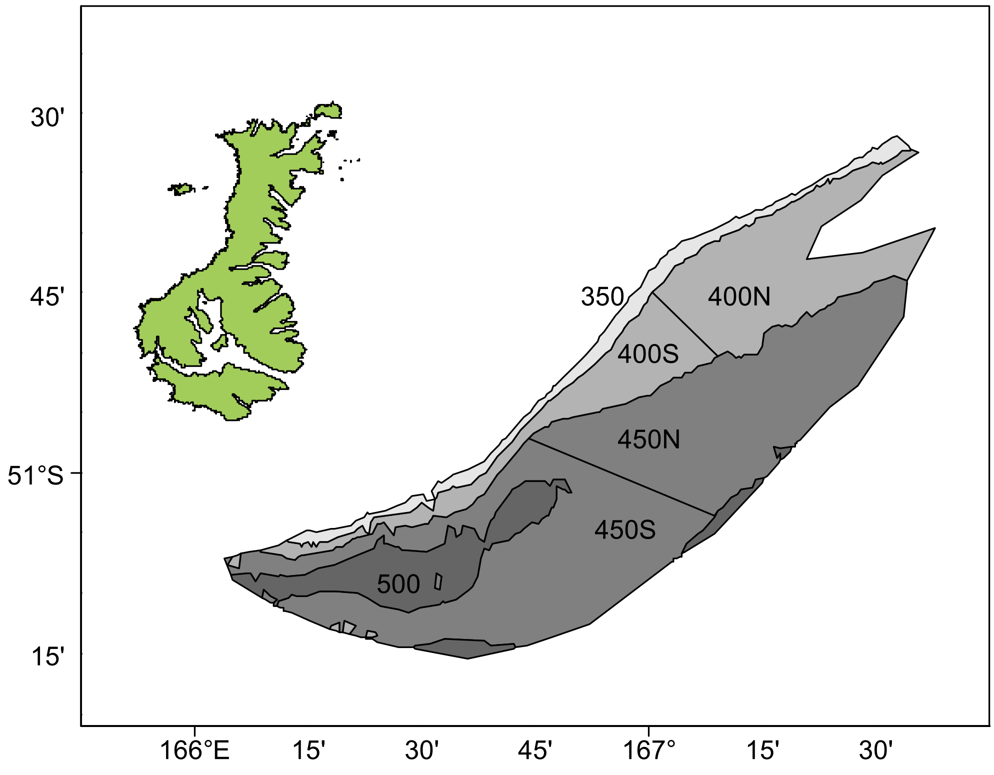


Figure 2: Survey strata for the 2016 photographic survey of SCI 6A.

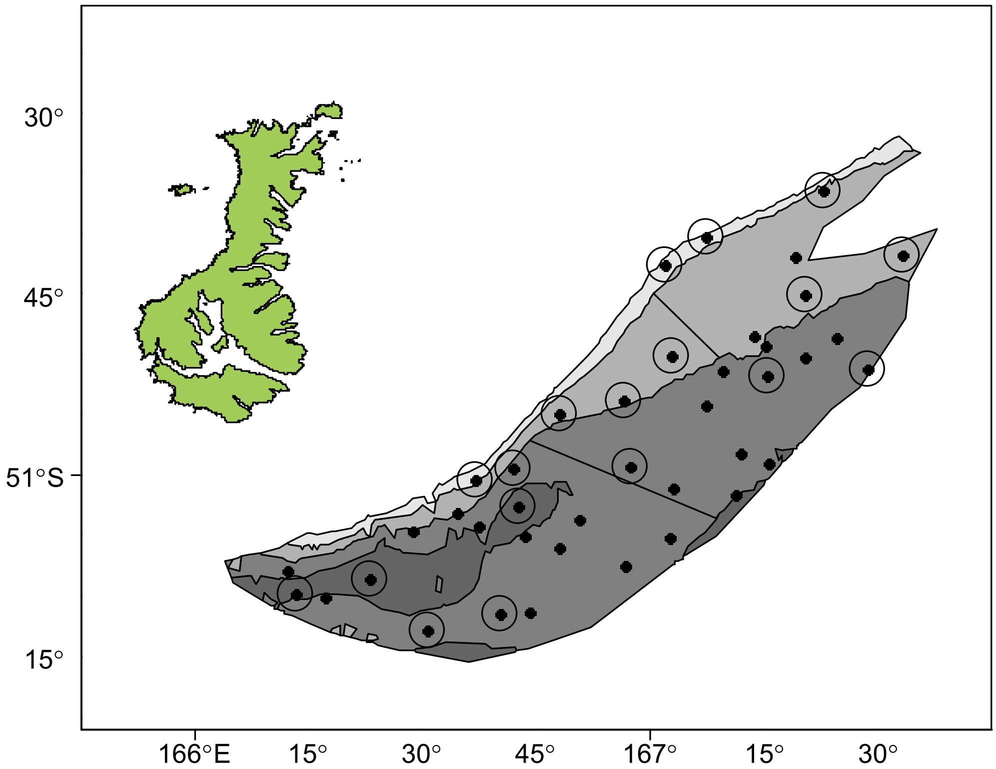


Figure 3: Station locations within each strata for 2016 survey for SCI 6A. Camera stations represented by strata label. Trawl stations represented by open symbol.

2.1 Photographic survey

As discussed above, a target of 40 photographic stations was set, on the basis of survey duration, and these were allocated to strata using the *allocate* package in R (to minimise the overall survey CV), on the basis of burrow densities observed in the 2013 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 provides a useful scampi index, and has two further 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 to 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 bottom 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 roughly 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, but at some stations a substantial swell hindered the maintenance of the critical altitude off the bottom, 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 (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 respectively as, 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. A recent 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 were not "characteristic", were 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 burrows because burrows 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 were, of necessity, partially subjective; we could not 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 assessed each potential burrow opening (paying more attention to attributes with a high ranking such as surface tracks, sediment fans, a shallow descent angle) and scored it only if it is "probably" a scampi burrow. Scores are 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 are individually identifiable within each image, providing an audit trail.

Once the images from any particular stratum or survey have 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 are 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 is 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 is a means of maintaining consistency among readers as well as refining the counts for a given image.

Reader and year calibration
To enable comparison of the 2016 survey data with previous surveys, the reference sets for SCI 6A (generated in 2008, and including images from 2007)(Tuck et al. 2009b), and augmented with images from 2008 in 2009 (Tuck et al. 2009a) and 2009 in 2013 (Tuck et al. 2015), and 2013 for the current analysis, was reread in 2016 (at the same time as the 2016 survey images), with each image in each reference set being read by all six readers, using the standard image scoring and re-reading procedure.

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. Interaction terms were created for reader_year (combination of reader and the year in which the image was read), strata_year (combination of survey strata and year the image was recorded in) and station_year (combination of station number and survey year). Burrow and scampi count data from individual images were aggregated at the station (or appropriate combination of reference set images) level and examined within a generalised linear mixed modelling framework, with strata_year, reader_year and readable area (offset) as explanatory variables, and station_year as random effects, with an assumed Poisson error distribution. The significance of terms was tested by sequentially dropping terms from a full model.

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). 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) for each station.

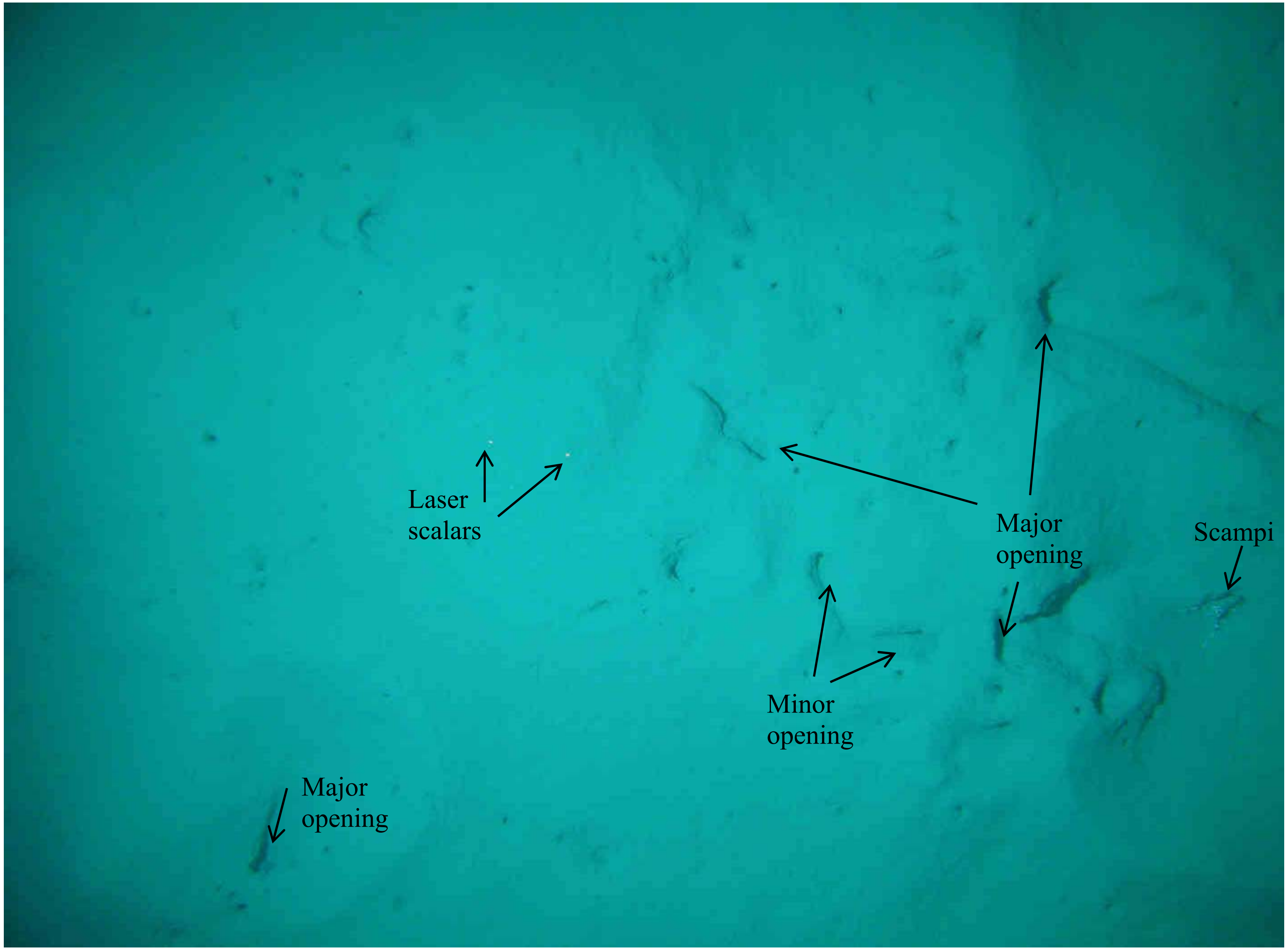


Figure 4: Example image from March 2006 survey in SCI 2 showing laser scaling dots, several characteristic scampi burrows and one large visible scampi.

2.2 Trawl survey

Trawl survey sampling was undertaken between 0600 and 1800 NZST, during the second half of the voyage, after the photographic survey had been completed. The first three random photographic stations allocated to each stratum were reselected as trawl stations. Trawl sampling was conducted with the *RV Kaharoa* scampi trawl, as with previous scampi surveys from this vessel (Cryer et al. 2003b; 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 during 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 seawater. Any animals with carapace punctures were excluded, and for tagged animals, 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 with sequentially numbered streamer tags (Hallprint type 4S, Figure 5), Hallprint T-bar tags, or both. The streamer tags have been used successfully in previous scampi studies (Cryer & Stotter 1997; 1999; Tuck & Dunn 2012), although tag return data suggest that some tag loss may be occurring at the moult, and a T-bar tag approach was therefore also used for this survey. Previous tagging investigations from recent surveys in this fishery have had good recoveries. The next scheduled research sampling in SCI 6A will be in 2019, and so it is anticipated that recoveries will be from commercial fishing activity. Tag mortality has been examined previously in this fishery (Tuck et al. 2015), but at the request of MPI and the Shellfish Working Group, no tag mortality component was included in this survey, as it was considered very unlikely that tag recapture data would be used to estimate stock size for this fishery.

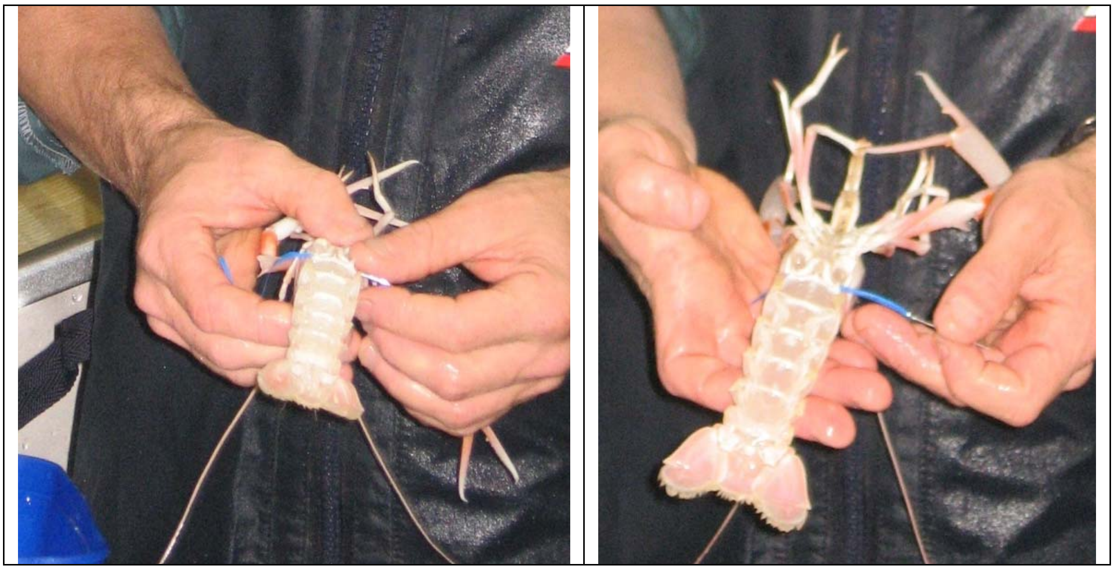


Figure 5: Photographs showing location of streamer tag in scampi.

3. RESULTS

The voyage was completed successfully between 22nd February and 1st April 2016. All photographic stations and trawl stations were completed, despite very poor weather during some parts of the voyage, with ten days being lost.

3.1 Photographic survey

Visibility was generally very good, but large swells throughout the survey meant that it was difficult to maintain the camera at a consistent altitude above the seabed. This meant that at some stations the target of 40 images per station was not met, despite running longer transects, as some images were taken from too high above the seabed to be considered useable. This has consistently been a problem for surveys in SCI 6A. Over the whole survey, a total area of 10 024 m^2 of seabed was viewed (acceptable quality images), with an average of 28.6 images per station, an average seabed area viewed by each image of 8.76 m^2, providing an average area viewed of 250.60 m^2 at each station. Previous surveys in SCI 6A have had an average viewed area per station of 207–315 m^2. All planned photographic stations were achieved (Table 2).

Table 2: Details of strata and number of photo stations completed for SCI 6A survey in 2016.

			Photo stations	
Stratum	Depth (m)	Area (km^2)	Planned	Completed
350	350–400	278	3	3
400N	400–450	789	5	5
400S	400–450	752	4	4
450N	450–500	1216	12	12
450S	450–500	1348	13	13
500	500–550	514	3	3

The image count data (including reference set counts) from the 2016 survey were combined with the previous data into a single dataset, and analysed within a generalised linear mixed modelling (GLMM) framework, with stratum_year, reader_year and readable area (offset) as explanatory variables, and image and station_year as random effects, and a Poisson error distribution. Models were examined for the counts of major burrow openings, and visible scampi.

For major burrow openings, a model testing the null hypotheses that there were no stratum_year or reader_year differences between burrow counts over time, detected highly significant effects (both considered as factors) (Table 3). Diagnostic plots for the model are shown in Figure 6.

Table 3: Analysis of deviance for a generalised linear mixed model relating the count of major burrow openings to reader_year, stratum_year, and readable area (offset) for SCI 6A.

	Df	Sum sq	Mean Sq	F value
Reader_year	29	244.14	8.4188	8.4188
Stratum_year	23	379.81	16.5137	16.5137

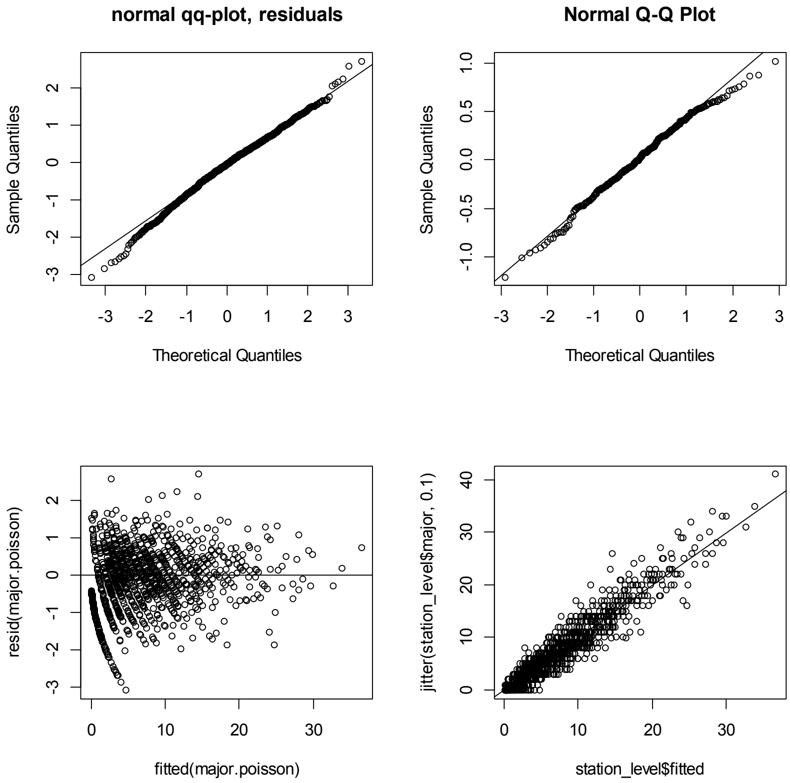


Figure 6: Diagnostic plots for generalised linear mixed effects model examining reader_year effects on counts of major burrow openings.

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 ith reader_year, and $\bar{c}$ is the average of the reader_year indices. These correction factors were applied to the individual counts when estimating overall abundance.

Table 4: Canonical indices (and variance, CV and upper and lower 95% CI) and correction factor 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 6A.

Reader_Year	Indices	Variance	CVs	Upper 95%	Lower 95%	Correction factor
AM_2013	2.130312	0.059066	0.114084	2.616381	1.644242	0.491327
AM_2016	0.986125	0.029714	0.174804	1.330882	0.641368	1.061406
BH_2007	0.652550	0.006669	0.125148	0.815881	0.489218	1.603984
BH_2008	0.797834	0.010235	0.126801	1.000167	0.595502	1.311900
BH_2009	0.783286	0.006903	0.106075	0.949460	0.617112	1.336267
DP_2007	0.507317	0.005105	0.140841	0.650219	0.364415	2.063166
DP_2008	1.068984	0.016583	0.120463	1.326530	0.811437	0.979134
DP_2009	0.986493	0.010484	0.103791	1.191271	0.781715	1.061010
DP_2013	1.682428	0.038064	0.115964	2.072630	1.292226	0.622124
DP_2016	1.288519	0.049016	0.171822	1.731312	0.845726	0.812312
HA_2007	0.800605	0.009349	0.120774	0.993990	0.607220	1.307360
HA_2008	1.016918	0.015414	0.122090	1.265228	0.768608	1.029265
HA_2009	1.150530	0.013951	0.102660	1.386757	0.914302	0.909737
HA_2013	1.351434	0.026041	0.119408	1.674178	1.028690	0.774495
HA_2016	0.895722	0.025445	0.178084	1.214750	0.576695	1.168531
IT_2007	0.947581	0.012452	0.117761	1.170756	0.724405	1.104580
IT_2008	1.118320	0.018093	0.120279	1.387341	0.849299	0.935939
IT_2009	0.833444	0.007787	0.105881	1.009935	0.656953	1.255848
IT_2013	1.425219	0.029000	0.119487	1.765809	1.084628	0.734399
IT_2016	0.963492	0.028285	0.174553	1.299853	0.627132	1.086338
JD_2007	0.640858	0.006334	0.124186	0.800030	0.481687	1.633246
JD_2008	1.167182	0.019694	0.120235	1.447855	0.886509	0.896757
JD_2009	0.728686	0.006295	0.108881	0.887366	0.570006	1.436392
MS_2007	0.777260	0.009347	0.124383	0.970616	0.583905	1.346626
MS_2008	0.941523	0.013311	0.122540	1.172271	0.710775	1.111687
MS_2009	1.076068	0.012359	0.103314	1.298414	0.853721	0.972689
MS_2013	1.584577	0.034876	0.117855	1.958076	1.211077	0.660542
MS_2016	1.176140	0.040678	0.171484	1.579517	0.772763	0.889927
NR_2013	1.047464	0.017321	0.125647	1.310686	0.784243	0.999250
NR_2016	0.873493	0.023735	0.176373	1.181613	0.565372	1.198269

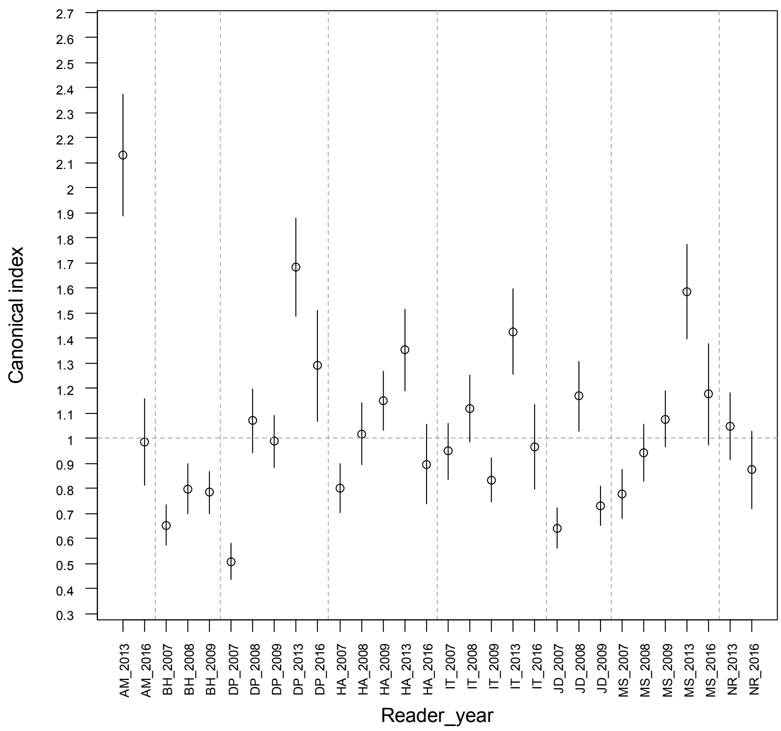


Figure 7: Canonical indices (and CV) for reader_year terms from a generalised linear mixed model relating the count of major burrow openings to reader_year, strata_year, and readable area for SCI 6A.

For visible scampi, reader_year effects were not retained in the final model (Table 5; Diagnostic plots in Figure 8), supporting our previously assumed (but untested) view that identification and counting of scampi is far less subjective than that of burrow openings.

Table 5: Analysis of deviance for a generalised linear mixed model relating the count of visible scampi to strata_year and readable area (offset) for SCI 6A.

	Df	Sum sq	Mean Sq	F value
Strata_year	23	154.11	6.7006	6.7006

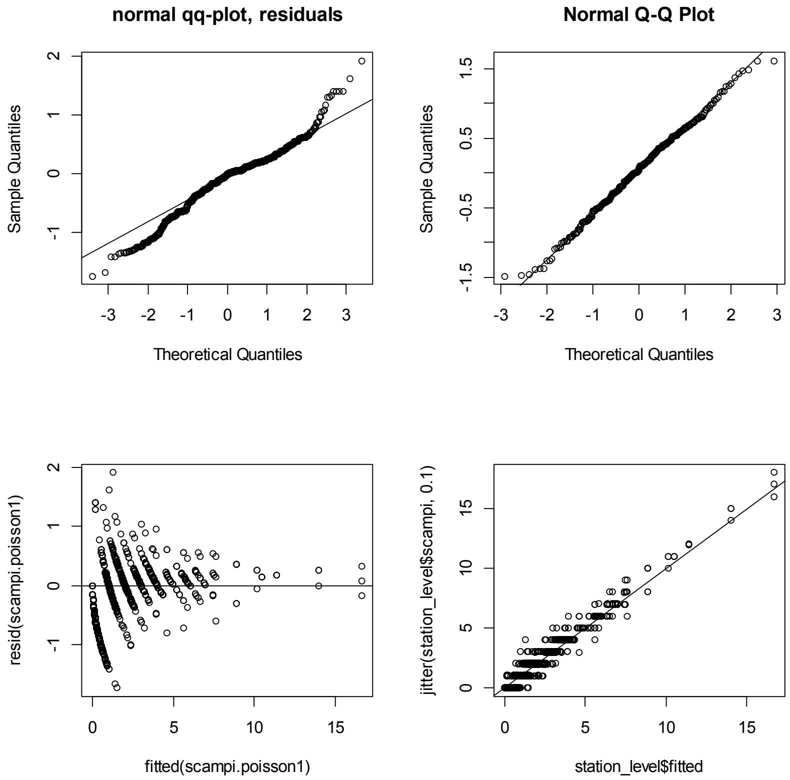


Figure 8: Diagnostic plots for generalised linear mixed effects model examining effects on counts of visible scampi.

The number of completed stations by stratum are provided in Table 2. The locations of photographic stations and relative burrow densities are shown in Figure 9. The uncorrected burrow density estimates at the station level varied from 0–0.08 m^{-2}, and reader correction factors had only minimal influence on overall density estimates. Densities of all scampi, and scampi out of their burrows ranged from 0 to 0.04 (Figure 10) and 0.02 m^{-2}, respectively. Scaling the densities to the combined area of the strata (4897 km^2) leads to abundance estimates of 146 million burrows or, assuming 100% occupancy, a maximum abundance estimate of the same number of animals (Table 6). Analysis of all SCI 6A surveys (with and without reader_year corrections) are presented in Appendix 1.

Overall, the corrected density of major scampi burrow openings was estimated to be 0.03 m^{-2}. The density was highest in the deepest stratum 303, particularly low in the shallowest stratum, and within the intermediate depths, was higher in the northern half of the particular strata. 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 6).

The estimated mean density of all visible scampi was 0.01 m^{-2}, with the spatial density patterns similar to those described for burrow openings above. Scaling the observed annual density of visible scampi by the area in each stratum leads to a minimum abundance estimate of 48 million animals for the surveyed area (Table 7). Counting animals out of burrows and walking free on the surface reduced this estimate to 27 million animals (Table 8). The CVs for visible scampi and scampi out of burrows from the bootstrapped estimates were comparable with those of the original estimates.

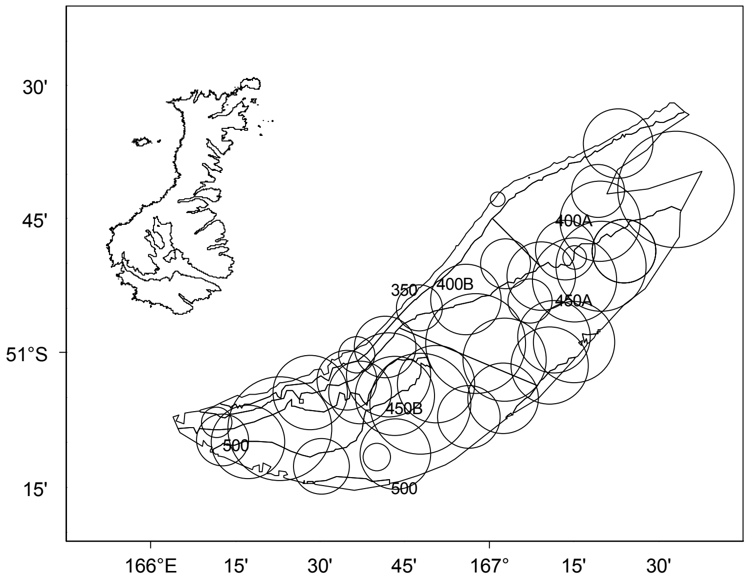


Figure 9: Station locations for the 2016 photographic survey of SCI 6A (area of symbol represents relative burrow density). Largest circle represents 0.08 burrows .m^{-2} (uncorrected for reader_year).

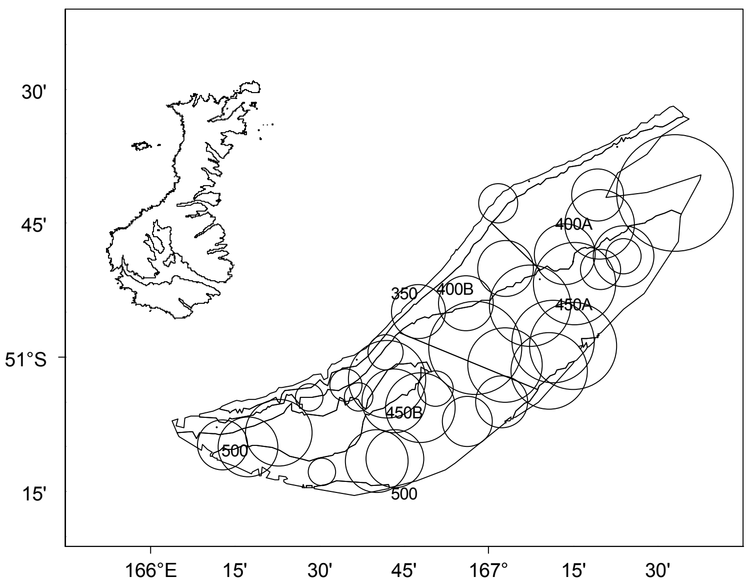


Figure 10: Station locations for the 2016 photographic survey of SCI 6A (area of symbol represents relative visible scampi density). Largest circle represents 0.036 visible scampi .m^{-2}.

Table 6: Estimates of the density and abundance of major burrow openings from the SCI 6A survey for 2016. 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	350	400A	400B	450A	450B	500	Fishery	Bootstrap
Area (km^2)	278	789	752	1216	1348	514	4897	
Stations	3	5	4	12	13	3	40	
Mean density ($.m^{-2}$)	0.0030	0.0398	0.0141	0.0341	0.0293	0.0445	0.0299	
CV	0.76	0.40	0.33	0.17	0.14	0.35	0.12	0.11
Abundance (millions)	0.85	31.36	10.58	41.44	39.54	22.88	146.65	145.71

Table 7: Estimates of the density and abundance of visible scampi from the SCI 6A survey for 2016. 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	350	400A	400B	450A	450B	500	Fishery	Bootstrap
Area (km^2)	278	789	752	1216	1348	514	4897	
Stations	3	5	4	12	13	3	40	
Mean density ($.m^{-2}$)	0.0000	0.0145	0.0062	0.0126	0.0077	0.0134	0.0099	
CV		0.45	0.25	0.22	0.21	0.17	0.14	0.13
Abundance (millions)	0.00	11.44	4.69	15.37	10.35	6.87	48.72	47.95

Table 8: Estimates of the density and abundance of scampi out of burrows from the SCI 6A survey for 2016. 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	350	400A	400B	450A	450B	500	Fishery	Bootstrap
Area (km^2)	278	789	752	1216	1348	514	4897	
Stations	3	5	4	12	13	3	40	
Mean density ($.m^{-2}$)	0.0000	0.0032	0.0062	0.0077	0.0039	0.0114	0.0057	
CV		0.62	0.25	0.30	0.32	0.07	0.14	27.53
Abundance (millions)	0.00	2.56	4.69	9.32	5.27	5.86	27.70	4.92

The trend in abundance in major burrow openings is shown in Figure 11. The calibration to account for reader_year effects increased the estimated abundance in 2007 and 2009, and reduced the estimated abundance in 2013, but does not change the overall pattern in the data. The estimated abundance of major burrow openings shows a slight increase between 2013 and 2016, having declined considerably between 2009 and 2013. The indices of scampi abundance (visible scampi, and scampi out of burrows) are presented in Figure 12. These show a steady decline between 2007 and 2009, a further slight decline by 2013, and an increase between 2013 and 2016. Estimates of scampi out of burrows are lower, but show a similar pattern.

Overall survey mean densities for the current and previous surveys in SCI 6A are provided in Table 9. The count of visible scampi as a percentage of burrows (which could be considered a minimum estimate of occupancy) was 33% (mean of 26% for survey series). The range observed is slightly higher than that from other SCI survey series (Tuck et al. 2013; Tuck et al. 2016). The proportion of scampi seen out of their burrows (scampi out as a proportion of all visible scampi) was 57% in 2016 (mean of 56% for survey series), which is considerably higher than other surveys in SCI 1, SCI 2 and SCI 3 (which average about 20%, Tuck et al. 2013; Tuck et al. 2016).

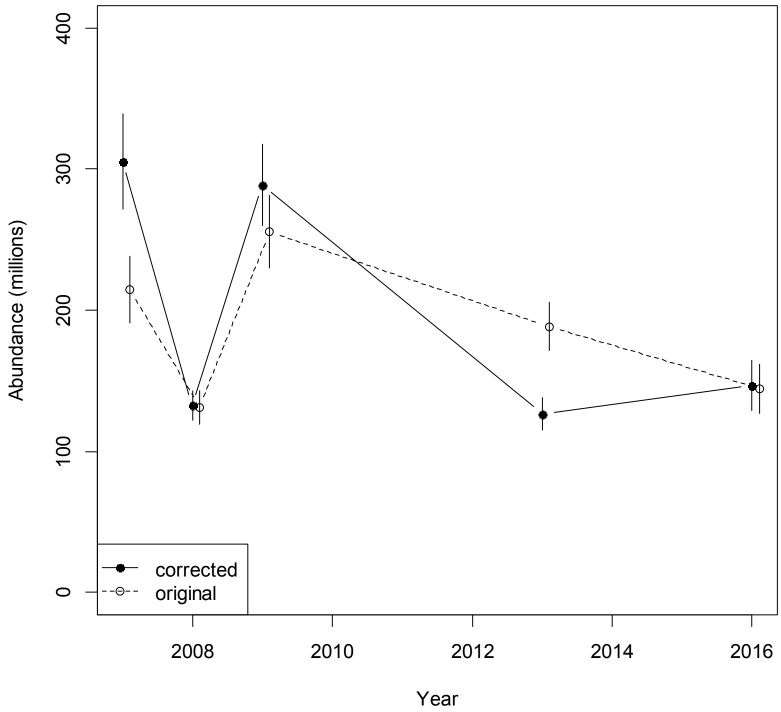


Figure 11: Estimated abundance of scampi major burrow openings (± CV) for SCI 6A.

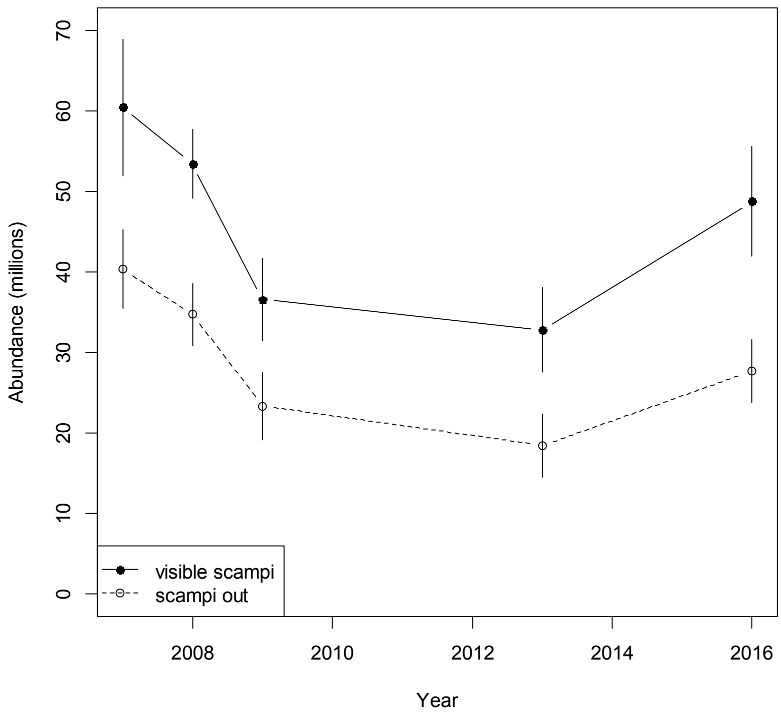


Figure 12: Estimated abundance of all visible scampi and those seen outside of a burrow (± CV) for SCI 6A.

Table 9: Overall survey mean densities (m^{-2}) of major burrow openings, visible scampi and scampi out of burrows, for the series of SCI 6A surveys.

	Major opening	Visible scampi	Scampi "out"	Scampi as % of openings	% of visible scampi "out"
2007	0.0624	0.0123	0.0082	0.20	0.67
2008	0.0270	0.0109	0.0071	0.40	0.65
2009	0.0590	0.0075	0.0048	0.13	0.64
2013	0.0258	0.0067	0.0038	0.26	0.56
2016	0.0299	0.0099	0.0057	0.33	0.57

3.2 Trawl survey

The location of trawl survey stations and relative scampi catch rates are shown in Figure 13. Biomass estimates are provided by strata for the 2016 survey in Table 10, and are compared with previous surveys estimated over the same strata (but with a different vessel) in Table 12 and Figure 14. Equivalent abundance estimates are provided for the 2016 survey in Table 11, and are compared with previous surveys in Table 13 and Figure 15.

Table 10: Trawl survey estimates by strata for SCI 6A. Mean values expressed as kg.nautical mile^{-1} with the *Kaharoa* scampi trawl gear.

	Stratum						Total
Strata	350	400N	400S	450N	450S	500	
Area (km^2)	278	789	752	1216	1348	514	4897
N. stations	3	3	3	3	3	3	18
Mean (kg.mile^{-1})	6.16	5.70	3.58	5.13	7.96	3.12	5.61
CV	0.57	0.17	0.13	0.14	0.19	0.22	0.09
Biomass (tonnes)	36.99	97.17	58.12	134.78	231.63	34.63	593.32

Table 11: Trawl survey estimates (abundance) by survey and stratum for SCI 6A. Mean values expressed as numbers mile^{-1} with the *Kaharoa* scampi trawl gear.

	Stratum						Total
Strata	350	400N	400S	450N	450S	500	
Area (km^2)	278	789	752	1216	1348	514	4897
N. stations	3	3	3	3	3	3	18
Mean (No. mile^{-1})	73.9	74.2	51.2	112.3	74.4	44.0	78.0
CV	0.56	0.13	0.07	0.25	0.12	0.29	0.11
Abundance (millions)	0.4	1.3	0.8	3.3	2.0	0.5	8.2

The overall raised trawl survey estimate was 593 tonnes (9% CV) (Table 10), or 8.2 million individuals (11% CV) (Table 11). Given that scampi live in burrows and are only available to trawl gear when emerged on the seabed, this is likely to be (as with all the trawl surveys) a considerable underestimate of the stock biomass. It is considerably lower than the 2013 estimate (1258 t, 26% CV) (Table 12). The trends in scampi abundance (in numbers) estimated from the trawl surveys follow very similar patterns to those shown by biomass (Table 13). Both biomass and abundance estimates from the trawl survey show a similar pattern over time, and show a marked decline since 2013 (when the survey was conducted from a different vessel, with a different trawl gear).

Table 12: Time series of raised trawl survey scampi stock estimates (tonnes) by survey strata for SCI 6A.

	Stratum							Total
	350	400 all	400N	400S	450N	450S	500	
2007	52.4	327.5			248.5	435.4	73.4	1137.2
2008	100.7	277.3			493.0	236.2	121.9	1229.2
2009	34.0		137.1	154.3	317.2	60.0	119.0	821.6
2013	38.9		215.6	319.8	247.4	311.2	125.0	1257.9
2016	37.0		97.6	58.1	231.6	134.8	34.6	593.8

Table 13: Time series of raised trawl survey scampi stock estimates (millions) by survey strata for SCI 6A.

	Stratum							Total
	350	400 all	400N	400S	450N	450S	500	
2007	0.3	3.9			3.4	5.6	1.2	14.4
2008	1.2	3.5			6.9	3.4	1.9	16.9
2009	0.4		1.5	1.8	4.0	0.7	1.5	9.9
2013	0.5		2.3	2.4	3.4	4.4	1.1	14.1
2016	0.4		1.3	0.8	3.3	2.0	0.5	8.2

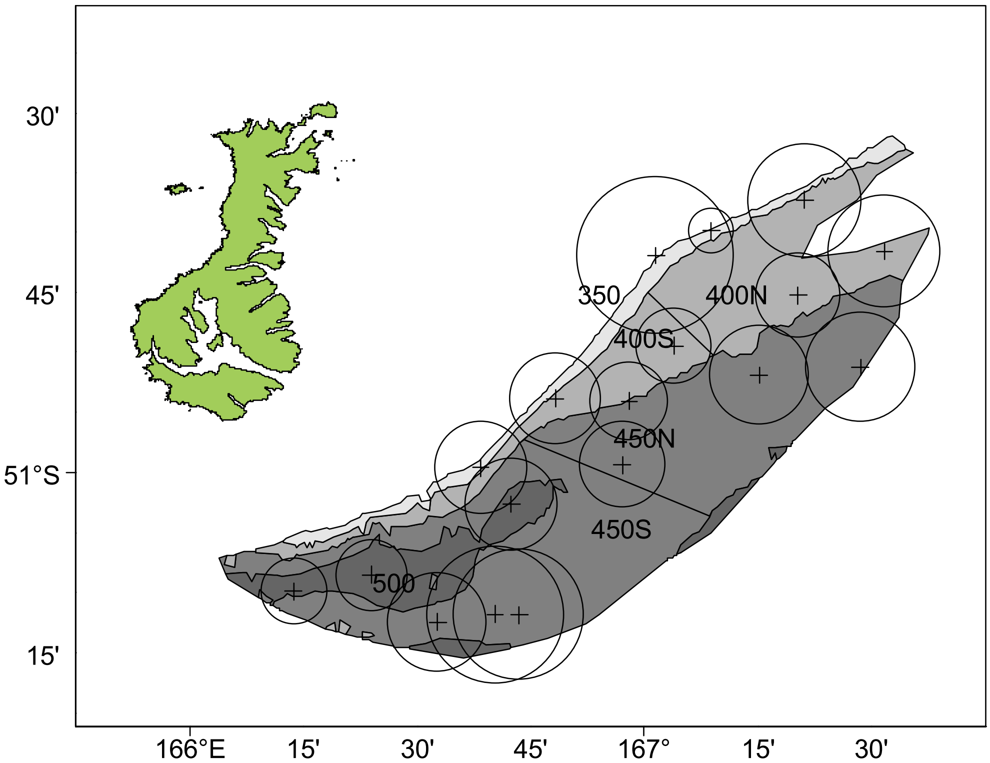


Figure 13: Trawl station locations for the 2016 photographic survey of SCI 6A (area of symbol represents relative scampi catch rate). Largest circle represents 39 kg.hr^{-1}.

Over the whole SCI 6A trawl survey, 291 kg of scampi were caught, accounting for about 4% of the total catch (6790 kg), with scampi being the sixth most abundant fish species. By weight, the most, dominant fish species in the catches were javelin fish (32.0%), oblique banded rattail (9.1%), ling (7.4%), hoki (7.4%), ghost shark (4.9%), and scampi (4.3%). Within commercial fishing activities, scampi forms a greater proportion of the total catch, as bycatch mitigation approaches reduce fish catch.

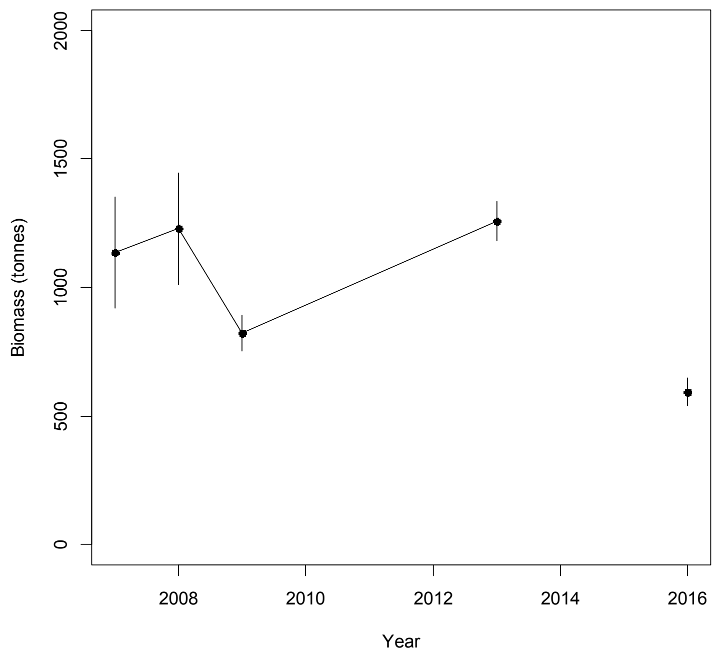


Figure 14: Plot of time series of trawl survey biomass estimates (± CV) for SCI 6A.

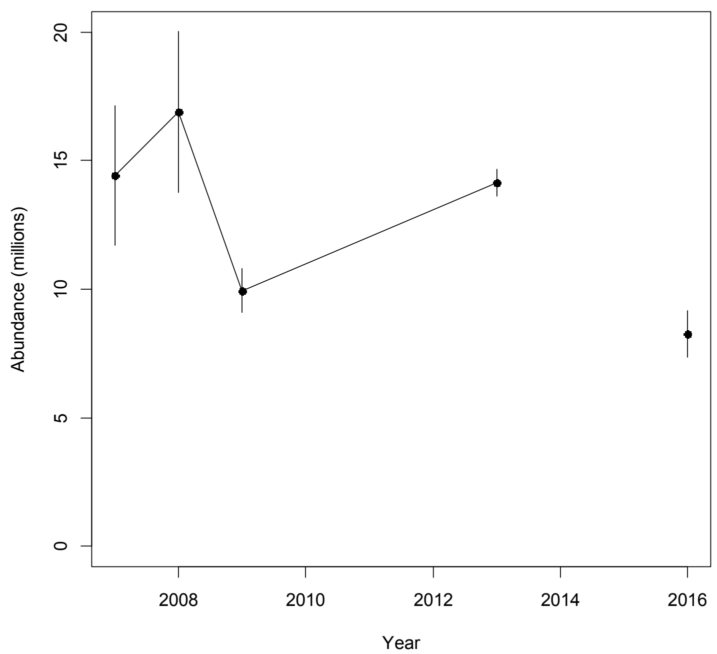


Figure 15: Plot of time series of trawl survey abundance estimates (± CV) for SCI 6A.

Catch rates (kg.km^{-2} swept area) of some common species are presented for recent SCI 6A surveys (Figure 16). Catch rates for the fish species from the *Kaharoa* 2016 survey are within the range of recent *San Tongariro* surveys, while the *Kaharoa* scampi catch rate is markedly lower. This may be related to better bottom contact with the *San Tongariro* gear.

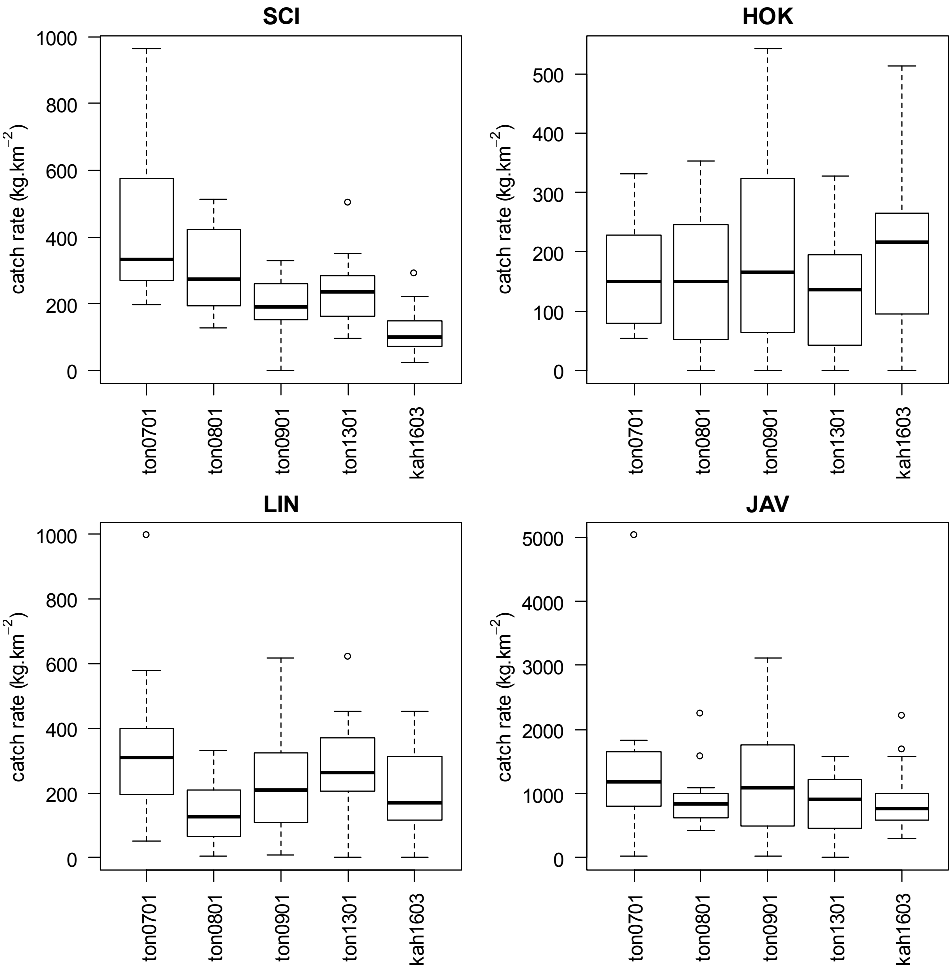


Figure 16: Catch rates of key species caught on recent SCI 6A surveys.

While the scampi length composition from the *Kaharoa* 2016 surveys appears different from the earliest *San Tongariro* surveys (2007–2009), the length composition appears very similar to that recorded in 2013 (Figure 17).

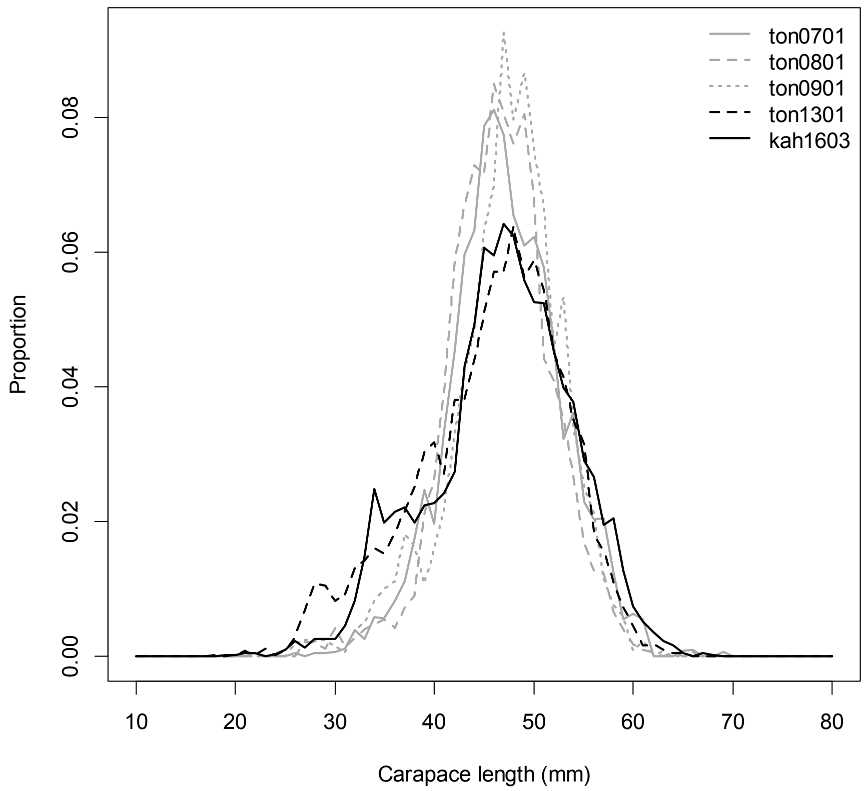


Figure 17: Proportion at length (both sexes combined) for scampi survey catches in SCI 6A.

Across the survey series, strata level estimates of abundance from trawl and photographic survey methods (burrows and visible animals) showed positive relationships (Figure 18 and Figure 19). Both sets of correlations were better when examined on an individual year basis, and were generally greater than 0.7, except for 2009, where trawl catch in strata 450S (estimated from two trawl stations, both with low catches) was considerably lower than might have been expected, given the number of scampi and burrows observed.

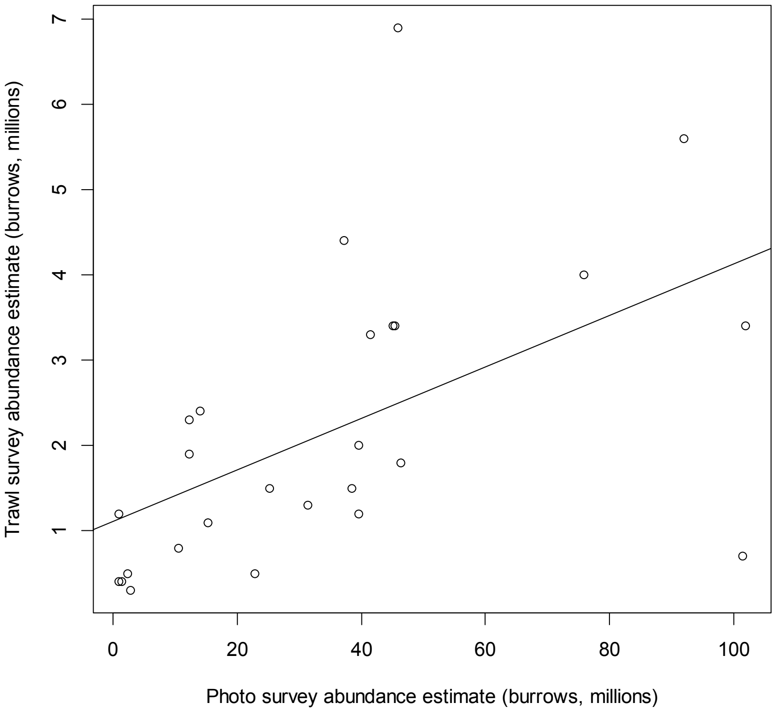


Figure 18: Relationship between stratum level photographic survey estimates of burrow abundance and trawl survey estimates of scampi abundance. Line represents least squares linear regression (r^2 = 0.28).

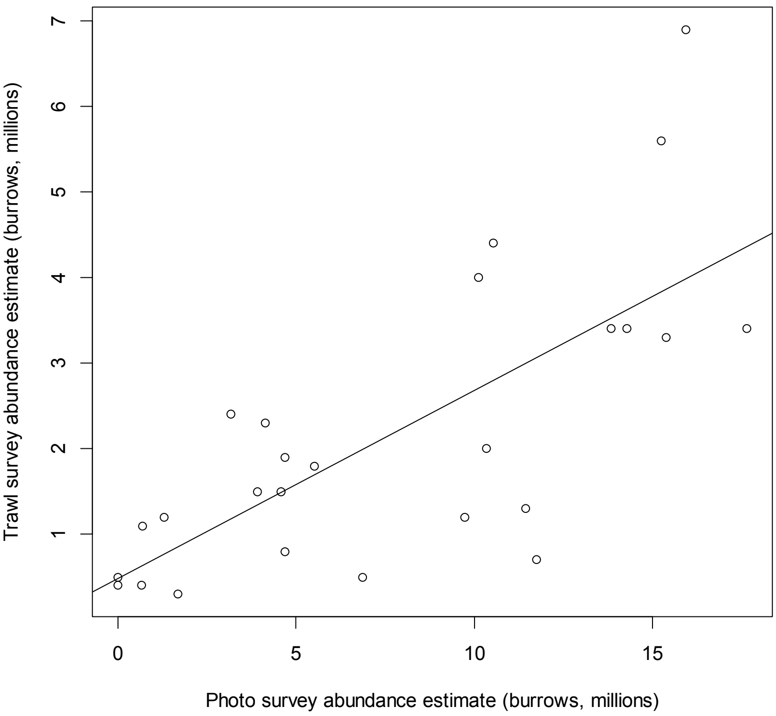


Figure 19: Relationship between stratum level photographic survey estimates of visible scampi abundance and trawl survey estimates of scampi abundance. Line represents least squares linear regression (r^2 = 0.53).

3.3 Tagging

Undamaged active scampi were tagged from each trawl catch, and released to investigate growth. The next scheduled research sampling in SCI 6A will be in 2019, and we anticipate that all recoveries will come from commercial fishing activity. During the trawling component of the survey, over 3880 scampi were tagged with streamer tags, and 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 20. The slight dominance of females in catches and tag releases was not as extreme as previous surveys in SCI 6A at this time of year (Tuck et al. 2015), where females have been predominant. The tagged scampi were released at 20 separate locations (Figure 21). 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 previously, short term (up to seven days) survival has been estimated at 88% in SCI 6A (Tuck et al. 2015) and, 76% in SCI 2 (Tuck et al. 2013) the difference assumed to be related to higher release mortality caused by warmer surface water temperatures in SCI 2.

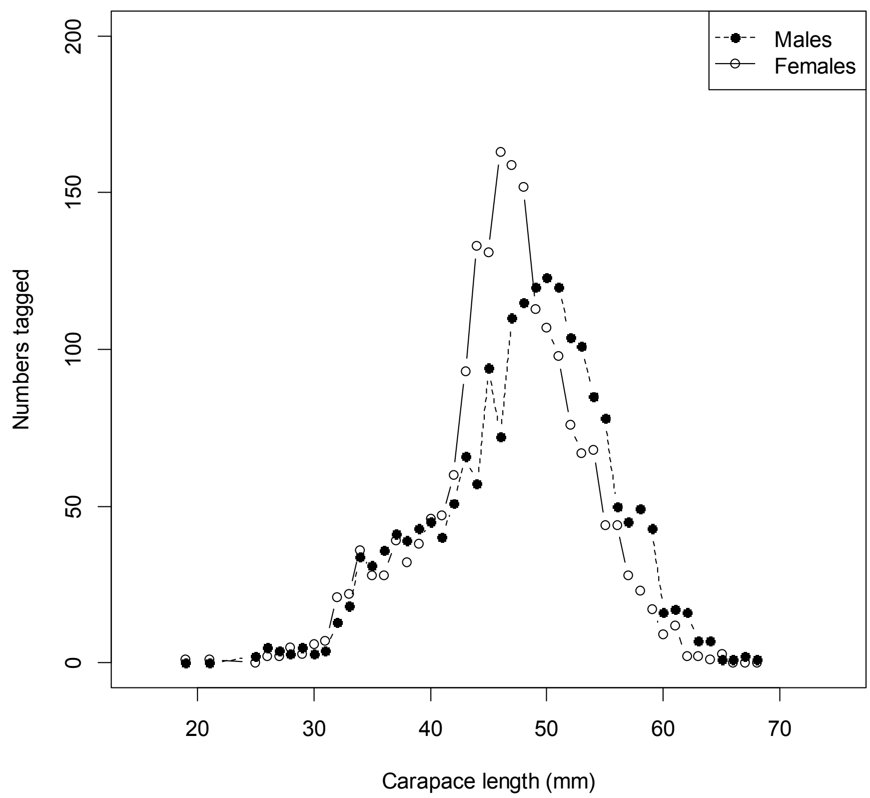


Figure 20: Length distribution of scampi tagged and released in SCI 6A during the KAH1603 voyage.

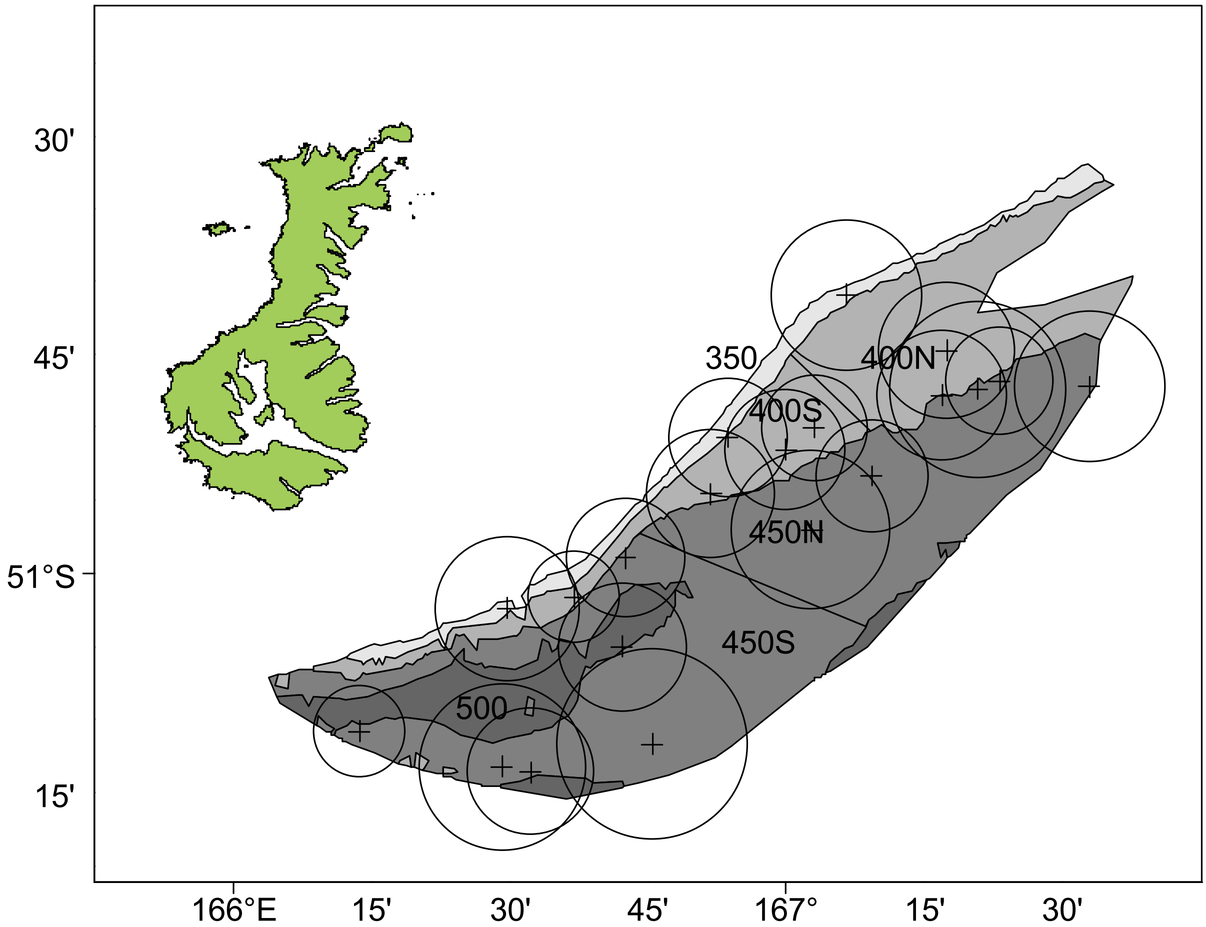


Figure 21: Map showing distribution of 2016 scampi release locations in SCI 6A, and relative numbers released at each location. Largest circles represent 385 animals. The smallest release batch was 90 animals, and the average release batch was 194 animals.

To date (October 2016) 45 recoveries have been reported to NIWA from the 2016 tagging in SCI 6A. Tag recovery rates from SCI 6A have generally been higher than from other scampi fisheries where tagging has been undertaken. 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 6A was conducted in February and March 2016, replicating the coverage of the 2013 survey. The photographic survey estimated a scampi burrow abundance of 145 million over the whole area, a slight increase on the 2013 estimate. Over the longer term, the two indices show slightly different patterns, and the visible animal index has been fitted within assessment models, rather than the burrow index. The photographic survey of visible scampi also showed an increase on the 2013 estimate. The trawl survey estimated a biomass of 593 tonnes. This represents a marked reduction from the 2013 estimate, but given that the vessel previously used for these surveys is no longer available, there may be a vessel effect, and the 2016 estimate may not be directly comparable. 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.

Over 3880 scampi were tagged and released as part of an investigation into growth, and to date, 45 scampi have subsequently been recaptured by fishers. These will be incorporated into the existing tag recapture dataset for this stock, and used to estimate growth rates within the stock assessment model.

5. ACKNOWLEDGMENTS

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 and the NIWA Activity Notifications team for their help in complying with the 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. The voyage was funded within project SCI2015-01. This report was reviewed by Bruce Hartill.

6. 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. <Go to ISI>://000185560800019

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.

Cryer, M., Downing, K., Hartill, B., Drury, J., Armiger, H.J., Middleton, C., Smith, M.D. (2003a) 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., Armiger, H., Smith, M., Middleton, C. (2003b) Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys before and after fishing in QMA 3, 2001. *Final Research Report for Ministry of Fisheries research project SCI2000-02*: 33.

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. *Final Research Report for Ministry of Fisheries Research Projects SCI2000-02 & SCI2001-01*.

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.

Cryer, M., Stotter, D.R. (1999) Movement and growth rates of scampi inferred from tagging, Alderman Islands, western Bay of Plenty. *NIWA Technical Report No.*, 49.

Doonan, I.J., Rasmussen, S. (2012) Random Station User Manual (RandonStation v1.00-2012-06-13). *NIWA unpublished report*: 47.

Francis, R.I.C.C. (1999) The impact of correlations in standardised CPUE indices. *New Zealand Fisheries Assessment Research Document*: 30.

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

Francis, R.I.C.C., Fu, D. (2012) SurvCalc v1.2. *NIWA Technical Report*, 134.

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.

ICES (2007) Report of the workshop on the use of UWTV surveys for determining abundance in *Nephrops* stocks throughout European waters (WKNEPHTV). *ICES ACFM*: 291.

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.

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, C.J., 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.

Snedecor, G.W., Cochran, W.C. (1989) *Statistical Methods*. Iowa State University Press, Iowa.

Tuck, I.D. (2014) Characterisation and length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1) and Hawke Bay/Wairaraoa (SCI 2). *New Zealand Fisheries Assessment Report*, 2014/33: 172 p.

Tuck, I.D. (2015) Characterisation and length-based population model for scampi (*Metanephrops challengeri*) at the Auckland Islands (SCI 6A). *New Zealand Fisheries Assessment Report*, 2015/21: 164 p.

Tuck, I.D. (2016) Characterisation and length-based population model for scampi (*Metanephrops challengeri*) on the Mernoo Bank (SCI 3). *New Zealand Fisheries Assessment Report*, 2016/55: 221 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., Bailey, N., Smith, R.S.M. (1997) 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). *Final Research Report for Ministry of Fisheries research project SCI2008-03*: 30 p.

Tuck, I.D., Dunn, A. (2012) Length-based population model for scampi (*Metanephrops challengeri*) in the Bay of Plenty (SCI 1), Wairarapa / Hawke Bay (SCI 2) and Auckland Islands (SCI 6A). *New Zealand Fisheries Assessment Report*, 2012/1: 125 p.

Tuck, I.D., Hartill, B., Parkinson, D., Drury, J., Smith, M., Armiger, H. (2009a) Estimating the abundance of scampi - Relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 6A (2009). *Final Research Report for Ministry of Fisheries research project SCI2008-01*: 26 p.

Tuck, I.D., Hartill, B., Parkinson, D., Harper, S., Drury, J., Smith, M., Armiger, H. (2009b) 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 SCI2008-01*: 37 p.

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 projects SCI2009-01 & SCI2010-01*: 29 p.

Tuck, I.D., Parkinson, D., Armiger, H., Smith, M., Miller, A., Rush, N., Spong, K. (2015) 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. (2016) Estimating the abundance of scampi in SCI 1 (Bay of Plenty) and SCI 2 (Wairarapa / Hawke Bay) in 2015. *New Zealand Fisheries Assessment Report*, 2016/17: 60 p.

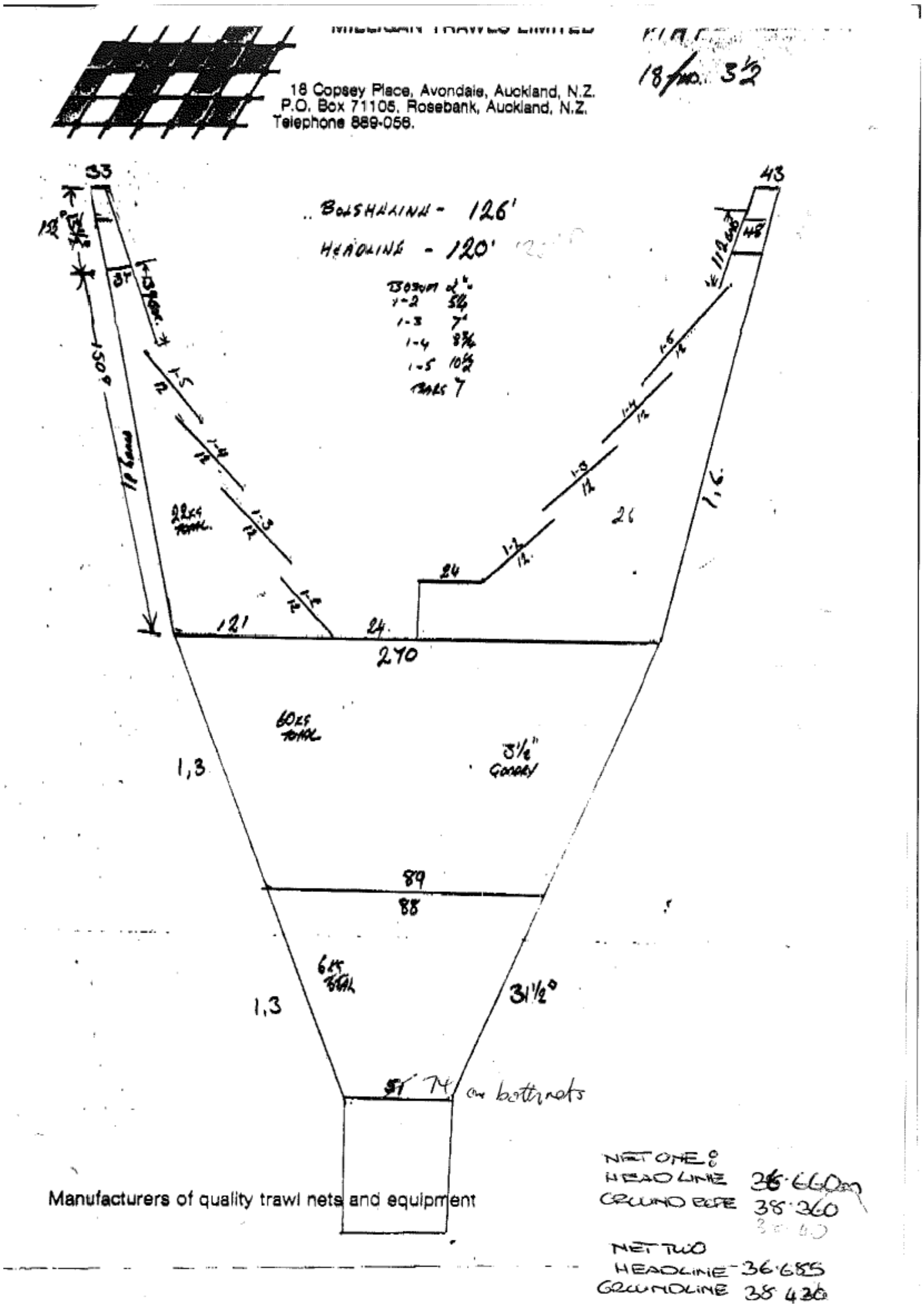
Tuck, I.D., Parkinson, D., Drury, J., Armiger, H., Miller, A., Rush, N., Smith, M., Hartill, B. (2013) Estimating the abundance of scampi - Relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 1 and SCI 2 (2012). *Final Research Report for Ministry of Fisheries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

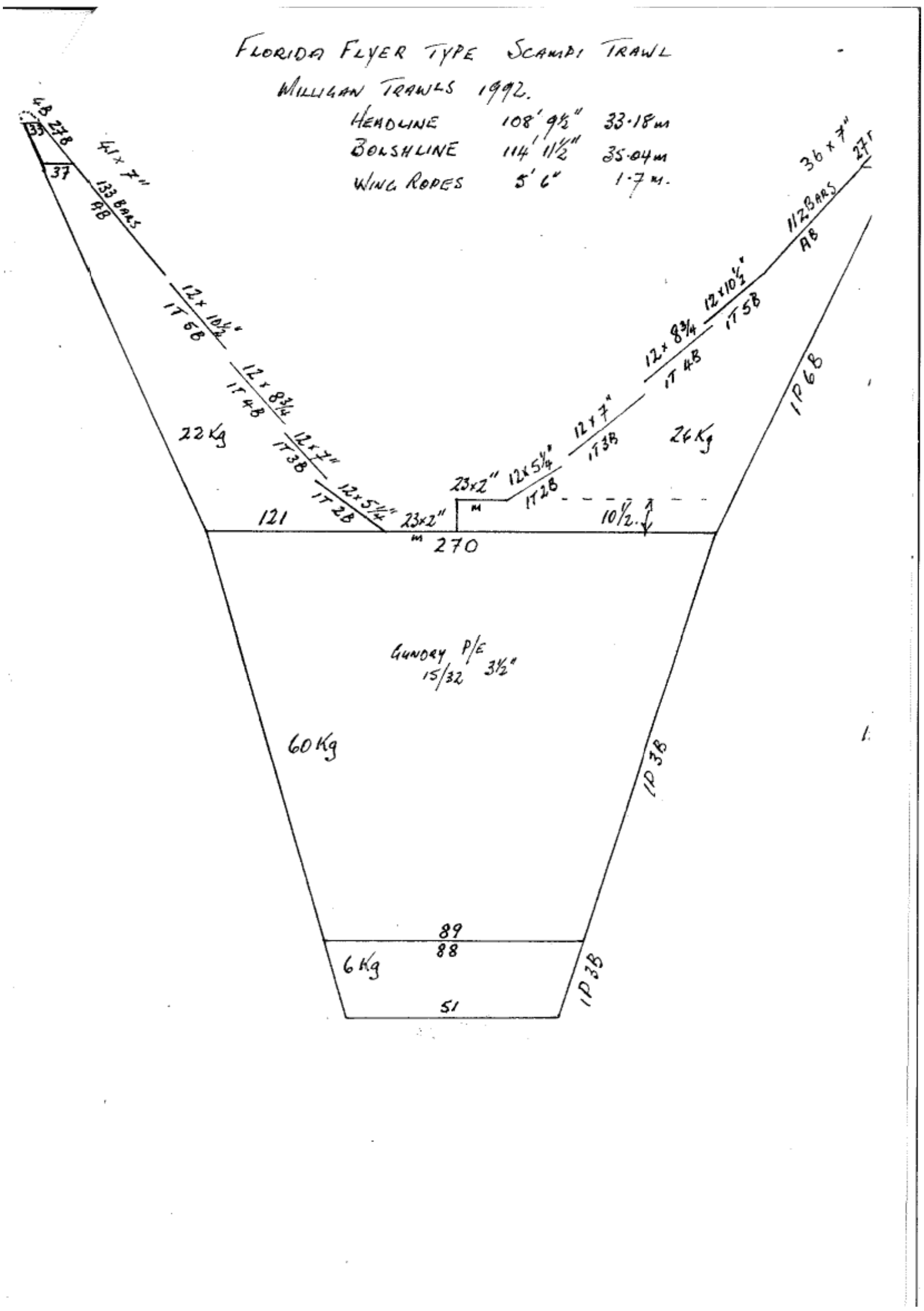
Tuck, I.D., Parkinson, D., Hartill, B., Drury, J., Smith, M., Armiger, H. (2007) Estimating the abundance of scampi - relative abundance of scampi, *Metanephrops challengeri*, from a photographic survey in SCI 6A (2007). *Final Research Report for Ministry of Fisheries research project SCI2006-02*, Objectives 1 & 2: 29.

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

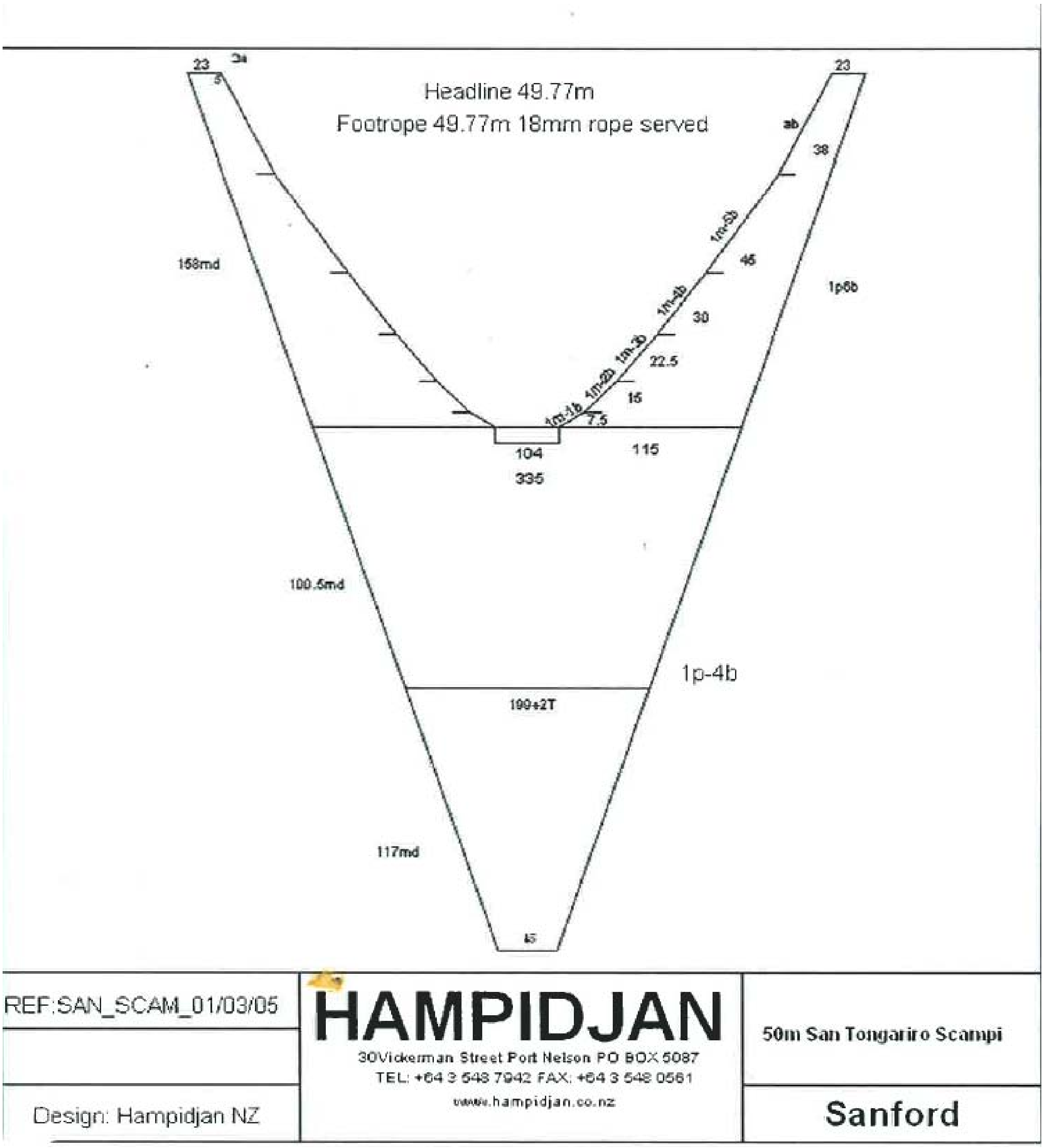
7. Appendix 1: Details of survey trawl gears

Kaharoa scampi trawl

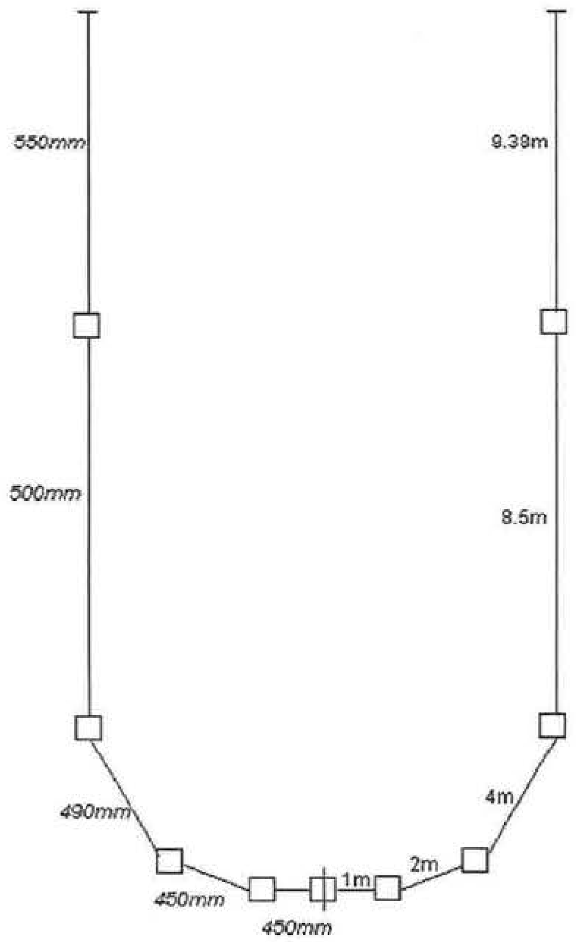



FLORIDA FLYER TYPE SCAMPI TRAWL
MILLIGAN TRAWLS 1992.
HEADLINE 108' 9½" 33·18m
BOLSHLINE 114' 11½" 35·04m
WING ROPES 5' 6" 1·7m.
41 x 7"
133 BARS
AB
37
33
27B
12 x 10½"
1T 6B
12 x 8¾
1T 4B
12 x 7"
1T 3B
12 x 5¼"
1T 2B
23x2"
22 Kg
121
270
10½.
24 Kg
36 x 7"
27T
112 BARS
AB
12 x 10½"
1T 5B
12 x 8¾
1T 4B
12 x 7"
1T 3B
12 x 5¼"
1T 2B
1P 6B
GUNDRY P/E
15/32 3½"
60 Kg
1P 3B
89
88
6 Kg
51

San Tongariro scampi trawl



San Tongariro Groundrope 49.77m



18mm 6/19RFC

Chain droppers 2 x 13mm M/L

☐ Scampi weights

Distance between weights

Distance between droppers

Gear comparison between Kaharoa and San Tongariro scampi trawls (as employed during scampi surveys)

Parameter	**Kaharoa**	**San Tongariro**
Groundrope length (m)	35.04	49.77
Headline length (m)	33.18	49.77
Groundrope type	Rubber cookies	Looks like rubber cookies
Groundrope cookie diameter (mm)	65	Reported as served rope on plan but looks like rubber cookies from photographs
Groundrope (extra weights)	No	Yes
Groundrope dropper heights	5 links of 8 mm long link chain. Aprox 200 mm. Note: 1 link is in between the rubber cookies	2 x 13 mm medium link chain Aprox 100 mm
Groundrope dropper spacing's	1 m apart	
Bottom contact	Video shows good contact	Extra weights on groundrope
Warps	Two warps	Single warp
Door type	Bison, Polaris. 1760 x 1200 mm. Code: 070515444	PolyIce Viking Extreme 3.9 m^2
Door weight	~ 300 kg	625 kg
Bridle length	6.5-6.6 m	
Wingspread (measured)	24 m	21 m
Headline height	Approx 1.0 m	1.5-1.8 m
Body of trawl mesh size (mm)	3.5" (88 mm) knot centres. About 80 mm actual opening. Twine is 3 mm twist	120 mm knot centres, 112.8 mm opening
Cod-end mesh size (Inside measurement.	42 mm opening or 48 mm knot centres. 3 mm twist	42 mm opening centres. 3 mm twist

8. Appendix 2: Summary of photo survey workup

Uncorrected analysis

2007

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	10	3	6	5	5	32
Mean (/sq m)	0.0078	0.0309	0.0338	0.0583	0.0458	0.0584	0.0438
CV	0.56	0.24	0.31	0.18	0.25	0.25	0.11
Millions	2.18	24.42	25.40	70.90	61.80	30.00	214.70

Scampi	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	10	3	6	5	5	32
Mean (/sq m)	0.0061	0.0123	0.0086	0.0145	0.0113	0.0189	0.0123
CV	0.52	0.21	0.35	0.14	0.41	0.33	0.14
Millions	1.69	9.67	6.48	17.65	15.25	9.72	60.45

Out	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	10	3	6	5	5	32
Mean (/sq m)	0.0061	0.0075	0.0072	0.0105	0.0066	0.0109	0.0082
CV	0.52	0.21	0.46	0.18	0.34	0.29	0.12
Millions	1.69	5.94	5.40	12.79	8.91	5.61	40.34

Uncorrected analysis

2008

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	4	6	3	9	9	10	41
Mean (/sq m)	0.0033	0.0170	0.0187	0.0376	0.0338	0.0224	0.0268
CV	0.64	0.24	0.46	0.11	0.16	0.16	0.09
Millions	0.91	13.43	14.08	45.71	45.62	11.53	131.28

Scampi	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	4	6	3	9	9	10	41
Mean (/sq m)	0.0047	0.0094	0.0136	0.0131	0.0103	0.0091	0.0109
CV	0.17	0.19	0.10	0.14	0.21	0.21	0.08
Millions	1.32	7.42	10.19	15.94	13.85	4.70	53.42

Out	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	4	6	3	9	9	10	41
Mean (/sq m)	0.0047	0.0068	0.0105	0.0062	0.0065	0.0074	0.0071
CV	0.17	0.26	0.24	0.18	0.30	0.23	0.11
Millions	1.32	5.36	7.92	7.60	8.73	3.80	34.73

Uncorrected analysis

2009

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	6	6	2	10	14	5	43
Mean (/sq m)	0.0045	0.0275	0.0559	0.0553	0.0664	0.0661	0.0522
CV	0.51	0.17	0.55	0.10	0.10	0.16	0.10
Millions	1.26	21.69	42.05	67.30	89.49	33.96	255.75
Scampi	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	6	6	2	10	14	5	43
Mean (/sq m)	0.0024	0.0058	0.0073	0.0083	0.0087	0.0077	0.0075
CV	1.00	0.37	0.53	0.23	0.20	0.28	0.14
Millions	0.68	4.59	5.52	10.11	11.75	3.93	36.59
Out	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	6	6	2	10	14	5	43
Mean (/sq m)	0.0024	0.0034	0.0073	0.0026	0.0062	0.0057	0.0048
CV	1.00	0.53	0.53	0.34	0.26	0.32	0.18
Millions	0.68	2.67	5.52	3.17	8.36	2.95	23.35

Uncorrected analysis

2013

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	5	4	6	8	13	4	40
Mean (/sq m)	0.0117	0.0237	0.0266	0.0559	0.0423	0.0417	0.0385
CV	0.56	0.29	0.26	0.17	0.16	0.28	0.09
Millions	3.25	18.67	19.98	68.03	57.08	21.42	188.43
Scampi	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	5	4	6	8	13	4	40
Mean (/sq m)	0.0000	0.0052	0.0042	0.0117	0.0078	0.0013	0.0067
CV		0.50	0.63	0.25	0.23		0.16
Millions	0.00	4.14	3.19	14.28	10.54	0.69	32.83
Out	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	5	4	6	8	13	4	40
Mean (/sq m)	0.0000	0.0036	0.0031	0.0065	0.0038	0.0004	0.0038
CV		0.75	0.65	0.30	0.32		0.21
Millions	0.00	2.84	2.34	7.93	5.11	0.22	18.44

Uncorrected analysis

2016

Major	350	400A	400B	450A	450B	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	5	4	12	13	3	40
Mean (/sq m)	0.0033	0.0399	0.0142	0.0323	0.0298	0.0429	0.0295
CV	0.78	0.39	0.38	0.17	0.16	0.34	0.12
Millions	0.93	31.51	10.65	39.29	40.14	22.04	144.55

Scampi	350	400A	400B	450A	450B	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	5	4	12	13	3	40
Mean (/sq m)	0.0000	0.0145	0.0062	0.0126	0.0077	0.0134	0.0099
CV		0.45	0.25	0.22	0.21	0.17	0.14
Millions	0.00	11.44	4.69	15.37	10.35	6.87	48.72

Out	350	400A	400B	450A	450B	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	5	4	12	13	3	40
Mean (/sq m)	0.0000	0.0032	0.0062	0.0077	0.0039	0.0114	0.0057
CV		0.62	0.25	0.30	0.32	0.07	0.14
Millions	0.00	2.56	4.69	9.32	5.27	5.86	27.70

Reader_year corrected analysis

2007

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	10	3	6	5	5	32
Mean (/sq m)	0.0103	0.0421	0.0477	0.0839	0.0683	0.0769	0.0624
CV	0.52	0.22	0.29	0.19	0.24	0.21	0.11
Millions	2.88	33.18	35.91	101.99	92.02	39.54	305.52

Reader_year corrected analysis

2008

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	4	6	3	9	9	10	41
Mean (/sq m)	0.0032	0.0176	0.0188	0.0378	0.0335	0.0240	0.0270
CV	0.61	0.22	0.42	0.11	0.13	0.16	0.08
Millions	0.90	13.85	14.14	45.95	45.14	12.33	132.32

Reader_year corrected analysis

2009

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	6	6	2	10	14	5	43
Mean (/sq m)	0.0050	0.0321	0.0616	0.0624	0.0752	0.0749	0.0590
CV	0.51	0.17	0.57	0.08	0.09	0.15	0.10
Millions	1.40	25.29	46.32	75.86	101.42	38.49	288.78

Reader_year corrected analysis

2013

Major	350	4001	4002	4502	4501	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	5	4	6	8	13	4	40
Mean (/sq m)	0.0082	0.0155	0.0186	0.0374	0.0276	0.0297	0.0258
CV	0.55	0.28	0.26	0.14	0.16	0.24	0.09
Millions	2.29	12.22	13.96	45.49	37.24	15.26	126.47

Reader_year corrected analysis

2016

Major	350	400A	400B	450A	450B	500	Fishery
Area (sq km)	278	789	752	1216	1348	514	4897
Count (stations)	3	5	4	12	13	3	40
Mean (/sq m)	0.0030	0.0398	0.0141	0.0341	0.0293	0.0445	0.0299
CV	0.76	0.40	0.33	0.17	0.14	0.35	0.12
Millions	0.85	31.36	10.58	41.44	39.54	22.88	146.65