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Photographic estimation of the abundance and biomass of scampi, *Metanephrops challengeri*

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Report Title: Photographic estimation of the abundance and biomass of scampi, *Metanephrops challengeri*

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7. **Executive Summary:**

A photographic survey of scampi burrows in the Bay of Plenty between Great Barrier Island and Cape Runaway, 200–600 m depth is described. A new digital camera system developed in 1999–2000 has significantly improved the logistics of such surveys. In particular, the availability of digital images permits "in-survey" quality assurance and this led to photographs of a significantly higher overall quality than has been possible in the past.

On first reading, the weighted average density of scampi burrow openings in February 2000 was about 0.10 m^{-2} with a *c.v.* of about 12%. This equates to about 489 million burrow openings in the survey area (about 200 million burrows if each burrow has an average of 2.5 openings). If the survey area is restricted to the area surveyed in 1998 (Cuvier Island to White Island), the weighted average density of scampi burrow openings was about 0.11 m^{-2} with a *c.v.* of about 9% (about 268 million burrow openings or 107 million burrows in the survey area). This is only about one-third of the comparable estimate for 1998.

The weighted average density of visible scampi was about 0.005 m^{-2} with a *c.v.* of about 17%. This equates to about 24 million scampi in the survey area and is a minimum estimate of population abundance. If the survey area is restricted to the area surveyed in 1998, the weighted average density of visible scampi was about 0.008 m^{-2} with a *c.v.* of about 20% (about 19 million scampi in the survey area). This is only about one-half of the comparable estimate for 1998.

The average weight of scampi estimated photographically in 2000 was 38.3 g, similar to the 1998 estimate of 35.4 g. The average weight of scampi estimated by trawl in 2000 was 59.5 g, very similar to the 1998 estimate of 60.5 g.

Initially, there were significant differences among the three readers in the interpretation of scampi burrows and burrow openings. To address these differences, about 100 images of scampi associated with burrows were examined by all three readers with the intention of developing a consistent concept of what should be scored as a scampi burrow. Following this process, much of the inconsistency disappeared and, for a sample of 400 images from the most contentious strata, correlation among readers increased from about 0.32 to about 0.86 (for all burrows) and to about 0.91 (for "definite" scampi burrows). The 400 images were incorporated in a semi-blind trial as a first step in the development of a rigorous, standardised counting protocol.

Female scampi start to mature (i.e., show signs of thickening of the ovaries) at a size of 25–30 mm orbital carapace length (OCL). However, the size at which 50% of the population is apparently close to extrusion of the first batch of eggs is about 36 mm OCL, and the size at which 50% of the population carries eggs is about 40 mm OCL. Some females are morphologically immature at 40 mm.

There are strong and consistent correlations between the widths of major and minor openings to scampi burrows, and between the size of burrows and their inhabitants. Burrow length is more variable. These relationships could be used to estimate population length frequency for that size range of the population which builds and maintains burrows; juvenile scampi sharing burrows with older animals could not be assessed in this way.

It should be possible to estimate the absolute recruited biomass of scampi (at an assumed size at recruitment) using photography. There are several apparently sensible definitions of size at recruitment and the choice among them is not simple. Any estimate of absolute biomass would probably be negatively biased by the need to be "reasonably certain" that burrows included in the analysis were currently occupied by scampi (the size of which could be inferred by the dimensions of the burrow). Indices of relative abundance based on "definite" major burrow openings bigger than the size likely to hold mature scampi would probably be more reliable.

8. Objectives:

Overall Objectives:

1. To estimate the abundance of scampi (*Metanephrops challengeri*).

Specific Objectives:

1. To apply photographic techniques to estimate the relative abundance of scampi in QMA 1.

2. To determine the feasibility of deriving estimates of absolute abundance from the relative abundance estimates obtained from Objective 1.

9. Methods:

Using *Kaharoa* we conducted a stratified random photographic survey of 52 stations within the areas currently fished for scampi in QMA 1 (200–600 m depth) (Figure 1, Table 1). We conducted complementary trawling at 24 stations to provide information on sex ratio, length frequency distribution, stage frequency distribution, and to extend the relationship established in 1998 between burrow density and trawl catch rate (Cryer & Hartill 1998). Acoustic seabed classification (using the *QTC-view* package) was conducted throughout the survey.

9.1 Survey design

The positions of stations within strata were randomised using the Random Stations package (RAND_STN v 1.7 for PCs; MAF Fisheries 1990) constrained to keep all stations at least 1 km apart (the approximate range of spatial autocorrelation from the 1998 photographic survey, Cryer & Hartill 1998). An independent list of alternative or second phase stations for each stratum was generated in case foul ground or other impediments to photography or trawling were encountered, but no replacements were needed.

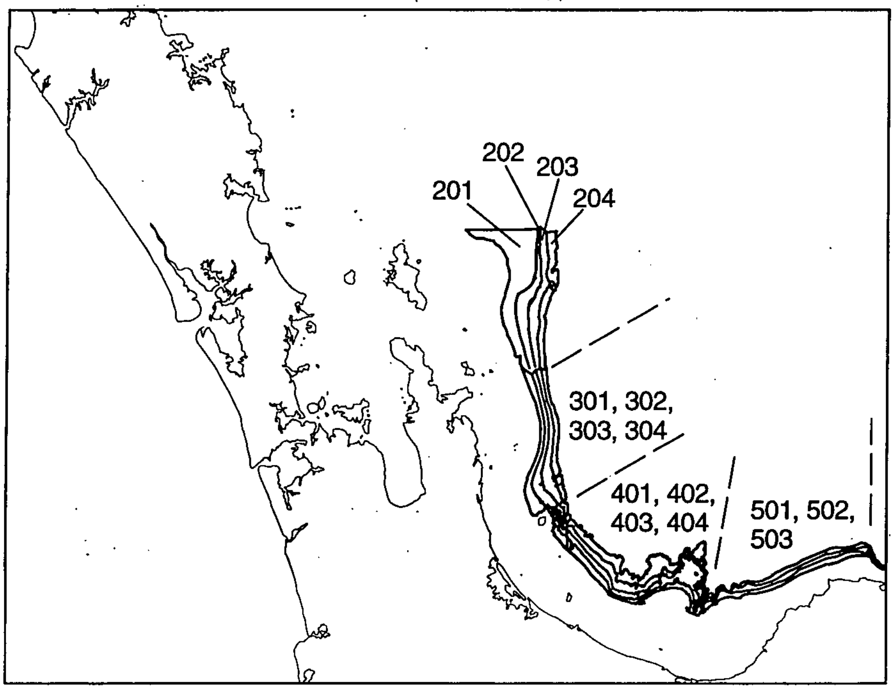

***Figure 1*: Sampling strata used in the photographic survey of scampi burrows in QMA 1. Strata were grouped geographically (here separated by dashed lines and coded by the first numeral of the stratum code) and by depth (coded by the last numeral of the stratum code: 1 = 200–300 m; 2 = 300–400 m; 3 = 400–500 m; 4 = 500–600 m).**

Photographic sampling was undertaken between 0500 and 1700 NZDT to coincide with the period of maximum trawl catchability of scampi. Although the time of day should have had 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 had two main advantages. First, a larger number of individuals could 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.

Table 1: **Design allocation of shots among strata for the February 2000 photographic survey to estimate relative biomass in QMA 1. Burrow densities were predicted using observed counts from photographs taken in 1998 where available, or from trawl catch rates and a regression technique where photographs were not available. Where the design allocation of shots is different from the number generated using the optimisation (*), this was to move the focus away from peripheral strata where there has been little fishing in recent years, and more onto strata where fishing has been more intense**

Stratum Code	Area (km^2)	Depth range (m)	Burrow density	Method of estimation	"Optimal" stations	Design stations
Great Barrier Island to Mercury Islands:						
201	839	200–300	0.0861	Trawl	3	3
202	307	300–400	0.4365	Trawl	4	4
203	311	400–500	0.4124	Trawl	4	*3
204	275	500–600	0.2124	Trawl	3	3
Aldermen Islands:						
301	315	200–300	0.0733	Photo	3	3
302	262	300–400	0.4693	Photo	3	*4
303	266	400–500	0.6724	Photo	5	5
304	209	500–600	0.3899	Photo	3	3
Mayor Island to White Island:						
401	237	200–300	0.2067	Photo	3	3
402	378	300–400	0.4803	Photo	5	5
403	290	400–500	0.4282	Photo	4	4
404	420	500–600	0.2894	Photo	3	3
White Island to Cape Runaway:						
501	218	200–300	0.1046	Trawl	3	3
502	186	300–400	0.3864	Trawl	3	3
503	166	400–500	0.4781	Trawl	3	3

9.2 Photography

We used a high resolution (Minolta Digita EX1500, 1344 x 1008 pixel) digital still camera to take photographs 3–5 m from the seabed using a custom-built steel cage on a trawl warp. The camera was triggered using a bottom contact system consisting of a weight attached by line to a weight-release switch on the camera frame. When the weight touched the seabed, the switch initiated the camera. The camera automatically hunts for appropriate focus and exposure settings, and we found from surface trials in complete darkness that there was usually a delay of 1–2 seconds between initiation and exposure of the image (by flash). This meant that we had to "hold" the camera in the critical area about 4 m off bottom for several seconds before winding it back to about 8 m off bottom to re-set the camera trigger. Image size was estimated using two lasers set parallel and 200 mm apart on the camera frame. Two red dots from the lasers were visible in almost all acceptable images, and the distance between the dots was used to estimate the linear dimensions of the image and hence the dimensions of any scampi and burrows observed and the image area.

The ship was navigated to each randomly chosen station, and the camera system was lowered and maintained about 4 m off-bottom using a modified CN22 acoustic headline monitor displaying distance off-bottom "real time" on the bridge. At each of three transects spaced about 1000 m apart at roughly constant depth, 12–14 frames were exposed as the ship drifted, using a nominal time delay of 60 seconds (to ensure that adjacent photographs did not overlap, Cryer & Hartill 1998).

Images were stored on 32 Mb "flash" cards in the camera. This amount of storage allowed us to use the lowest available compression ratio for the digital (JPEG) images, resulting in files of about 1.0–1.5 Mb each. After the completion of a transect, the flash card was removed from the camera and the images were downloaded through a specialised reader to the hard drive of a dedicated PC. A blank flash card was placed in the camera ready for the next transect. The downloaded images were briefly checked and counted to ensure that sufficient had been collected. Images were not erased from the flash card until the data from the PC had been copied to at least one CD. Thus once the images had been copied from the flash card to the PC, there were always at least two copies of the information on board. Three CD copies of each image were eventually made and stored in different parts of the ship.

The development of a high resolution digital camera system solved many problems we had previously with emulsion systems; no darkroom facilities were required and data were "downloaded" from the camera to a ship-board computer in full daylight. Quick inspections were sufficient to verify that focus and exposure were correct and that sufficient images had been collected at each transect. Images were also automatically available in a digital format suited to post-hoc measurement of animals and burrows, and digital photographs can be easily manipulated (in brightness, contrast, and spectral balance) to aid interpretation.

Images were examined at least once by three scorers (including M. Cryer who examined all images for the 1998 survey). For each image, the primary criterion of usability was that there was sufficient visibility and contrast in the photograph to discern fine seabed detail, and that no more than about 50% of the frame was obscured by suspended material or other features. If this criterion was met the image was accepted and the percentage of the frame within which the seabed was clearly and sharply visible was estimated. Each reader examined the stations in a different order, to "randomise" the effects of any learning process.

Counts were then made of the number of burrow openings, and the probable number of burrows using, as a loose guide, the burrow identification guide and key given by Marrs *et al.* (1996) for *Nephrops norvegicus*. Openings were counted directly, while the number of burrows was estimated by "grouping" together sets of openings which appeared (from their size, the direction of the various tunnels, and general morphology) to be linked. This technique is at least partially subjective. According to Marrs *et al.* (*op. cit.*), the burrows of *Nephrops norvegicus* usually have multiple, large (2–15 cm wide), crescent-shaped openings, at least some of which descend at a shallow angle into the substrate. The distance between major openings (to a putative burrow complex) is usually greater than 50 cm. Spoil heaps are common, and there are often well-marked tracks leading from some openings. The burrows of large *Nephrops norvegicus* are much more distinctive than those of smaller individuals.

Our preliminary observations of the type of burrows and openings associated with scampi, the burrows of *Metanephrops challengeri*, appear to be broadly similar to those of *N. norvegicus*. Where scampi were present at a burrow opening (making burrow identification relatively positive), these burrows appeared to have crescent-shaped openings and, especially for the larger openings, well-formed paths or tracks progressing along the substrate some distance from the burrow. However, many burrow openings, even for quite large scampi, appeared to be less than 50 cm apart. This may be a difference between the biology of *M. challengeri* and *N. norvegicus*. These "local" characteristics guided our counts.

The number of scampi visible in each photograph was noted and subdivided into those present at the opening to a burrow, and those walking on the seabed surface free of any burrow. The criterion used to separate these two categories (in the rare event that there was some uncertainty) was the visibility of the telson: if the telson was visible, then that individual was considered to be "on the surface". Different criteria, such as a specified distance from the nearest burrow opening, could be used.

All scampi observed in the images were measured using image analysis software. The (apparently) longer of the two chelipdes (the most commonly-observed and easily-measured body part) was measured in pixels together with the separation of the two laser pointers in the image (which were known to be 200 mm apart). Cheliped lengths were converted to orbital carapace length (OCL) using previously-derived morphometric relationships for QMA 1 scampi, and OCL was converted to individual weight using length-weight relationships in Annala *et al.* (2000). As the sex of scampi of calculated OCL less than 49 mm in photographs cannot be reliably ascertained, the average of the two weights predicted by separate length-weight relationships for the two sexes was used as the estimated weight for animals of this size class. Scampi with a calculated OCL of 49 mm or more are highly likely to be males, so the length-weight regression for males only was used to estimate their weight.

For each image, a note was made of any other items of interest such as linear marks (possibly trawl marks), fish, any visible invertebrates, and whether or not any counts of openings, burrows, or scampi should be considered subjective or questionable. These ancillary data are stored on Excel spreadsheets at NIWA, Auckland but are not considered further here.

9.3 Trawl and associated sampling

Trawling was conducted on (nominally) 2 n. mile shots parallel to depth contours at 2.8–3.0 kn (1.4–1.5 ms^{-1}) in a manner as close as possible to that used during relative biomass surveys on previous *Kaharoa* voyages (KAH9301, KAH9401, KAH9501; Cryer 1997). Shots were made between 0600 and 1700 (NZDT). Exact distances trawled were determined using GPS and netsonde records. Shots of 1.5 n. mile or more were accepted as valid, and were made so as to pass as close as possible to the photographic stations. One random station was untrawlable, so the photographic transects and the trawling were conducted nearby (within 1 n. mile).

The lengths of all scampi were measured (as orbital carapace length, OCL, to the next whole millimetre below the actual length) at all stations, up to a maximum of about 25 kg. Subsampling (where more than about 25 kg was caught) was conducted at four stations. An estimated 2876 scampi were caught, of which 1652 (57%) were measured. For females only, the stages of external eggs and internal gonads were recorded (after a method described by Cryer & Stotter, 1997, see also Appendix 1) in addition to the length for all animals measured at each trawl shot (691 animals). A sample of scampi was retained for determination of moult stage to assist with modelling growth rates (Project SCI9802). These data are stored on the EMPRESS database *trawl* but only the lengths are considered further here.

The weights of scampi and all finfish species caught at each shot were estimated by direct weighing (Seaway motion-compensating scales) or by subsampling and weighing (for highly abundant species of small body size) to a final precision of 0.1 kg. The lengths of all QMS finfish (principally hoki, ling, gemfish and red cod) were measured with a precision of 1 cm, together with all non-QMS finfish historically measured during scampi trawl studies (mirror and lookdown dories, brown stargazers, ribaldo, cardinalfish *etc.*). These data can be found on the EMPRESS *trawl* database but are not considered further here.

Except for prawn killers (*Ibacus alticrenatus*) and sea pens, both of which were occasionally very abundant, all invertebrates from each trawl were preserved (by freezing or fixation as appropriate) for later identification and enumeration.

Bottom water temperature was measured at each trawl shot using the remote sensing facility of the net monitor. The monitor was calibrated on deck (in water) using a mercury in glass thermometer (marked at intervals of 0.1 °C) as a reference. Readings by the two methods were within 0.2 °C of one another at about 20 °C. These data can be found on the EMPRESS *trawl* database but are not considered further here.

9.5 QTC-View acoustic seabed classification

The acoustic seabed classification system *QTC-view* interfaced to a scientific echo sounder energising a 38 kHz narrow beam transducer and differential GPS was operated throughout the voyage. This system analyses the quality of returning seabed echoes from a downward pointing transducer, enabling such echoes to be classified into groups of similar quality (*e.g.* Magorrian *et al.* 1995). The published literature on this technique is not yet extensive (although *see* Prager *et al.* 1995 for some early results), but it appears that the analytical approach used is considerably more flexible than the earlier "*RoxAnn*" method of signal interpretation (Provencher *et al.* 1995) and uses more of the information contained in echoes returning from the seabed.

The use of acoustic technology allowed assessment of seabed type throughout the voyage and the system was running during all operational and steaming time other than when photographic gear was in the water (when contamination of acoustic returns is a possibility). The availability of photographs from a wide variety of sites means that a large library of "ground truthed" reference sites was collected. It is likely that all ground covered by the ship during the voyage will be classified into distinct seabed types, but initial indications are that, apart from one area of foul ground, most of the ground covered is soft sediment of similar structure. However, the degree of bioturbation (e.g., burrows dug by scampi and other macroinvertebrates) may also influence the quality of acoustic returns (Greenstreet *et al.* 1997, Pinn & Robertson 1998) and we will be exploring the acoustic data for such signals. If the degree of bioturbation, especially by scampi, is detectable acoustically, then additional "indirect" sampling power will be available from acoustic information collected over a much broader scale than photographs. Given the predicted low c.v.s for the photographic survey, this is unlikely to be an issue for formal statistical uncertainty, but might be useful in reducing unmeasurable uncertainty associated with large spatial "holes" in randomly-selected sampling patterns, and with areas which cannot be sampled by trawl. This work is still underway.

9.6 Data analysis

Photographic data were analysed using methods analogous to those in the *Trawlsurvey* Analysis Program (Vignaux 1994) for trawl surveys. The mean density of burrow openings at a given station was estimated as the sum of all counts (openings, burrows, or scampi) divided by the sum of all image areas. For any given stratum, the mean density of openings and its associated variance was estimated using standard parametric methods, giving each station an equal weighting (the total sampled areas were similar). The total number of openings in the stratum was then 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 derived using the formula for strata of unequal sizes given by Snedecor and Cochran (1989):

For the overall mean,
$$\bar{x}_{(y)} = \sum W_i.\bar{x}_i \tag{1}$$

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

where $s^2_{(y)}$ is the variance of the overall mean density, $\bar{x}_{(y)}$, of burrow openings in the surveyed area of each QMA, 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 the sampling fraction was small (less than 0.01) in all strata.

10. Results:

10.1 Number of stations occupied

The number and distribution of photographic and trawl stations occupied was very similar to the design (Table 2). One photographic station was removed from stratum 201 and replaced with an additional one in stratum 403 to avoid a time-consuming steam to the former and the probable loss of a station elsewhere due to time constraints. The 23 trawl stations were occupied exactly as in the design, although one had to be repeated twice because of net damage caused by foul ground.

***Table 2*: Design and actual allocation of shots among strata for a photographic and trawl survey to estimate relative biomass of scampi in QMA 1**

			Photo stations		Trawl stations	
Stratum	Area (km^2)	Depth (m)	Design	Actual	Design	Actual
201	839	200–300	3	2	1	1
202	307	300–400	4	4	2	2
203	311	400–500	3	3	2	2
204	275	500–600	3	3	1	1
301	315	200–300	3	3	1	1
302	262	300–400	4	4	2	2
303	266	400–500	5	5	2	2
304	209	500–600	3	3	1	1
401	237	200–300	3	3	1	1
402	378	300–400	5	5	2	2
403	290	400–500	4	5	2	2
404	420	500–600	3	3	1	1
501	218	200–300	3	3	1	1
502	186	300–400	3	3	2	2
503	166	400–500	3	3	2	2
Totals	4679		52	52	23	23

10.1 Number of photographs, sampling frequency, and sampled area

Of the 2117 images saved to disk, about 1840 (86%) were considered suitable for counting scampi burrows (compared with 68% of emulsion-based images in 1998). The rejected images included photographs taken in mid-water (95 images), on the deck (92 images), or because of poor quality (69–110 images according to the reader). The three readers scored readability independently, and the number of photographs considered usable varied from 1821 to 1861. Of the 1930 sea-bed images, therefore, only about 5% were rejected because of poor quality. This is a considerable improvement on the 1998 method, made possible by the use of the direct acoustic monitoring of distance off-bottom rather than the new cameras.

The total number of captured, readable images was very close (97–99%) to the nominal target of 1872 photographs (36 at each of 52 stations, Table 3), but the distribution among these stations was not even (range 15–43, excluding the last station where only two images were captured before the flash system failed and could not be repaired before the end of the voyage). The number of photographs per station was much more consistent than we managed in the 1998 survey (11–95 photographs per station) as, using the new system, it was rare to expose additional frames due to swell and handling difficulties (this was a significant problem in 1998, despite relatively calm weather). In addition, the "real time" availability of images meant that additional transects could be completed if the number of captured images was too small.

The target time lag between consecutive photographs in 2000 was one minute (90 seconds in 1998). Over 90% of all images and almost all images within transects were separated by this amount. This again is a significant improvement on the method we used in 1998, and can also be attributed to the use of direct monitoring of distance off-bottom. Operationally, this has two main advantages; fewer images were spoiled by sediment plumes from the dragging trigger weight, and fewer "repeat" or overlapping photographs of the same ground were taken (reducing the possibility of spurious precision in the counts).

All three readers scored about two-thirds of accepted images as grade 2 (good quality), about one quarter as grade 1 (excellent), and the remainder (about 6–7%) as grade 3 (borderline). The proportion of grades varied greatly among stations: grade 1, 0–89% of images; grade 2, 10–100%; grade 3, 0–64%. Probably because of increasing water clarity, there was a decrease in the proportion of poor quality images with increasing depth, and a concomitant increase in good quality images. The proportion of images of excellent quality was variable, but not apparently related to depth (Figure 2).

Table 3: **Number of photographic stations and transects occupied, and the number of useable seabed images and their aggregate area accepted by three readers from voyage KAH0001. Stratum codes are those used in the previous photographic survey (KAH9801) and in trawl surveys (KAH9301, 9401, and 9501)**

			Number of images scored			Total area (m^2) of scored images		
Stratum	Stns	Transects	Reader 1	Reader 2	Reader 3	Reader 1	Reader 2	Reader 3
201	2	5	65	68	67	561	588	582
202	4	12	158	159	159	1 562	1 569	1 562
203	3	9	117	119	119	1 236	1 256	1 256
204	3	8	101	101	101	1 150	1 156	1 156
301	3	7	88	89	89	783	793	793
302	4	13	150	153	153	1 342	1 369	1 369
303	5	17	186	197	190	1 624	1 710	1 660
304	3	9	108	108	108	1 184	1 184	1 184
401	3	9	111	111	111	1 021	1 021	1 021
402	5	15	203	204	204	1 912	1 921	1 921
403	5	12	175	180	178	1 771	1 823	1 796
404	3	7	60	60	60	684	684	684
501	3	10	69	76	71	594	655	612
502	3	9	109	113	112	969	1 022	1 012
503	3	9	121	123	123	1 280	1 303	1 303
Totals	52	151	1821	1861	1845	17 673	18 055	17 910

The sampled area of each photograph depends on the exact height of the camera above the seabed at the time of exposure. In 1998, estimating the area of seabed in each photograph was complicated by uncertainty over the extent to which the trigger weight might have sunk into soft sediments before the camera was triggered (the known dimensions of the trigger weight were used to scale image area). In the 2000 survey, parallel lasers were used to scale the seabed images, and this is not subject to the same uncertainty; unless the seabed is very steep, the two laser dots on the seabed can be assumed to be 200 mm apart and this can be used to estimate the area of the image. Most images in 2000 covered an estimated seabed area of 7–12 m^2 (Figure 3), at which range the flash coverage and exposure were good.

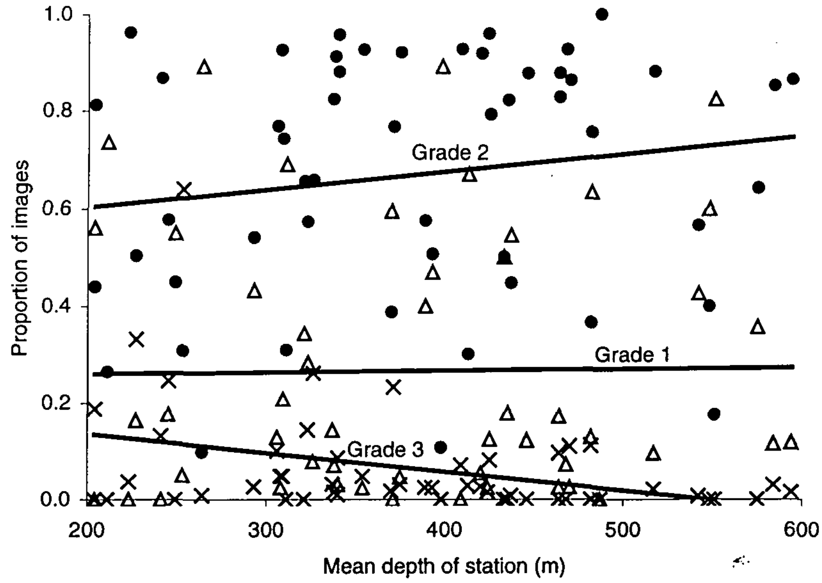

***Figure 2*: The average proportion by station of images classified as grade 1 (triangles, excellent quality), grade 2 (closed circles, good quality), and grade 3 (crosses, borderline quality). Lines denote linear regressions showing the average proportion for each grade by depth.**

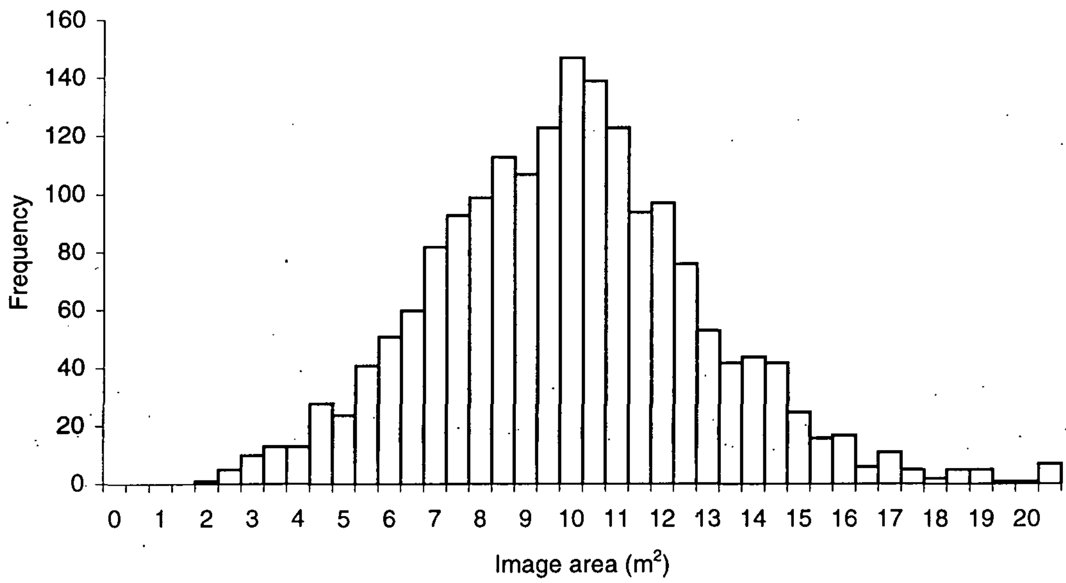

***Figure 3*: Frequency distribution of the estimated area in each image within which the seabed was sufficiently well-defined to allow counts to be made of scampi burrows.**

Only 3–6% of images had an estimated usable proportion of less than 70%. This varied with the reader; one reader accepted slightly more borderline images than the other two but scored these with a lower readable area. This is a distinct improvement on 1998 when about 10% of accepted images were 30–50% occluded.

10.2 Density of scampi burrows and burrow openings

At the first reading, from the 1821–1861 images accepted for analysis, 2433 and 2483 burrow openings were counted by two of the readers and 944 by the third. The three readers estimated that these openings were components of 1362, 1462, and 820 burrows, respectively (Table 4, Appendices 3 & 4). Clearly, there are major differences in interpretation between the first two readers and the third reader, but the first two readers agreed on about two-thirds of the accepted images.

There can be no guarantee that all openings in the field of view were counted, nor that all openings counted belonged to scampi. Many types of burrowing animal are found in or on marine sediments, and the holes and burrows of these various taxa cannot always be reliably distinguished. Overseas studies (e.g., Marrs *et al.* 1996) have shown that the burrows of *Nephrops norvegicus* usually have several distinguishing features, but that none of these is 100% reliable in ascribing a particular seabed feature to a scampi burrow or opening. Scampi burrows are often simple linear tunnels with openings at one or both ends, but they can also be very complex and have many openings, separated by up to about 1.5 m (although the average maximum dimension of a burrow is thought to be about 500 mm, Marrs *et al.* 1996). Thus, any estimate of the number of burrows in a photograph and the number of openings associated with those burrows must be at least partly subjective. In addition, whereas the size of a single burrow opening is small compared with the sampling footprint, the size of a burrow with one to many openings is much larger and similar in scale to the sampling footprint. This means that estimates of mean burrow density made by scaling up the mean number of burrows partly or wholly within a number of photographs will be positively biased. Recent simulation work has shown this bias to be potentially large (~30%) for burrows of *Nephrops norvegicus* counted by video transect (ICES 2000).

For the two readers in broad agreement, the mean density of putative burrow openings by stratum varied from 0.008 to 0.308 m^{-2} (0.008–0.239 for reader 2) with an overall mean (Gt. Barrier Island to Cape Runaway) of 0.105 m^{-2} (0.104 m^{-2}) (Table 5, Appendices 2 & 3). The mean density of putative scampi burrows by stratum varied from 0.004 to 0.158 m^{-2} (0.007–0.137 for reader 2) with an overall mean of 0.058 m^{-2} (0.062 m^{-2}). Reader 3 made lower counts for most strata. The density estimates for readers 1 and 2 are similar to those observed for *Nephrops norvegicus* in Scottish waters on the Fladen Ground (0.006–0.312 m^{-2}, Bailey *et al.* 1993) and in the Firth of Clyde (0.072–0.390 m^{-2}, Tuck *et al.* 1997), but are about half of the estimates of overall density given by Cryer & Hartill (1998) for the 1998 photographic survey between Cuvier Island and White Island (which was assessed by only one reader).

We therefore examined the February 2000 counts for the 1998 survey area between Cuvier Island and White Island (Table 6). For the two readers in broad agreement, the mean density of putative burrow openings by stratum varied from 0.013 to 0.211 m^{-2} (0.013–0.233 for reader 2) with an overall mean of 0.113 m^{-2} (0.122 m^{-2}). The mean density of putative scampi burrows by stratum varied from 0.007 to 0.113 m^{-2} (0.007–0.132 for reader 2) with an overall mean of 0.062 m^{-2} (0.073 m^{-2}). Reader 3 usually made lower counts.

Table 4: **The mean density and standard error of mean density of putative scampi burrow openings for three readers (*see* Tables 1–3 for details of allocations of stations and transects among strata). Figures in parentheses are c.v.s for the overall mean estimates**

		Reader 1		Reader 2		Reader 3	
Stratum	Area (km^2)	Mean	S.E.	Mean	S.E.	Mean	S.E.
201	839	0.0084	0.0084	0.0075	0.0045	0.0000	0.0000
202	307	0.1921	0.0803	0.2394	0.0495	0.0137	0.0041
203	311	0.0422	0.0097	0.1855	0.0579	0.0032	0.0009
204	275	0.0242	0.0144	0.1014	0.0857	0.0019	0.0019
301	315	0.0126	0.0062	0.0320	0.0152	0.0000	0.0000
302	262	0.2113	0.0603	0.2334	0.0488	0.0306	0.0062
303	266	0.1939	0.0203	0.2295	0.0492	0.0162	0.0076
304	209	0.0434	0.0188	0.0876	0.0214	0.0045	0.0025
401	237	0.0306	0.0186	0.0628	0.0336	0.0120	0.0062
402	378	0.1623	0.0291	0.1960	0.0365	0.0783	0.0466
403	290	0.1666	0.0151	0.1546	0.0307	0.1215	0.0656
404	420	0.0749	0.0382	0.0127	0.0079	0.2482	0.2257
501	218	0.3078	0.1897	0.0315	0.0158	0.1207	0.0551
502	186	0.1553	0.0744	0.0769	0.0181	0.1694	0.0280
503	166	0.2353	0.0788	0.0634	0.0214	0.1203	0.0211
Total	4 679	0.1045	(0.12)	0.1040	(0.09)	0.0574	(0.37)

Table 5: **The mean density (with its c.v.) for reader 1, and estimated abundance of putative scampi burrow openings between Gt. Barrier Island and Cape Runaway, 200–600 m depth**

Stratum	Area (km^2)	Mean Density (m^{-2})	c.v.	Estimated Abundance
201	839	0.0084	1.0000	7 007 362
202	307	0.1921	0.4178	58 982 950
203	311	0.0422	0.2306	13 130 981
204	275	0.0242	0.5945	6 642 023
301	315	0.0126	0.4948	3 957 921
302	262	0.2113	0.2855	55 366 213
303	266	0.1939	0.1047	51 586 806
304	209	0.0434	0.4327	9 060 492
401	237	0.0306	0.6079	7 244 885
402	378	0.1623	0.1794	61 339 279
403	290	0.1666	0.0905	48 324 598
404	420	0.0749	0.5092	314 72 663
501	218	0.3078	0.6162	67 104 581
502	186	0.1553	0.4789	28 891 981
503	166	0.2353	0.3348	39 058 969
Total (1998 area)	2 377	0.1129	0.0996	268 352 858
Total (all strata)	4 679	0.1045	0.1204	489 171 705

Using February 2000 data from reader 1, the estimated abundance of burrow openings was 489 million between Gt. Barrier Island and Cape Runaway, and 268 million in the 1998 survey area between Cuvier Island and White Island. The latter is only 30% of the comparable estimate for 1998 (883 million openings, Cryer & Hartill 1998)), and is highly significantly different (by simulation, $p < 0.001$).

Table 6: **A comparison of the estimated average density and population abundance of scampi burrow openings (front or rear) in the 1998 and 2000 photographic surveys, limited to the area surveyed in 1998 (Cuvier Island to White Island, 200–600 m). Data from reader 1 in both years**

	1998 survey (KAH9801)			2000 survey (KAH0001)			
Stratum	Mean density (m^{-2})	*c.v.*	Estimated abundance	Mean density (m^{-2})	*c.v.*	Estimated abundance	Change
301	0.0691	0.64	21 761 157	0.0126	0.49	3 957 921	-82%
302	0.4526	0.52	118 589 319	0.2113	0.29	55 366 213	-53%
303	0.6646	0.51	176 796 429	0.1939	0.10	51 586 806	-71%
304	0.398	0.48	83 176 812	0.0434	0.43	9 060 492	-89%
401	0.1902	0.53	45 068 781	0.0306	0.61	7 244 885	-84%
402	0.4967	0.28	187 739 309	0.1623	0.18	61 339 279	-67%
403	0.4236	0.41	122 853 679	0.1666	0.09	48 324 598	-61%
404	0.3015	0.90	126 648 953	0.0749	0.51	31 472 663	-75%
Total	0.3713	0.09	882 634 439	0.1129	0.10	268 352 858	-70%

Cryer & Hartill (1998) tabulated direct estimates by stratum of burrow abundance and estimated that, by this method, there was a total of 468 million burrows between Cuvier Island and White Island. However, they noted that this method was probably positively biased by edge effects (since confirmed by simulation work by European workers on *N. norvegicus*, ICES 2000), and we do not pursue it here.

10.3 Density and size of visible scampi

The three readers observed slightly different numbers of scampi in the images they each accepted for analysis during the first reading. The differences in the number observed were not due entirely to the different numbers of images; some scampi were missed or not recorded by one, two, or all three observers, although some images were equivocal. Of 124 and 126 scampi observed by readers 1 and 2, however, about 60% (63% for reader 2) were partly obscured in burrows and the remaining 40% (37%) were walking on the surface. Reader 3 recorded only 101 definite scampi, of which only 47% were in burrows. This was another major difference in interpretation among the readers and was probably a result of reader 3 applying a stricter criterion of acceptance for scampi partly obscured by a burrow (for instance, only the chelipeds or antennae of some scampi accepted by readers 1 and 2 were visible, and reader 3 may not have considered this as sufficient evidence).

Estimates of visible scampi per unit area can be considered as minimum absolute abundance estimates (minimum because we presume that at least some scampi must be hidden in their burrows some of the time). The mean density of visible scampi by stratum varied from 0 to 0.022 m^{-2} (0–0.019 for reader 2) with an overall mean of 0.005 m^{-2} for both readers 1 (Table 7) and 2.

Table 7: **The mean density, standard deviation of mean density, and estimated number of individual visible scampi in each of the sampled strata, data from Reader 1**

Stratum	Area (km^2)	Mean Density (m^{-2})	s.d.	*c.v.*	Estimated Abundance
201	839	0.0000	0.0000	–	0
202	307	0.0049	0.0047	0.48	1 508 591
203	311	0.0023	0.0023	0.56	727 579
204	275	0.0039	0.0067	1.00	1 071 656
301	315	0.0000	0.0000	–	0
302	262	0.0144	0.0079	0.27	3 768 227
303	266	0.0142	0.0063	0.20	3 773 130
304	209	0.0014	0.0025	1.00	298 761
401	237	0.0020	0.0035	1.00	482 216
402	378	0.0220	0.0196	0.40	8 319 508
403	290	0.0067	0.0061	0.41	1 951 641
404	420	0.0000	0.0000	–	0
501	218	0.0011	0.0019	1.00	237 102
502	186	0.0072	0.0075	0.60	1 338 969
503	166	0.0030	0.0035	0.67	502 710
Total	4 679	0.0051	0.0009	0.17	23 980 090

Table 8: **A comparison of the estimated average density and population abundance of visible scampi in the 1998 and 2000 photographic surveys, limited to the area surveyed in 1998 (Cuvier Island to White Island, 200–600 m). Data from reader 1 in both years**

Stratum	1998 survey (KAH9801) Mean density (m^{-2})	*c.v.*	Estimated abundance	2000 survey (KAH0001) Mean density (m^{-2})	*c.v.*	Estimated abundance	Change
301	0.0007	0.62	215 421	0.0000	–	0	–
302	0.0159	0.30	4 162 768	0.0144	0.27	3 768 227	-9%
303	0.0362	0.24	9 638 360	0.0142	0.20	3 773 130	-61%
304	0.0114	0.34	2 373 991	0.0014	1.00	298 761	-88%
401	0.0041	0.50	963 105	0.0020	1.00	482 216	-51%
402	0.0308	0.29	11 654 909	0.0220	0.40	8 319 508	-29%
403	0.0144	0.46	4 164 508	0.0067	0.41	1 951 641	-53%
404	0.0027	0.44	1 148 174	0.0000	–	0	–
Total	0.0144	0.14	34 321 236	0.0078	0.20	18 593 483	-46%

From this analysis, it can be estimated that the abundance of scampi (of all sizes) between Gt. Barrier Island and Cape Runaway, 200–600 m depth, in February 2000 was at least 24–26 million animals (with a c.v. of 17–30%, depending on reader). This is lower than the minimum estimate of at least 34 million animals (with a c.v. of about 14%) recorded by Cryer & Hartill (1998) for the significantly smaller area between Cuvier Island and White Island in 1998. Restricting the 2000 analysis to this area reduces the minimum estimate to 18–20 million animals (with a c.v. of 20–39%, depending on reader), 53–59% of the 1998 estimate (Table 8). The first readings of readers 1 and 2 both suggested that the abundance of visible scampi between Cuvier Island and White Island was significantly lower in 2000 than it was in 1998 (by simulation, $p < 0.01$).

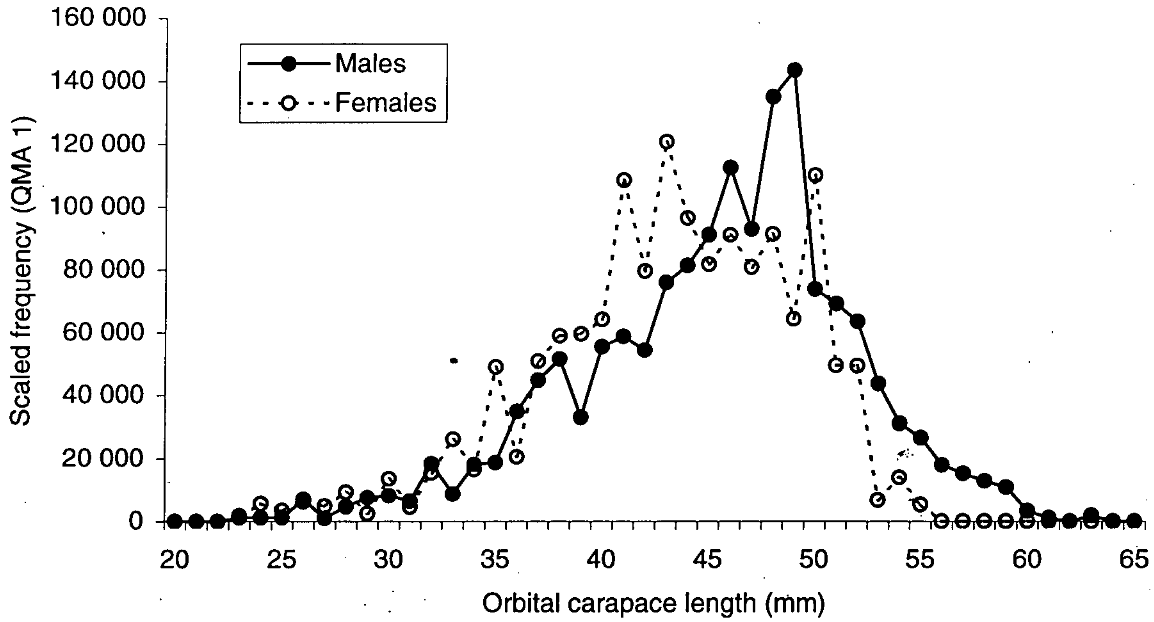

***Figure 4*: Length frequency distributions (scaled to the whole survey area) for male and female scampi taken by trawl during the 2000 survey. A total of 2876 scampi were caught, of which 1652 were measured. The scaled total is 3.00 million animals in the survey area, assuming a trawl width of 40 m.**

During the 2000 survey, a total of 173.0 kg of scampi was caught, comprising an estimated 2876 individuals, of which 1652 were sexed and measured. This equates to an estimated average weight of 60.2 g for animals caught during the voyage. The length frequency distributions of male and female scampi (Figure 4) were used to estimate the population average weight of animals vulnerable to the gear (scaled by catch weight and stratum size) using the length-weight regressions given by Annala *et al.* 2000. Using this method, the population average weight of males was estimated to be 64.8 g and that of females to be 53.9 g. The overall average was 59.5 g. This is very close to the average weight of the animals caught because most shots swept similar areas and the strata are mostly of similar size; the weighting procedure had relatively little effect. Cryer & Hartill (1998) estimated the average weight of scampi caught by trawl between Cuvier Island and White Island in 1998 to be 60.5 g.

The smallest estimated length for a measurable scampi observed in a photograph in 2000 was 17 mm OCL, the largest 62 mm. Using the average predicted weight for male and female length weight regressions for animals up to 48 mm and the predicted weight from a male length weight regression for all larger animals, the estimated average weight for measurable scampi in the 2000 survey was 38.3 g. This is close to the 1998 estimate of 35.4 g (Cryer & Hartill 1998).

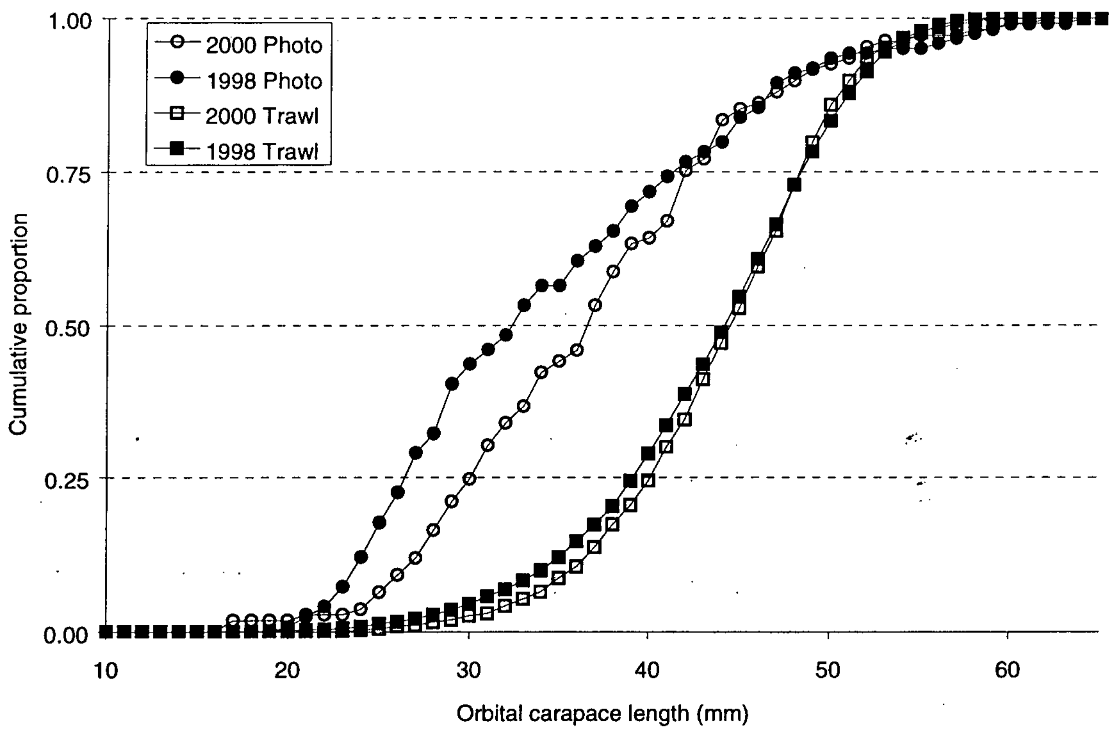

***Figure 5*: Cumulative proportional length frequency distributions of scampi caught by trawl (squares) and by photography (circles). Closed symbols, 1998 survey, open symbols, 2000 survey.**

The estimated cumulative proportional length frequency distributions of measurable scampi observed in photographs and from parallel trawling in 1998 and 2000 are shown in Figure 5. Both trawl and photographic distributions from 2000 show fewer small animals than in 1998, although the difference between the two trawl samples is much less than the difference between in the two photographic samples. That both trawl and photographic methods show fewer small animals in 2000 suggests that this may be a real feature of the population; either small scampi were emerging from their burrows less in 2000, or there were fewer of them.

10.4 Variability in interpretation among readers

The interpretation and counting of scampi burrow openings among the three readers can be explored at several levels. At the level of single images, all three readers agreed on the count of burrow openings for 433 of the 1821 (24%) images accepted by reader 1 as usable. There was agreement among at least two readers for 1188 images (65%). The remaining 633 images (34%) where all three counts were different contain most of the variability among the readers.

Table 9: **The level of agreement among the three readers for three levels of image quality (as scored by reader 1)**

Level of agreement	Quality of image			Total
	Excellent	Good	Borderline	
All agreed	118	297	18	433
One disagreement	168	536	51	755
All disagree	202	381	50	633
Total	488	1214	119	1821

Differences in counts of burrow opening were not caused by variation in image quality. There was complete disagreement over the counts for about 40% of images of excellent quality, and a very similar proportion for images of borderline quality. This suggests that the differences in counts are caused by differences in reader interpretation as to what constitutes a burrow likely to be inhabited by scampi.

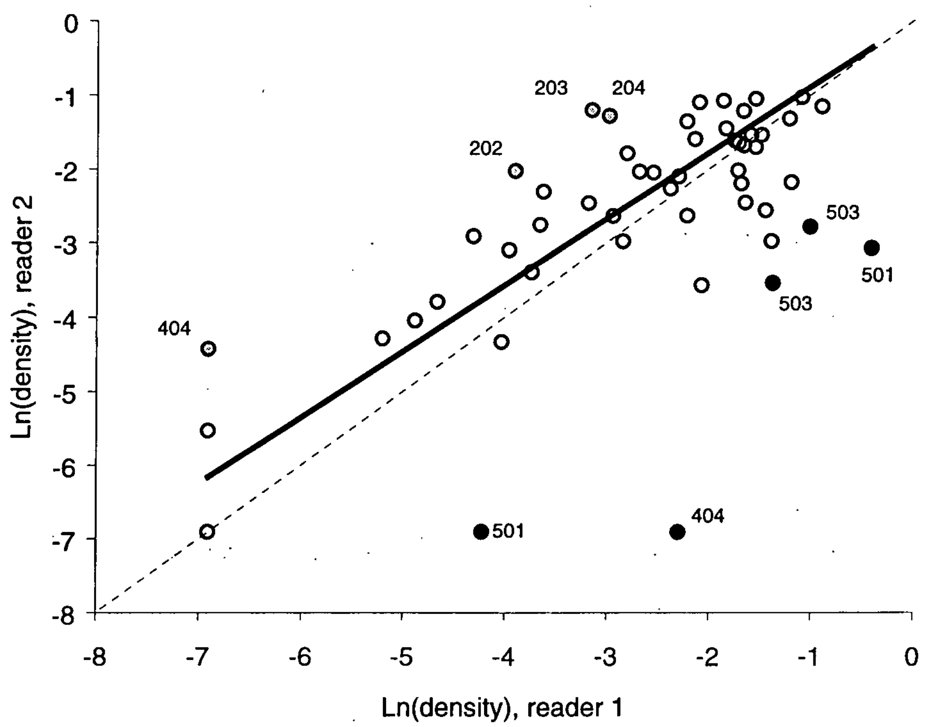

Figure 6: **Correlation (at a station level) between estimated density of scampi burrow "openings" (front or rear) by readers 1 and 2. The solid line is a least squares regression of reader 2's estimates on reader 1's estimates and the dotted line is the theoretical line of equivalence. Stratum codes are given for stations where the difference between the two readers was extreme.**

At a station level (all transects at a station combined), there was reasonable correlation between the estimates of burrow opening density generated by readers 1 and 2 (Figure 6; log-transformed data, $r_{50} = 0.64$, $p < 0.001$). However, there were some stations at which the estimates of density were very different for the two readers. Such stations had burrows and openings that most vividly portray the differences in interpretation among readers, and we used them to develop criteria for more consistent interpretations. We have developed a library of images of confirmed scampi burrows (with associated animals) and found it indispensable.

At the stratum level (Figure 7), readers 1 and 2 agreed quite closely for the four strata that cover about two-thirds of the commercial fishery (strata 302, 303, 402, and 403, Mercury Islands to White Island, 300–500 m depth). This means that indices generated for the core area of the fishery using counts from these two readers would be very similar. However, there were wide disagreements between these two readers for strata 203 (Great Barrier Island, 400–500 m) and 501 (Cape Runaway, 200–300 m). Reader 3 estimated consistently low or very low densities in the strata where the commercial fishery concentrates, but recorded his highest counts in strata 404 (Mayor Island, > 500 m) and 502 (Cape Runaway, 300–400 m). There was also a north-south trend in interpretation; in the northern strata, reader 2 tended to have the highest readings whereas reader 1 or reader 3 had higher readings in the southern (eastern) strata. Images from these strata were re-examined to assess the extent to which the first reading was consistent with our developing understanding of what constitutes a scampi burrow.

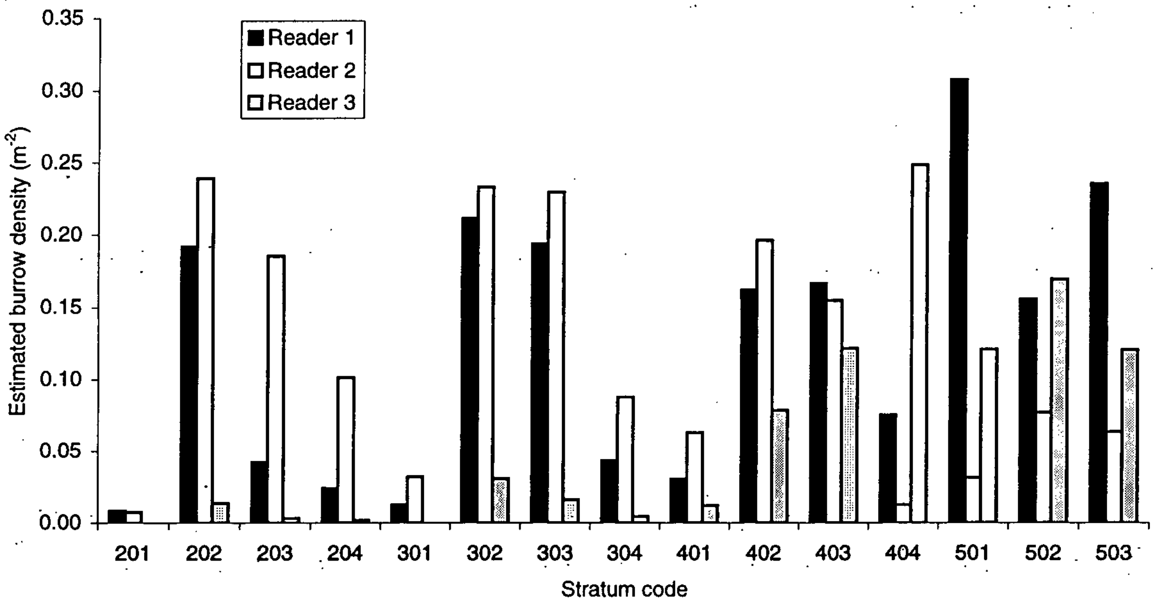

Figure 7: **Estimates at a stratum level of the density of scampi burrow "openings" (front or rear) by the three readers. The bulk of the fishery is in strata 302, 303, 402, and 403 where readers 1 and 2 tended to agree quite closely. Stations within strata were weighted equally because they contained similar numbers of photographs.**

10.5 Interpretation of differences between 1998 and 2000

At first reading by reader 1 (Martin Cryer), the estimated density of burrow openings in 2000 was considerably lower than in 1998. The difference was quite consistent among strata and applied to the number of scampi (2000 estimate about 50% of the 1998 estimate) as well as to the number of burrow openings (2000 estimate about 30% of the 1998 estimate). There are five plausible explanations:

- The abundance of scampi declined between 1998 and 2000
- M. Cryer's interpretation of scampi burrows changed between 1998 and 2000

- Digital images lack the definition required to classify burrows accurately
- Either the 1998 or 2000 method of estimating image area was biased
- By chance stations of lower density were sampled in 2000 (or insufficient images were taken to provide a reliable assessment of average density)

The Shellfish Fishery Assessment Working Group considered each of these propositions in detail at a meeting in September 2000. The working group considered it unlikely that the abundance of scampi would have declined by 70% between 1998 and 2000 without some indication in the fishery (average unstandardised CPUE increased by about 6% between the 1997–98 and 1998–99 fishing years, unpublished results of project SCI1999/01). The definition of digital images was shown to be lower than that of emulsion images, but at the scale of most scampi burrows, the group considered this not to be a problem. The decline in visible scampi between 1998 and 2000 was of similar magnitude to the decline in burrows, and interpretations of scampi are more certain than those of burrows. This is consistent with the proposition that stations of lower density were sampled in 2000. Photographically-estimated length frequency distributions for the two years were very similar, suggesting that resolution was not an issue in the detection of small (less visible) scampi, and that any bias in estimating image area (and linear dimensions within images) was probably small.

Overall, the working group thought that interpretations of scampi burrows had probably changed between 1998 and 2000 (following M. Cryer's discussions with overseas scientists involved in similar work in the Scottish fishery). It was also considered plausible that, by chance, stations of relatively low density were visited in 2000, especially since the density of visible scampi was also lower in 2000. The working group agreed to the following actions to examine the issue:

- Assembly of the library of definite scampi burrows was a priority
- Differences in interpretation among readers should be explored and rationalized
- All non-agreed images for 2000 should be re-read, possibly "by committee"
- Density and biomass estimates for 2000 should be recalculated
- Images from 1998 should be re-read by more than one reader
- Density and biomass estimates for 1998 should be recalculated and compared with 2000
- The precise location of 2000 photographs should be compared with 1998 photographs
- If possible, density estimates at locations sampled in both years should be compared

10.6 Development of a standardised protocol for counting burrows

There were significant differences among the three readers in the interpretation of scampi burrows and burrow openings, and at the photograph level, correlation between readers (with about 2000 degrees of freedom) averaged only 0.32. The first step in rationalising this inconsistency was the compilation of a library of images showing scampi associated with burrows. About 100 emulsion images from the 1998 survey were scanned electronically, printed to A4 pages, and compiled into a "library". All three readers examined these images independently and took note of the characteristics of burrows and burrow openings associated with scampi. Notes were then compared and the "defining characteristics" broadly agreed (Appendix 2).

A sample of 400 images from the most contentious strata was selected for assessment of these defining characteristics in a "semi-blind" trial. These images accounted for 69% of all between-reader variation in the 2000 survey, and about 71% of between-reader variation in the core area of the QMA 1 fishery in strata 302, 303, 402, and 403 (Mercury Islands to White Island, 300–500 m depth). Many of the stations selected for analysis were "outliers" in the relationship shown in Figures 6 & 7, but some were from high density strata to allow a large number of burrows to be examined. All three readers convened with independent computers with access to the images. Each nominated image was viewed and manipulated (in spectral intensity, contrast, brightness, and magnification) by each of the readers until all were satisfied with their interpretation and counts (based on the agreed defining characteristics). The interpretations were then discussed and recorded. Sometimes one or more reader changed their interpretation following discussion.

During these discussions, a consensus developed that burrows seen to be inhabited by *Metanephrops challengeri* usually have a shallow, crescentic "major" opening, a "fan" of spoils spreading in front of the major opening, a minor opening that is usually trench- or tunnel-like but can be either steep or shallow, and well-defined tracks leading to either or both of the openings. Moreover, most of these burrows have two openings, are linear, and are quite short (often less than the 50 cm regarded as a minimum for *Nephrops norvegicus*, Marrs *et al.* 1996). Complex burrow systems and single opening burrows seem to be rare for *M. challengeri.* This may represent a difference in the burrowing behaviours of the two species, or it may be a factor of density, depth, substrate type, or time of year.

***Table 10*: Average number of "definite" and "probable" burrow openings (per image) recorded by three readers using a standardised counting protocol for 401 images in a semi-blind trial**

	All openings		Major openings only	
Reader	Definite	Definite + Probable	Definite	Definite + Probable
Reader 1	0.68	1.72	0.35	0.94
Reader 2	0.73	1.82	0.40	1.01
Reader 3	0.60	1.60	0.33	0.98

***Table 11*: Correlation coefficients (399 d.f.) for all burrow openings (major plus minor) and for major openings only among three readers scoring 401 sea-bed images according to a preliminary set of agreed "defining characteristics" in a semi-blind trial**

All openings

	Definite openings only			Probable + definite openings	
	Reader 1	Reader 2		Reader 1	Reader 2
Reader 2	0.939	–	Reader 2	0.875	–
Reader 3	0.913	0.879	Reader 3	0.861	0.842

Major openings only

	Definite openings only			Probable + definite openings	
	Reader 1	Reader 2		Reader 1	Reader 2
Reader 2	0.938	–	Reader 2	0.861	–
Reader 3	0.921	0.886	Reader 3	0.835	0.818

The three readers accepted and scored similar numbers of burrows at the second reading (Table 10) and correlation of burrow density estimates among readers increased from about 0.32 (for the first reading) to about 0.86 (for all burrows) and to about 0.91 (for those considered to be "definite" scampi burrows, Table 11). All three readers recorded the same count at first and second readings for about 40% of the images, but the relative proportions of increases and decreases at the second count were very different. Readers 1 and 2 recorded a higher count at the second reading about 25% of the time, whereas reader 3 had a higher count at the second reading for 53% of images. Readers 1 and 2 both recorded about 24% fewer openings at the second count (after examining the library of images of scampi associated with burrows) whereas reader 3 recorded about a five-fold increase. These differences are not likely to be representative of differences across the whole survey; the images for the semi-blind trial were selected because the showed the greatest disparities at the first reading.

***Table 12*: Differences between counts at the first and second reading for three readers in a semi-blind trial to examine the most contentious images**

	No change	2nd count lower	2nd count higher	1st count zeros	2nd count zeros	1st count openings	2nd count openings	Change in openings
Reader 1	174	125	102	170	164	900	688	-23.6%
Reader 2	155	154	92	117	150	961	730	-24.0%
Reader 3	155	29	217	336	171	122	640	+424.6%

The developing consensus about burrow structure in *Metanephrops challengeri* (codified as a set of agreed characteristics) suggests that it should be possible to generate a consistent and reliable relative index of biomass for this species by counting burrows. This could be done several ways by counting all openings or just major openings, and by counting openings probably belonging to scampi or just those "definitely" belonging to scampi. Consistency among readers for the subsample of 400 images was greatest for the most constrained count, that of "definite, major entrances". Because the size of even major entrances is small compared with the size of photographs, this count should also be an unbiased index of the number of burrows.

10.7 Feasibility of developing an absolute abundance index (Objective 2)

Photographic sampling methods have been used in the assessment of several European stocks of *Nephrops norvegicus* for some years (e.g., Bailey *et al.* 1993, Anon. 1997, Marrs *et al.* 1996, Tuck *et al.* 1997, Marrs *et al.* 1998). These assessments have tended to concentrate on underwater television (rather than still photographs) and have been shown (Tuck *et al.* 1997) to generate biomass estimates similar to those generated by larval surveys and analytical approaches in vogue within the ICES area (Virtual population analysis, VPA, and Length cohort analysis, LCA). This ability to generate comparable (absolute) biomass estimates for reliably assessed stocks in Europe suggests that it should be (at least scientifically) feasible to develop estimates of absolute scampi abundance and biomass from estimates of the relative abundance of their burrows. Some of the problems were summarised by Marrs *et al.* 1998:

- Consistent identification of burrows is difficult in areas with a high overall density of burrows (including scampi and other species).
- Differentiation of burrows is difficult in areas with a high density of small scampi.
- Counting can be difficult in turbid waters, and this is not always improved by siting the camera closer to the seabed (especially with regard to edge effects).
- There is no infallible means of assessing the occupancy of individual burrows.
- Tow length needs to be carefully optimised and measured (for still cameras this problem would relate to assessing the camera field of view).
- Edge effects mean that counting all burrows which impinge on a video transect is likely to be positively biased when scaling up to stratum area.

- Accurate scaling of counts to estimate stratum abundance can be a real problem where sediment type distribution (and consequent scampi density) is poorly known.

Some of these problems relate also to the generation of consistent relative biomass indices, and are discussed under Objective 1.

Part of the analysis of the 1998 pilot photographic survey (Cryer & Hartill 1998) was an assessment of absolute biomass of scampi (of all size classes) within the survey area. As there was almost no information available on the mean number of entrances per burrow, the mean number of scampi per burrow, assumed values based on overseas studies were used for these calculations. Local estimates from photographs or parallel trawling were used to estimate the mean weight of scampi in the population

The assumed values for the mean number of entrances for each burrow used by Cryer & Hartill (1998) were based primarily on work on *Nephrops norvegicus* in Scottish, Swedish, and Mediterranean waters (Chapman & Rice 1971, Rice & Chapman 1971, Atkinson 1974, 1989, Tuck *et al.* 1994, Marrs *et al.* 1996, and Hillis 1974, Nash 1980 both cited in Marrs *et al.* 1996). Burrow structure was examined in these studies by resin casting, by direct observation by SCUBA divers using torches, or by "mapping", whereby entrances are grouped together by experienced observers into putative burrows using high quality still photographs. These authors agreed that the best quality information was derived from resin casts, but similar results were generated by SCUBA divers inspecting entrances and tunnels. The information generated by mapping was thought to be the most subjective. In European studies, many burrows were simple tunnels with two entrances, but some were complex and had six entrances or more (Marss *et al.* 1996). In some places, the complexity and patchiness of burrows varies seasonally (Tuck *et al.* 1994, Marss *et al.* 1998).

Because of the great depth at which this species occurs, none of the diver methods of assessing the number of entrances per burrow can be used for *M. challengeri*. However, some of these methods might be simulated using a highly-specified remote operated vehicle with a manipulator arm and, perhaps, some means of injecting resin, dye, or irritant to elucidate burrow structure or expel the inhabitant. Remote operated vehicles with this level of specification are very expensive, especially if they are to work at depths over about 200 m (when a system with a "garage" or "staging point" becomes necessary to avoid problems with drag from a long, trailing umbilical). Considering the depth and the likelihood of access to a suitably powerful and sophisticated remote operated vehicle, it will probably be more fruitful to attempt burrow mapping using good quality seabed images and video. Our work suggests that most burrows of *M. challengeri* are short, linear, and simple, usually with two distinctly different openings. If this is characteristic of the species (and not just of the season, depth, and location of our sampling to date), then "burrow mapping" will be more reliable than it has been found to be in Europe, as well as being more tractable.

European studies have tended to indicate that only a single adult *Nephrops norvegicus* is usually found in each burrow. However, these burrows are often shared with other taxa (such as certain crabs and fish, e.g., Marrs *et al.* 1996), and with juvenile *Nephrops norvegicus* (Tuck *et al.* 1994). We cannot judge how this might relate to *M. challengeri*, but we think the best approach is probably to make long term (many hours or days) video observation using moored cameras.

According to Marrs *et al.* (1996), burrows tend to decay and fall into disrepair quite soon after the occupant leaves, suggesting that burrows are under relatively frequent repair by the occupant. Moreover, burrows which are destroyed experimentally are very quickly re-established (within about 2 days) suggesting that repair work can be rapid if need be. However, despite the speed and efficiency with which *Nephrops norvegicus* can repair its burrow, no completely reliable means has been found to assess the occupancy of given burrows from its "state of repair", even when direct and careful observation by divers is possible. The three indicators that gave the best evidence of whether or not a burrow was occupied are, apparently, the cross sectional shape of the entrance, the presence of tracks on the sediment surface near to the burrow, and evidence of recent excavation (Marrs *et al.* 1996). Occupied burrows in European studies were more likely than unoccupied burrows to have clear signs of tracks and recent excavation, and tended to have a "subcircular" cross section (a flat floor, steep walls, and a domed roof) as opposed to the dorso-ventrally flattened elliptical cross section common in decaying burrows. Some of these characteristics can be observed in good quality photographs, but according to Marrs *et al.* (1996), even in combination they do not give a wholly reliable indication of occupancy.

Most of the burrows seen to be inhabited by *M. challengeri* have these same characteristics as those currently inhabited by *N. norvegicus*. These are a well-formed, crescentic major opening, tracks on the sediment surface, and a "fan" of recent spoils in front of the major opening (usually of a slightly different colour or texture than the surrounding sediment). Again, given the likely costs and difficulties associated with a highly-specified remote operated vehicle, we think that video filming using moored cameras offers the best opportunity by observing the "comings and goings" of scampi and other invertebrates from burrows of particular types.

The most important information required to convert an estimate of abundance to an estimate of biomass in a given area is the population length frequency distribution. The work carried out by NIWA in 1998 and this project (Cryer & Hartill 1998, 2000) shows that estimates of length frequency distribution can be made using measurements from photographic images, and that these may be better than direct estimates from trawl caught animals. However, the relative emergence rates of large and small scampi appear from both studies to be different; Cryer & Hartill (1998) showed that large scampi were much more likely to be walking free on the sediment surface than partly obscured within a burrow, and work under Objective 1 (this document and Cryer & Hartill 2000) suggests that *M. challengeri* may not be "fully selected" to the photographic method until a size of 26–30 mm OCL. This would lead to positive bias in a photographic estimate of length frequency (and average weight) applied to the number of burrows or burrow openings.

We therefore examined the possibility that population length frequency and average weight could be estimated by reference to the size of burrow openings. Overseas studies (e.g., Marrs *et al.* 1996) and our casual observations of the size of burrows and their associated scampi suggested that there may be a relationship between entrance width and the size of the occupant. We examined this proposition by assessing the relationship between animal size and burrow size from images wherein scampi can be seen partially within a given burrow entrance (i.e., they are almost certainly living in the burrow).

It is not possible to estimate orbital carapace length (OCL, the standard measurement for scampi) directly from photographs, so we used morphometric relationships to estimate OCL from the length of the opposable segment on chelipeds (which are the most frequently visible body parts). Two regressions were used (Figure 8) because cheliped length seems to increase (relatively) for scampi longer than about 44 mm OCL. Both regressions were highly significant (r_{103} = 0.93, and r_{15} = 0.75, respectively, for segments shorter or longer than 44 mm). Four "outliers" above the regression line came from animals thought to have regenerating chelipeds. This is likely to be a feature of wild populations and including these damaged animals precludes bias that would be introduced by analysis of only undamaged animals.

The relationship between cheliped length and OCL was used to estimate the size of 76 scampi seen in 75 clear photographs taken in 1998. The estimates of OCL were compared with the width of the major opening, the width of the minor opening, and the distance between the two openings. The minor opening was not visible in all photographs selected, preventing the latter two measurements for 24 burrows.

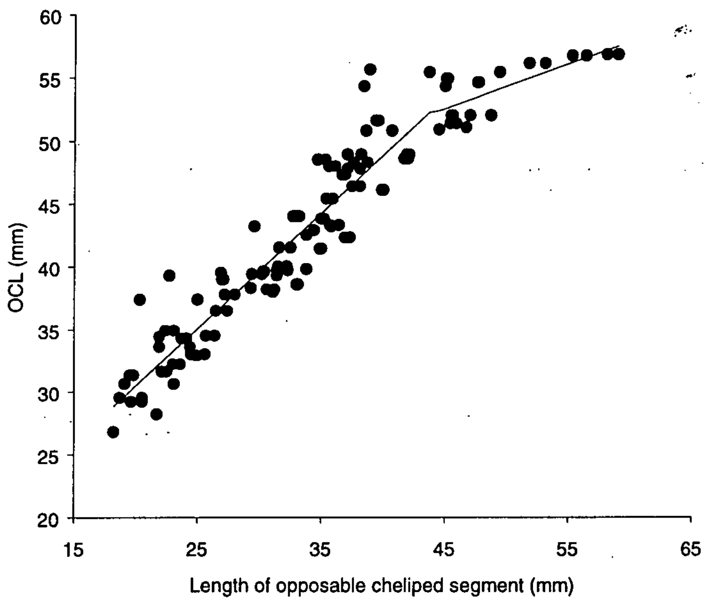

***Figure 8*: Relationship between the length of the opposable segment of the cheliped and OCL for QMA 1 scampi. Least squares regression lines for segment length less and more than 44 mm (lines) are used to estimate OCL for scampi in photographs.**

The estimated length frequency distribution of scampi in the photographs selected for measurement was comparable with the "population" length frequency distribution from the 1998 and 2000 surveys and covered almost the whole range of animal sizes encountered during trawl surveys (about 20–65 mm OCL). We estimated that, on average, major burrow openings were 81 mm wide (range 32–177 mm, Figure 9), minor openings were 39 mm wide (11–97 mm) and the two openings were 285 mm apart (62–652 mm). The minor opening was always narrower than the major opening (mean 51%, range 28–81%, Figure 10) and this ratio did not vary with the size of inhabitant (r_{49} = 0.07). The distance between the openings was usually 2–7 times the width of the major opening. There was a very high correlation between the widths of the two openings (r_{49} = 0.70) and reasonable correlation between the width of the major opening and the distance between the openings (r_{49} = 0.59).

We found highly significant relationships between the size and scampi and all three dimensions of their burrows (Figure 11). The relationships between scampi size and the width of the major opening (r_{74} = 0.81) and minor opening (r_{49} = 0.68) were stronger than that between scampi size and the distance between the two openings (r_{49} = 0.56). All the burrows we measured were simple linear tunnels of a width closely related to the body size of the inhabitant, but of quite variable length.

10.8 Methods of estimating recruited (absolute) biomass

Recruited biomass is not easy to estimate because there is no generally-accepted "size at recruitment". Scientific observers rarely measure scampi smaller than about 30 mm OCL from commercial trawl shots (Cryer & Coburn 2000) and it is likely that few such small animals are caught. However, the size at "first appearance" in commercial catches is a poor measure of size at recruitment because it may vary with fishing practice (changes in fishing depth or location, mesh sizes, or season). We suggest that it would be preferable to define the size at recruitment as the size at sexual maturity, which can be estimated analytically and accorded a suitable "knife-edge" or ogive value. Because there is a good relationship between burrow opening width and animal size, recruited biomass can then be estimated using the proportion of burrows estimated to be large enough to accommodate sexually mature animals.

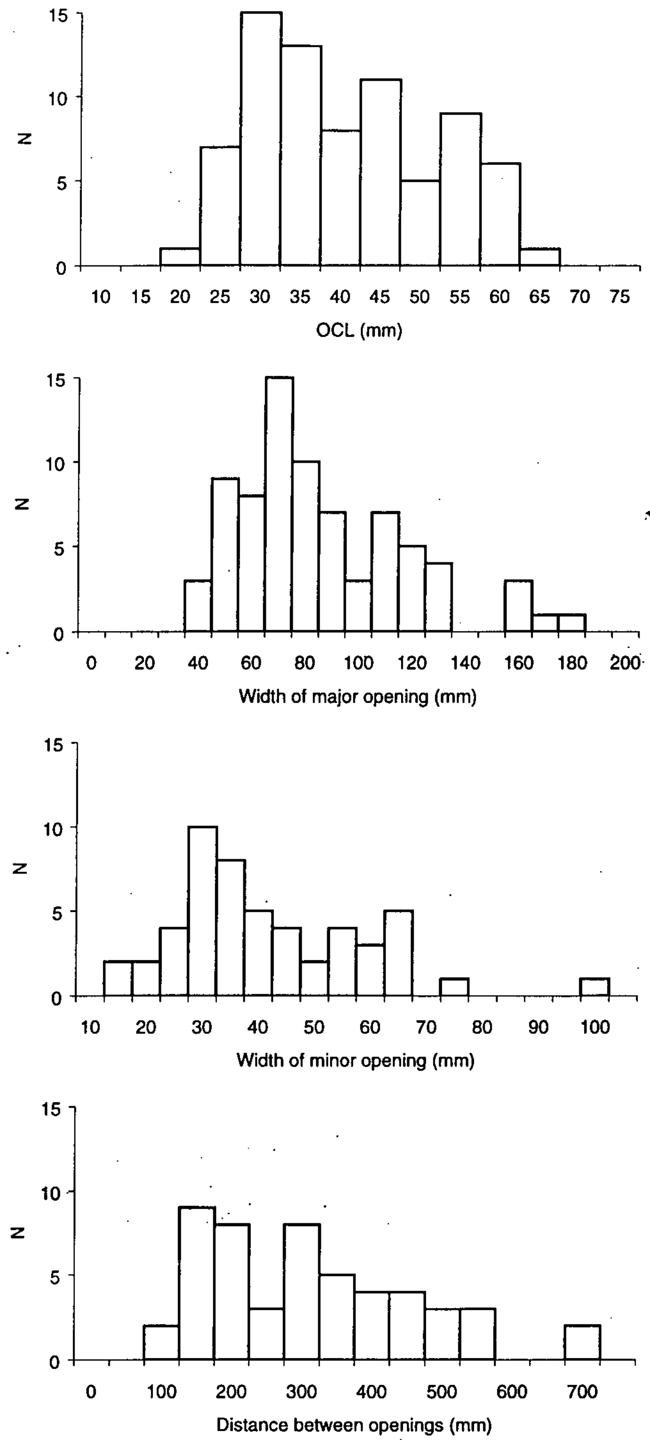

***Figure 9*: Frequency distributions for the size of scampi measured and the three burrow dimensions.**

We examined length and stage frequency data for 24 811 female scampi measured in QMAs 1 and 2 on trawl surveys, tagging trials, and selectivity experiments. The staging method was described by Cryer & Stotter 1997 but is summarised in Appendix 1. Immature internal gonads were recorded for almost all animals smaller than 25 mm OCL (Figure 12), and the size at which 50% had developing gonads was about 30 mm OCL. Few females smaller than 35 mm OCL carried eggs and some as large as 40 mm OCL were still morphologically immature. Only size classes larger than about 36 mm OCL had more than 50% with internal gonads showing the characteristic blue colour of the external eggs, and only size classes larger than about 40 mm OCL had more than 50% carrying eggs.

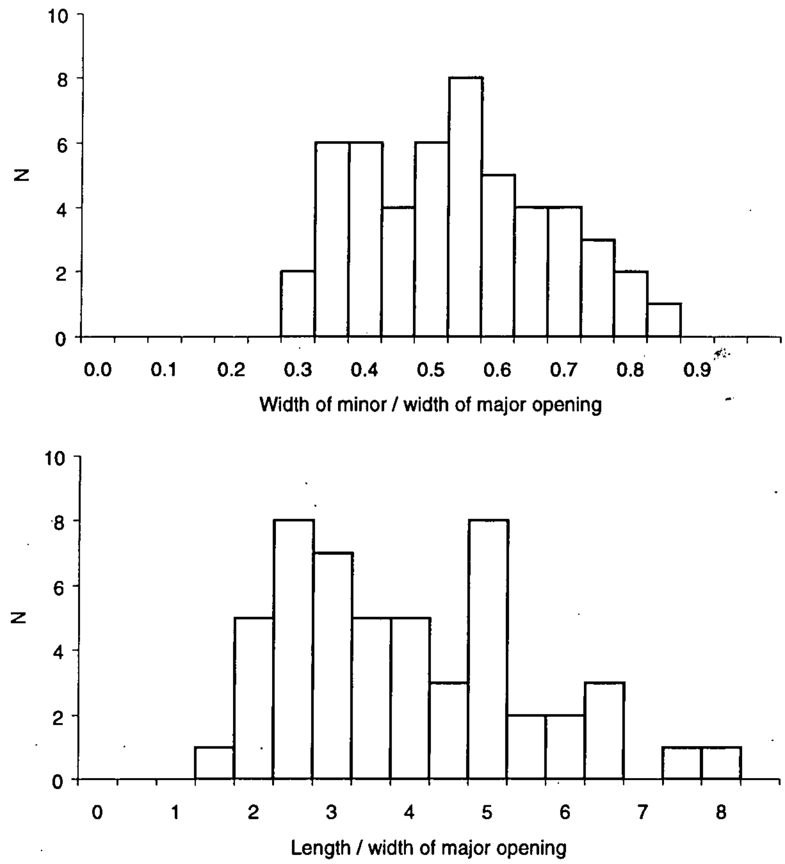

Figure 10: **Frequency distributions for the ratios of minor opening width (top) and burrow length (bottom) to major opening width.**

Maturity might be defined by the presence of thickening (developing) gonads, by the presence of gonads showing the blue colouration characteristic of external eggs, or by the carriage of external eggs. We estimated a size at which 50% of females from QMAs 1 and 2 are mature for each (respectively, 30, 36, and 40 mm OCL). Any could be used as a size at recruitment; clearly the last mentioned would be the most precautionary.

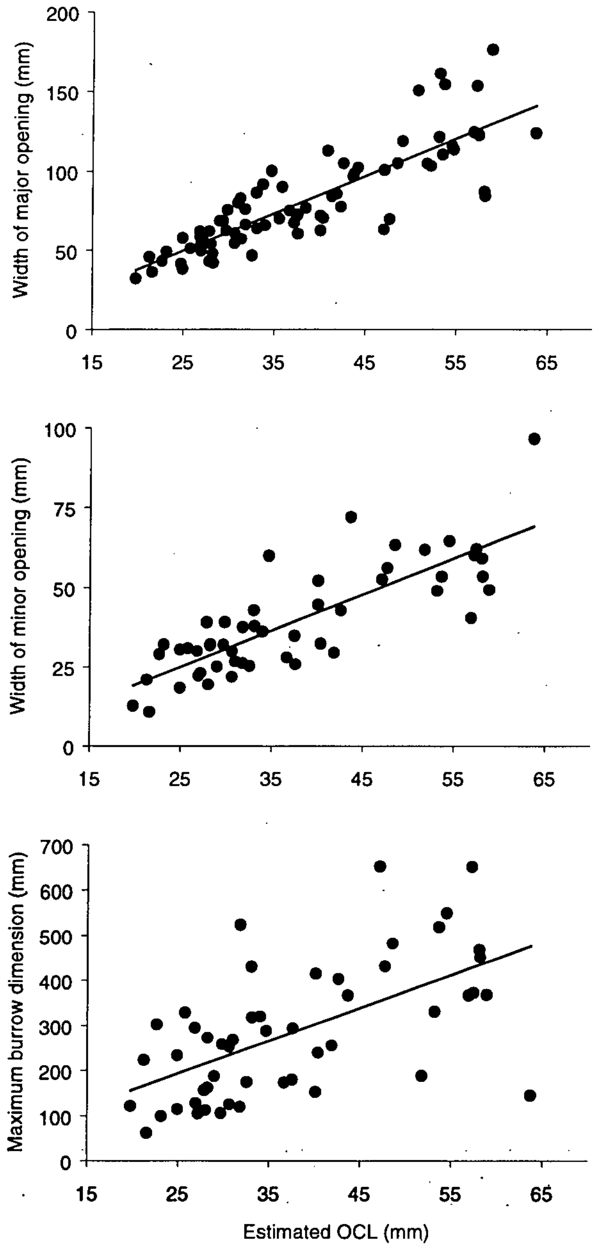

***Figure 11*: Relationships between the size of scampi and (top to bottom) the width of the major opening, the width of the minor opening, and the distance between the two.**

These results suggest that it would be possible to estimate the absolute recruited biomass of scampi photographically using the density and size distribution of burrow openings. Methods analogous to those used to generate weighted population length frequency distributions from stratified trawl survey data could be used to estimate the population width distribution of "definite" scampi burrow openings. Those unlikely, by dint of their size, to be inhabited by a mature scampi could be excluded. This could be done using "knife edged" values for size at maturity and acceptable burrow size or probabilistically using a maturity ogive and a regression between animal size and burrow width. This approach would be tractable using current equipment and techniques, although a slightly higher image resolution would be useful for the detailed measurements required.

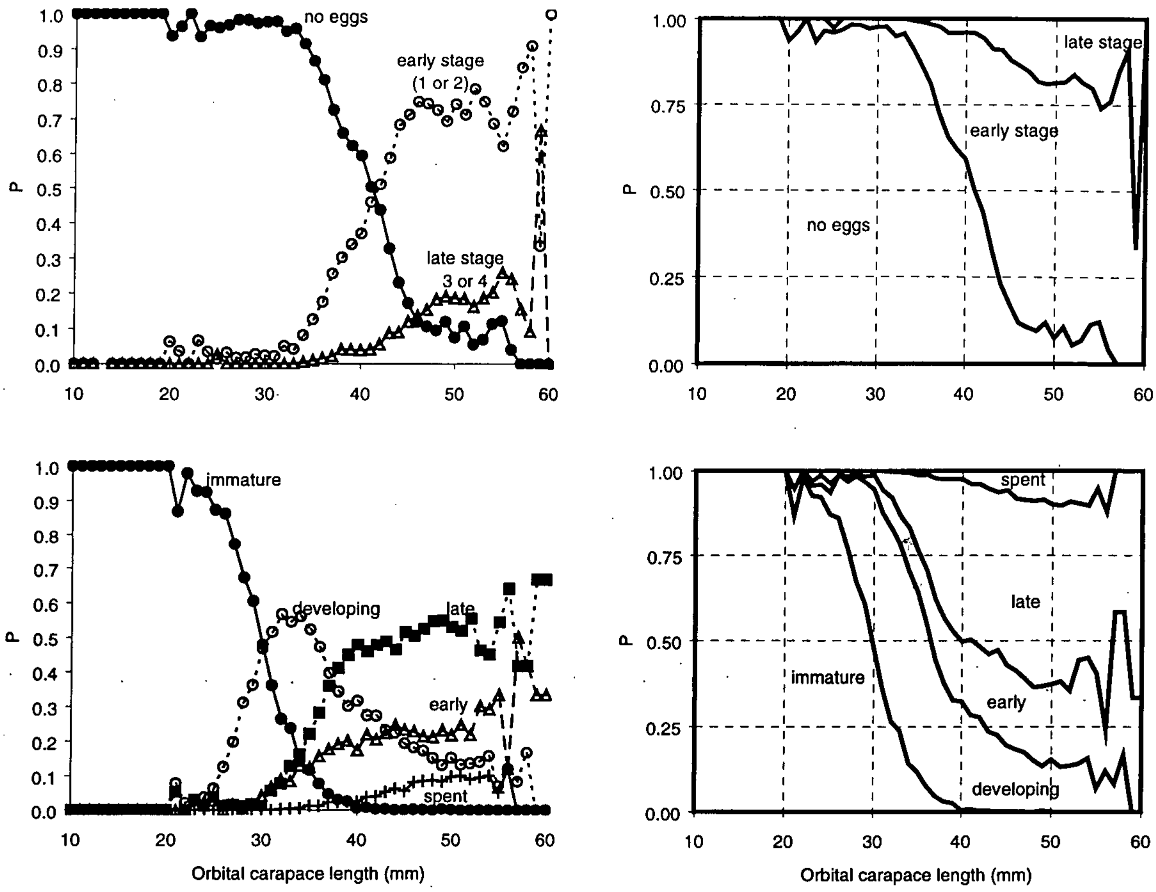

Figure 12: **Proportions of female scampi from QMAs 1 and 2 carrying early and late-stage eggs (top) and having gonads of particular developmental stages (bottom). Left hand panels show proportions plotted independently, right hand panels show proportions "stacked". Females outside the range 25–50 mm OCL are rare making estimates of proportions by 1 mm size class unreliable.**

An absolute recruited biomass estimate would probably be best considered as a "minimum" estimate because of the need to be "reasonably certain" that burrows included in the analysis were currently occupied by scampi. Indices of relative abundance based on "definite" or "probable" burrow openings would probably be more reliable. The highest correlation and agreement among readers was found for a restricted set of burrow openings, those considered to be "definite and "major". At this stage, we think that the weighted average density of "definite, major burrow openings of a size likely to contain mature scampi" offers the best prospects as a consistent and repeatable index of relative abundance for monitoring the recruited biomass of *M. challengeri*.

10.9. Acoustic seabed classification

Acoustic signatures collected and digitised using the *QTC-View* data acquisition system were analysed using *QTC-Impact*. Although the principal component analysis within *QTC-Impact* was able to distinguish four substantive data clusters, the wide spread and broad overlap of these clusters suggests that the data are relatively homogeneous (Appendix 5). This might be expected because almost all of the acoustic sampling was undertaken while the ship steamed among stations within strata specifically designed to sample scampi, and it is known that scampi require a particular sediment type for their burrows.

We have not analysed the relationship between acoustic signature and sediment type or the density and size of scampi burrows. There does not appear to be a strong geographic or bathymetric pattern in the four acoustic clusters and they seem to be intermingled. There may be a preponderance of clusters 3 and 4 in areas we might expect to be of harder substrate or foul ground (e.g., around White Island), but these relationships have not been analysed formally. The common pattern of acoustic clusters stratified by depth does not appear to hold for these data.

A considerable amount of additional data was collected using NIWA's own *CREST* system which apparently continued to work while *QTC-View* was inoperable (especially while the camera was in the water). Thus, although this is not a formal part of this project, we expect to be able to improve the analysis and make more explicit links among sediment type, scampi burrow density, the degree of "other" bioturbation, and acoustic signature.

11. Conclusions:

1. The new digital camera system developed in 1999–2000 significantly improved our capability to undertake quantitative surveys of scampi burrows in that locating the camera in the right area above the seabed was much easier, the overall quality and consistency of images has increased, the measurement of seabed area has become easier and more certain, the availability of digital images permitted "in-survey" quality assurance, and measurement of scampi and burrows from images has become much more efficient.

2. Digital images currently offer slightly lower resolution than emulsion images printed to a large format but, at the scale of a scampi or a scampi burrow, this does not seem to be limiting.

3. The weighted average density of scampi burrow openings from a February 2000 photographic survey in the Bay of Plenty (Great Barrier Island to Cape Runaway, 200–600 m depth) was about 0.10 m^{-2} with a c.v. of about 12%. This equates to about 489 million burrow openings in the survey area (about 200 million burrows if each burrow has an average of 2.5 openings, although our data seem to suggest that most *M. challengeri* burrows have two openings).

4. If the survey area is restricted to the area surveyed photographically in 1998 (Mercury Islands to White Island), the weighted average density of scampi burrow openings was about 0.11 m^{-2} with a c.v. of about 9% (about 268 million burrow openings in the survey area). This is only about one-third the comparable estimate for 1998.

5. The weighted average density of visible scampi was about 0.005 m^{-2} with a c.v. of about 17%. This equates to about 24 million scampi in the survey area and this can be considered a minimum estimate of population abundance.

6. If the survey area is restricted to the area surveyed photographically in 1998, the weighted average density of visible scampi was about 0.008 m^{-2} with a c.v. of about 20% (about 19 million scampi in the survey area). This is only about one-half the comparable estimate for 1998.

7. The average weight of scampi estimated photographically in 2000 was 38.3 g, similar to the 1998 estimate of 35.4 g. The average weight of scampi estimated by trawl in 2000 was 59.5 g, very similar to the 1998 estimate of 60.5 g.

8. An image library from the 1998 survey showing scampi associated with burrows has been compiled and should serve as a basis for the development of a consistent counting and recording protocol. Burrows observed to be inhabited by scampi tend to have a single shallow, crescent shaped major opening, a "fan" of spoil in front of this opening, usually a minor opening (which can be quite steep) joined by a simple, short, linear tunnel, and clear tracks associated with the major or minor opening, or both. Further images from the 2000 survey will be added later.

9. For a sample of about 400 images (from strata where disagreement between readers was greatest) re-examined by all three readers, correlation among readers increased from about 0.3 to about 0.9. Correlation and agreement among readers was greater for burrows classified as "definite" (as opposed to "probable").

10. For one reader, average burrow density estimated from the second reading was about 20% lower than that from the first. This will further exacerbate the difference between 1998 and 2000 surveys, but these estimates are not based on comparable counting protocols. A consistent counting protocol should be developed as a matter of urgency.

11. The widths of both major and minor scampi burrow openings are very strongly correlated with the size of the inhabitant, the former being about twice as wide as the latter. The distance between the two openings is less strongly correlated with the size of the inhabitant.

12. Research data from almost 25 000 female scampi examined in QMAs 1 and 2 suggest that scampi start to mature at about 30 mm OCL, but that some animals do not mature until about 40 mm OCL. Size at 50% maturity (for the population) could be 30, 36, or 40 mm, depending on the definition of maturity used. The commercial fishery takes very few animals smaller than 30 mm.

13. These results suggest that it would be possible to estimate the absolute recruited biomass of scampi using photography, but that this estimate would probably be negatively biased by the need to be "reasonably certain" that burrows included in the analysis were currently occupied by scampi. Indices of relative abundance based on "definite" major burrow openings would probably be more reliable.

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12. Publications:

Other than the mandatory voyage programme, voyage report, and a progress report discussed at the 5 September, 2000, meeting of the Shellfish Fishery Assessment Working Group, there are no publications at this stage.

13. Data Storage:

Data from trawl stations are in the Empress database *trawl*. Data from photographic stations are currently in hard copy and in a variety of Excel spreadsheets on a secure, backed-up server and will be copied to *trawl*. Photographic images are held as lightly compressed JPEG files on a secure, backed-up server and in three additional copies on CD-ROM at two different sites. A set of CD-ROM copies will be archived at the Greta Point facility before the end of the project. Analytical files are held in a variety of Excel spreadsheets on a secure, backed-up server.

Appendix 1: **Developmental stages for eggs and ovaries for female New Zealand scampi, Metanephrops challengeri**

External eggs

Stage 0:	No external eggs carried.
Stage 1:	Eggs blue with no visible embryonic development.
Stage 2:	Embryo visible as a white cap of tissue at one pole of the egg.
Stage 3:	Orange/red spot apparent among the blue pigment. Eggs progressively lose their blue coloration and become orange, and the tissue cap expands.
Stage 4:	Egg takes on an opaque white appearance as the actively moving embryo fills the egg. No blue remains, and orange red coloration fades as the yolk is metabolised.

Internal ovaries

Stage 1:	Ovaries translucent, extending into thin lateral filaments.
Stage 2:	Ovaries grey-white, occupying about two-thirds of the cephalothorax. Appearance is thickened, cylindrical, and with swollen ends.
Stage 3:	Ovaries grey-white, with patches of pale blue pigment. Appearance is extended, diameter about 5 mm.
Stage 4:	Ovaries ripe and blue, occasionally with some patches of white. Surface is irregular, appearance is thickened with spatulate proximities. Ovaries fill entire cephalothorax.
Stage 5:	Ovary spent and grey-white in colour, often with some residual blue eggs. Appearance is small, shapeless, and watery. Soft to the touch.
Stage 8:	Atretic.

Appendix 3a: **Estimates for three readers of burrow opening density (m^{-2}) by stratum and for the whole survey area Gt Barrier Island to Cape Runaway**

Openings, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0084	0.1921	0.0422	0.0242	0.0126	0.2113	0.1939	0.0434	0.0306	0.1623	0.1666	0.0749	0.3078	0.1553	0.2353	0.10455	mean density
sd	0.0118	0.1606	0.0169	0.0249	0.0108	0.1207	0.0454	0.0325	0.0322	0.0651	0.0337	0.0661	0.3285	0.1288	0.1364	0.01259	sd mean
var	0.0001	0.0258	0.0003	0.0006	0.0001	0.0146	0.0021	0.0011	0.0010	0.0042	0.0011	0.0044	0.1079	0.0166	0.0186		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0084	0.0803	0.0097	0.0144	0.0062	0.0603	0.0203	0.0188	0.0186	0.0291	0.0151	0.0382	0.1897	0.0744	0.0788	12.0%	c.v.
cv	1.00	0.42	0.23	0.59	0.49	0.29	0.10	0.43	0.61	0.18	0.09	0.51	0.62	0.48	0.33		
calc	2.2E-06	2.8E-05	4.2E-07	7.1E-07	1.8E-07	1.1E-05	1.3E-06	7.0E-07	8.9E-07	5.5E-06	8.7E-07	1.2E-05	7.8E-05	8.7E-06	7.8E-06	0.00016	var mean
N	7.01E+06	5.90E+07	1.31E+07	6.64E+06	3.96E+06	5.54E+07	5.16E+07	9.06E+06	7.24E+06	6.13E+07	4.83E+07	3.15E+07	6.71E+07	2.89E+07	3.91E+07	489,171,705	Abundance

Openings, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0075	0.2394	0.1855	0.1014	0.0320	0.2334	0.2295	0.0876	0.0628	0.1960	0.1546	0.0127	0.0315	0.0769	0.0634	0.10403	mean density
sd	0.0064	0.0991	0.1002	0.1485	0.0263	0.0975	0.1100	0.0371	0.0583	0.0816	0.0687	0.0136	0.0274	0.0314	0.0371	0.00927	sd mean
var	0.0000	0.0098	0.0100	0.0221	0.0007	0.0095	0.0121	0.0014	0.0034	0.0067	0.0047	0.0002	0.0007	0.0010	0.0014		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0045	0.0495	0.0579	0.0857	0.0152	0.0488	0.0492	0.0214	0.0336	0.0365	0.0307	0.0079	0.0158	0.0181	0.0214	8.9%	c.v.
cv	0.61	0.21	0.31	0.85	0.47	0.21	0.21	0.24	0.54	0.19	0.20	0.62	0.50	0.24	0.34		
calc	6.6E-07	1.1E-05	1.5E-05	2.5E-05	1.0E-06	7.5E-06	7.8E-06	9.1E-07	2.9E-06	8.7E-06	3.6E-06	5.0E-07	5.4E-07	5.2E-07	5.8E-07	0.00009	Var mean
N	6.28E+06	7.35E+07	5.77E+07	2.79E+07	1.01E+07	6.12E+07	6.11E+07	1.83E+07	1.49E+07	7.41E+07	4.48E+07	5.31E+06	6.86E+06	1.43E+07	1.05E+07	486,737,182	Abundance

Openings, reader 3

	Stratum 201	stratum 202	stratum 203	Stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	Km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0000	0.0137	0.0032	0.0019	0.0000	0.0306	0.0162	0.0045	0.0120	0.0783	0.1215	0.2482	0.1207	0.1694	0.1203	0.05744	Mean density
sd	0.0000	0.0083	0.0015	0.0033	0.0000	0.0123	0.0171	0.0043	0.0107	0.1043	0.1467	0.3910	0.0955	0.0485	0.0366	0.02122	Sd mean
var	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0003	0.0000	0.0001	0.0109	0.0215	0.1529	0.0091	0.0024	0.0013		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	Sites
sem	0.0000	0.0041	0.0009	0.0019	0.0000	0.0062	0.0076	0.0025	0.0062	0.0466	0.0656	0.2257	0.0551	0.0280	0.0211	36.9%	c.v.
cv	#DIV/0!	0.30	0.27	1.00	#DIV/0!	0.20	0.47	0.55	0.52	0.60	0.54	0.91	0.46	0.17	0.18		
calc	0.0E+00	7.3E-08	3.2E-09	1.2E-08	0.0E+00	1.2E-07	1.9E-07	1.2E-08	9.9E-08	1.4E-05	1.7E-05	4.1E-04	6.6E-06	1.2E-06	5.6E-07	0.00045	Var mean
N	0.00E+00	4.22E+06	9.98E+05	5.22E+05	0.00E+00	8.03E+06	4.31E+06	9.50E+05	2.85E+06	2.96E+07	3.52E+07	1.04E+08	2.63E+07	3.15E+07	2.00E+07	268,756,132	Abundance

Appendix 3b: **Estimates for three readers of burrow density (m^{-2}) by stratum and for the whole survey area Gt Barrier Island to Cape Runaway**

Burrows, reader 1

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503		
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0042	0.1041	0.0240	0.0151	0.0070	0.1130	0.1036	0.0234	0.0166	0.0983	0.0914	0.0375	0.1576	0.0956	0.1419	0.05778	mean density
sd	0.0059	0.0863	0.0072	0.0162	0.0046	0.0645	0.0293	0.0160	0.0155	0.0370	0.0209	0.0330	0.1726	0.0760	0.0886	0.00679	sd mean
var	0.0000	0.0074	0.0001	0.0003	0.0000	0.0042	0.0009	0.0003	0.0002	0.0014	0.0004	0.0011	0.0298	0.0058	0.0079		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0042	0.0431	0.0042	0.0093	0.0027	0.0323	0.0131	0.0092	0.0089	0.0166	0.0093	0.0191	0.0996	0.0439	0.0512	11.8%	c.v.
cv	1.00	0.41	0.17	0.62	0.38	0.29	0.13	0.39	0.54	0.17	0.10	0.51	0.63	0.46	0.36		
calc	5.6E-07	8.0E-06	7.6E-08	3.0E-07	3.3E-08	3.3E-06	5.6E-07	1.7E-07	2.1E-07	1.8E-06	3.4E-07	2.9E-06	2.2E-05	3.0E-06	3.3E-06	0.00005	var mean
N	3.50E+06	3.19E+07	7.46E+06	4.16E+06	2.21E+06	2.96E+07	2.76E+07	4.90E+06	3.93E+06	3.71E+07	2.65E+07	1.57E+07	3.44E+07	1.78E+07	2.36E+07	270,357,845	Abundance

Burrows, reader 2

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503		
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0075	0.1367	0.1078	0.0560	0.0285	0.1316	0.1236	0.0562	0.0502	0.1176	0.0905	0.0067	0.0213	0.0478	0.0387	0.06211	mean density
sd	0.0064	0.0521	0.0428	0.0766	0.0237	0.0515	0.0576	0.0260	0.0446	0.0489	0.0382	0.0074	0.0185	0.0174	0.0219	0.00502	sd mean
var	0.0000	0.0027	0.0018	0.0059	0.0006	0.0027	0.0033	0.0007	0.0020	0.0024	0.0015	0.0001	0.0003	0.0003	0.0005		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0045	0.0261	0.0247	0.0442	0.0137	0.0258	0.0257	0.0150	0.0257	0.0219	0.0171	0.0043	0.0107	0.0100	0.0126	8.1%	c.v.
cv	0.61	0.19	0.23	0.79	0.48	0.20	0.21	0.27	0.51	0.19	0.19	0.64	0.50	0.21	0.33		
calc	6.6E-07	2.9E-06	2.7E-06	6.7E-06	8.5E-07	2.1E-06	2.1E-06	4.5E-07	1.7E-06	3.1E-06	1.1E-06	1.5E-07	2.5E-07	1.6E-07	2.0E-07	0.00003	var mean
N	6.28E+06	4.20E+07	3.35E+07	1.54E+07	8.99E+06	3.45E+07	3.29E+07	1.17E+07	1.19E+07	4.45E+07	2.62E+07	2.80E+06	4.64E+06	8.89E+06	6.43E+06	290,597,670	Abundance

Burrows, reader 3

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502	503		
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0000	0.0130	0.0024	0.0019	0.0000	0.0202	0.0096	0.0037	0.0091	0.0603	0.1061	0.2131	0.1130	0.1565	0.1137	0.04952	mean density
sd	0.0000	0.0086	0.0001	0.0033	0.0000	0.0080	0.0102	0.0044	0.0082	0.0804	0.1303	0.3348	0.1041	0.0573	0.0389	0.01825	sd mean
var	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0065	0.0170	0.1121	0.0108	0.0033	0.0015		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0000	0.0043	0.0001	0.0019	0.0000	0.0040	0.0046	0.0025	0.0047	0.0360	0.0583	0.1933	0.0601	0.0331	0.0224	36.9%	c.v.
cv	#DIV/0!	0.33	0.02	1.00	#DIV/0!	0.20	0.48	0.69	0.52	0.60	0.55	0.91	0.53	0.21	0.20		
calc	0.0E+00	8.0E-08	1.4E-11	1.2E-08	0.0E+00	5.1E-08	6.7E-08	1.3E-08	5.7E-08	8.4E-06	1.3E-05	3.0E-04	7.8E-06	1.7E-06	6.3E-07	0.00033	var mean
N	0.00E+00	3.99E+06	7.44E+05	5.22E+05	0.00E+00	5.29E+06	2.55E+06	7.74E+05	2.17E+06	2.28E+07	3.08E+07	8.95E+07	2.46E+07	2.91E+07	1.89E+07	231,708,608	Abundance

Appendix 3c: **Estimates for three readers of scampi in holes (m^{-2}) by stratum and for the whole survey area Gt Barrier Island to Cape Runaway**

Scampi in holes, reader 1

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0000	0.0049	0.0015	0.0010	0.0000	0.0098	0.0055	0.0014	0.0020	0.0130	0.0036	0.0000	0.0000	0.0031	0.0023	0.00299	mean density
sd	0.0000	0.0047	0.0026	0.0017	0.0000	0.0072	0.0041	0.0025	0.0035	0.0138	0.0026	0.0000	0.0000	0.0030	0.0040	0.00061	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0000	0.0024	0.0015	0.0010	0.0000	0.0036	0.0018	0.0014	0.0020	0.0062	0.0012	0.0000	0.0000	0.0017	0.0023	20.3%	c.v.
cv	#DIV/0!	0.48	1.00	1.00	#DIV/0!	0.37	0.33	1.00	1.00	0.47	0.32	#DIV/0!	#DIV/0!	0.56	1.00		
calc	0.0E+00	2.4E-08	1.0E-08	3.3E-09	0.0E+00	4.1E-08	1.1E-08	4.1E-09	1.1E-08	2.5E-07	5.1E-09	0.0E+00	0.0E+00	4.7E-09	6.6E-09	0.00000	var mean
N	0.00E+00	1.51E+06	4.73E+05	2.68E+05	0.00E+00	2.56E+06	1.45E+06	2.99E+05	4.82E+05	4.92E+06	1.05E+06	0.00E+00	0.00E+00	5.77E+05	3.79E+05	13,975,207	Abundance

Scampi in holes, reader 2

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0000	0.0049	0.0030	0.0010	0.0000	0.0077	0.0050	0.0046	0.0031	0.0127	0.0041	0.0000	0.0000	0.0048	0.0007	0.00315	mean density
sd	0.0000	0.0057	0.0053	0.0017	0.0000	0.0075	0.0049	0.0055	0.0053	0.0141	0.0036	0.0000	0.0000	0.0043	0.0013	0.00068	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0000	0.0029	0.0030	0.0010	0.0000	0.0038	0.0022	0.0032	0.0031	0.0063	0.0016	0.0000	0.0000	0.0025	0.0007	21.6%	c.v.
cv	#DIV/0!	0.58	1.00	1.00	#DIV/0!	0.49	0.44	0.69	1.00	0.50	0.39	#DIV/0!	#DIV/0!	0.52	1.00		
calc	0.0E+00	3.6E-08	4.1E-08	3.3E-09	0.0E+00	4.4E-08	1.5E-08	2.0E-08	2.4E-08	2.6E-07	9.8E-09	0.0E+00	0.0E+00	9.8E-09	7.0E-10	0.00000	var mean
N	0.00E+00	1.51E+06	9.46E+05	2.68E+05	0.00E+00	2.01E+06	1.33E+06	9.63E+05	7.23E+05	4.79E+06	1.20E+06	0.00E+00	0.00E+00	8.85E+05	1.24E+05	14,751,910	Abundance

Scampi in holes, reader 3

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
mean	0.0000	0.0006	0.0008	0.0000	0.0000	0.0065	0.0020	0.0014	0.0020	0.0085	0.0025	0.0000	0.0000	0.0037	0.0037	0.00185	mean density
sd	0.0000	0.0011	0.0013	0.0000	0.0000	0.0040	0.0019	0.0025	0.0035	0.0098	0.0039	0.0000	0.0000	0.0065	0.0034	0.00044	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000		
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
sem	0.0000	0.0006	0.0008	0.0000	0.0000	0.0020	0.0008	0.0014	0.0020	0.0044	0.0017	0.0000	0.0000	0.0037	0.0020	24.0%	c.v.
cv	#DIV/0!	1.00	1.00	#DIV/0!	#DIV/0!	0.30	0.42	1.00	1.00	0.51	0.69	#DIV/0!	#DIV/0!	1.00	0.53		
calc	0.0E+00	1.3E-09	2.6E-09	0.0E+00	0.0E+00	1.2E-08	2.2E-09	4.1E-09	1.1E-08	1.3E-07	1.2E-08	0.0E+00	0.0E+00	2.2E-08	4.8E-09	0.00000	var mean
N	0.00E+00	1.71E+05	2.37E+05	0.00E+00	0.00E+00	1.71E+06	5.20E+05	2.99E+05	4.82E+05	3.22E+06	7.26E+05	0.00E+00	0.00E+00	6.97E+05	6.10E+05	8,675,099	Abundance

Appendix 3d: **Estimates for three readers of scampi not in holes (m^{-2}) by stratum and for the whole survey area Gt Barrier Island to Cape Runaway**

Scampi on surface, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	Stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
Rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
Mean	0.0000	0.0000	0.0008	0.0029	0.0000	0.0046	0.0087	0.0000	0.0000	0.0090	0.0031	0.0000	0.0011	0.0041	0.0007	0.00214	mean density
Sd	0.0000	0.0000	0.0014	0.0051	0.0000	0.0037	0.0079	0.0000	0.0000	0.0098	0.0049	0.0000	0.0019	0.0045	0.0013	0.00049	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000		
Count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
Sem	0.0000	0.0000	0.0008	0.0029	0.0000	0.0018	0.0035	0.0000	0.0000	0.0044	0.0022	0.0000	0.0011	0.0026	0.0007	22.9%	c.v.
Cv	#DIV/0!	#DIV/0!	1.00	1.00	#DIV/0!	0.40	0.40	#DIV/0!	#DIV/0!	0.49	0.70	#DIV/0!	1.00	0.64	1.00		
Calc	0.0E+00	0.0E+00	3.0E-09	3.0E-08	0.0E+00	1.1E-08	4.0E-08	0.0E+00	0.0E+00	1.3E-07	1.8E-08	0.0E+00	2.6E-09	1.1E-08	7.0E-10	0.00000	var mean
N	0.00E+00	0.00E+00	2.54E+05	8.04E+05	0.00E+00	1.21E+06	2.32E+06	0.00E+00	0.00E+00	3.40E+06	9.01E+05	0.00E+00	2.37E+05	7.62E+05	1.24E+05	10,004,883	Abundance

Scampi on surface, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	Stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
Rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
Mean	0.0000	0.0013	0.0008	0.0029	0.0000	0.0063	0.0083	0.0000	0.0000	0.0062	0.0023	0.0000	0.0010	0.0028	0.0007	0.00197	mean density
Sd	0.0000	0.0027	0.0014	0.0051	0.0000	0.0063	0.0075	0.0000	0.0000	0.0075	0.0034	0.0000	0.0017	0.0049	0.0013	0.00045	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000		
Count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
Sem	0.0000	0.0013	0.0008	0.0029	0.0000	0.0031	0.0033	0.0000	0.0000	0.0034	0.0015	0.0000	0.0010	0.0028	0.0007	22.9%	c.v.
Cv	#DIV/0!	1.00	1.00	1.00	#DIV/0!	0.50	0.40	#DIV/0!	#DIV/0!	0.54	0.65	#DIV/0!	1.00	1.00	1.00		
Calc	0.0E+00	7.8E-09	3.0E-09	3.0E-08	0.0E+00	3.1E-08	3.6E-08	0.0E+00	0.0E+00	7.4E-08	8.8E-09	0.0E+00	2.2E-09	1.2E-08	7.0E-10	0.00000	var mean
N	0.00E+00	4.14E+05	2.54E+05	8.04E+05	0.00E+00	1.66E+06	2.22E+06	0.00E+00	0.00E+00	2.36E+06	6.71E+05	0.00E+00	2.17E+05	5.23E+05	1.24E+05	9,239,731	Abundance

Scampi on surface, reader 3

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	Stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679	km^2
Rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355		
Mean	0.0000	0.0007	0.0065	0.0029	0.0000	0.0021	0.0050	0.0000	0.0000	0.0072	0.0046	0.0166	0.0051	0.0048	0.0007	0.00387	mean density
Sd	0.0000	0.0014	0.0062	0.0051	0.0000	0.0025	0.0067	0.0000	0.0000	0.0074	0.0042	0.0288	0.0065	0.0043	0.0013	0.00157	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000		
Count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52	sites
Sem	0.0000	0.0007	0.0036	0.0029	0.0000	0.0012	0.0030	0.0000	0.0000	0.0033	0.0019	0.0166	0.0037	0.0025	0.0007	40.7%	c.v.
Cv	#DIV/0!	1.00	0.55	1.00	#DIV/0!	0.60	0.60	#DIV/0!	#DIV/0!	0.46	0.40	1.00	0.73	0.52	1.00		
Calc	0.0E+00	2.0E-09	5.6E-08	3.0E-08	0.0E+00	4.9E-09	2.9E-08	0.0E+00	0.0E+00	7.2E-08	1.3E-08	2.2E-06	3.0E-08	9.8E-09	7.0E-10	0.00000	var mean
N	0.00E+00	2.11E+05	2.03E+06	8.04E+05	0.00E+00	5.43E+05	1.33E+06	0.00E+00	0.00E+00	2.74E+06	1.35E+06	6.99E+06	1.12E+06	8.85E+05	1.24E+05	18,122,573	Abundance

Appendix 3e: **Estimates for three readers of all visible scampi (m^{-2}) by stratum and for the whole survey area Gt Barrier Island to Cape Runaway**

All visible scampi, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	Stratum 503	Results
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679 km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355	
mean	0.0000	0.0049	0.0023	0.0039	0.0000	0.0144	0.0142	0.0014	0.0020	0.0220	0.0067	0.0000	0.0011	0.0072	0.0030	0.00513 mean density
sd	0.0000	0.0047	0.0023	0.0067	0.0000	0.0079	0.0063	0.0025	0.0035	0.0196	0.0061	0.0000	0.0019	0.0075	0.0035	0.00086 sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0001	0.0000	
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52 sites
sem	0.0000	0.0024	0.0013	0.0039	0.0000	0.0039	0.0028	0.0014	0.0020	0.0088	0.0027	0.0000	0.0011	0.0043	0.0020	16.8% c.v.
cv	#DIV/0!	0.48	0.56	1.00	#DIV/0!	0.27	0.20	1.00	1.00	0.40	0.41	#DIV/0!	1.00	0.60	0.67	
calc	0.0E+00	2.4E-08	7.7E-09	5.2E-08	0.0E+00	4.9E-08	2.5E-08	4.1E-09	1.1E-08	5.0E-07	2.9E-08	0.0E+00	2.6E-09	3.0E-08	5.1E-09	0.00000 var mean
N	0.00E+00	1.51E+06	7.28E+05	1.07E+06	0.00E+00	3.77E+06	3.77E+06	2.99E+05	4.82E+05	8.32E+06	1.95E+06	0.00E+00	2.37E+05	1.34E+06	5.03E+05	23,980,090 Abundance

All visible scampi, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679 km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355	
mean	0.0000	0.0063	0.0039	0.0039	0.0000	0.0140	0.0133	0.0046	0.0031	0.0189	0.0065	0.0000	0.0010	0.0076	0.0015	0.00513 mean density
sd	0.0000	0.0078	0.0047	0.0067	0.0000	0.0084	0.0068	0.0055	0.0053	0.0193	0.0067	0.0000	0.0017	0.0086	0.0026	0.00092 sd mean
var	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0001	0.0000	
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52 sites
sem	0.0000	0.0039	0.0027	0.0039	0.0000	0.0042	0.0030	0.0032	0.0031	0.0086	0.0030	0.0000	0.0010	0.0049	0.0015	17.9% c.v.
cv	#DIV/0!	0.62	0.71	1.00	#DIV/0!	0.30	0.23	0.69	1.00	0.46	0.46	#DIV/0!	1.00	0.65	1.00	
calc	0.0E+00	6.6E-08	3.3E-08	5.2E-08	0.0E+00	5.5E-08	3.0E-08	2.0E-08	2.4E-08	4.9E-07	3.5E-08	0.0E+00	2.2E-09	3.9E-08	2.8E-09	0.00000 var mean
N	0.00E+00	1.93E+06	1.20E+06	1.07E+06	0.00E+00	3.67E+06	3.54E+06	9.63E+05	7.23E+05	7.14E+06	1.87E+06	0.00E+00	2.17E+05	1.41E+06	2.47E+05	23,991,641 Abundance

All visible scampi, reader 3

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results
area	839	307	311	275	315	262	266	209	237	378	290	420	218	186	166	4679 km^2
rel_A	0.1793	0.0656	0.0665	0.0588	0.0673	0.0560	0.0568	0.0447	0.0507	0.0808	0.0620	0.0898	0.0466	0.0398	0.0355	
mean	0.0000	0.0012	0.0073	0.0029	0.0000	0.0086	0.0070	0.0014	0.0020	0.0158	0.0071	0.0166	0.0051	0.0085	0.0044	0.00573 mean density
sd	0.0000	0.0015	0.0050	0.0051	0.0000	0.0064	0.0057	0.0025	0.0035	0.0165	0.0066	0.0288	0.0065	0.0101	0.0045	0.00169 sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0008	0.0000	0.0001	0.0000	
count	2	4	3	3	3	4	5	3	3	5	5	3	3	3	3	52 sites
sem	0.0000	0.0007	0.0029	0.0029	0.0000	0.0032	0.0025	0.0014	0.0020	0.0074	0.0030	0.0166	0.0037	0.0058	0.0026	29.5% c.v.
cv	#DIV/0!	0.58	0.40	1.00	#DIV/0!	0.37	0.37	1.00	1.00	0.47	0.41	1.00	0.73	0.69	0.58	
calc	0.0E+00	2.3E-09	3.7E-08	3.0E-08	0.0E+00	3.2E-08	2.1E-08	4.1E-09	1.1E-08	3.6E-07	3.3E-08	2.2E-06	3.0E-08	5.4E-08	8.4E-09	0.00000 var mean
N	0.00E+00	3.83E+05	2.27E+06	8.04E+05	0.00E+00	2.25E+06	1.85E+06	2.99E+05	4.82E+05	5.96E+06	2.07E+06	6.99E+06	1.12E+06	1.58E+06	7.34E+05	26,797,673 Abundance

***Appendix 4a*:** **Estimates for three readers of burrow openings (m^{-2}) by stratum and for the 1998 survey area between Cuvier Island and White Island**

Openings, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0126	0.2113	0.1939	0.0434	0.0306	0.1623	0.1666	0.0749	0.0000	0.0000	0.0000	0.11290	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0108	0.1207	0.0454	0.0325	0.0322	0.0651	0.0337	0.0661	0.0000	0.0000	0.0000	0.01125	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0001	0.0146	0.0021	0.0011	0.0010	0.0042	0.0011	0.0044	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0062	0.0603	0.0203	0.0188	0.0186	0.0291	0.0151	0.0382	#DIV/0!	#DIV/0!	#DIV/0!	10.0%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.49	0.29	0.10	0.43	0.61	0.18	0.09	0.51	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.8E-07	4.4E-05	5.2E-06	2.7E-06	3.4E-06	2.1E-05	3.4E-06	4.5E-05	0.0E+00	0.0E+00	0.0E+00	0.00013	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.96E+06	5.54E+07	5.16E+07	9.06E+06	7.24E+06	6.13E+07	4.83E+07	3.15E+07	0.00E+00	0.00E+00	0.00E+00	268,352,858	Abundance

Openings, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0320	0.2334	0.2295	0.0876	0.0628	0.1960	0.1546	0.0127	0.0000	0.0000	0.0000	0.12189	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0263	0.0975	0.1100	0.0371	0.0583	0.0816	0.0687	0.0136	0.0000	0.0000	0.0000	0.01130	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0007	0.0095	0.0121	0.0014	0.0034	0.0067	0.0047	0.0002	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0152	0.0488	0.0492	0.0214	0.0336	0.0365	0.0307	0.0079	#DIV/0!	#DIV/0!	#DIV/0!	9.3%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.47	0.21	0.21	0.24	0.54	0.19	0.20	0.62	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.0E-06	2.9E-05	3.0E-05	3.5E-06	1.1E-05	3.4E-05	1.4E-05	1.9E-06	0.0E+00	0.0E+00	0.0E+00	0.00013	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.01E+07	6.12E+07	6.11E+07	1.83E+07	1.49E+07	7.41E+07	4.48E+07	5.31E+06	0.00E+00	0.00E+00	0.00E+00	289,723,180	Abundance

Openings, reader 3

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0306	0.0162	0.0045	0.0120	0.0783	0.1215	0.2482	0.0000	0.0000	0.0000	0.07792	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0123	0.0171	0.0043	0.0107	0.1043	0.1467	0.3910	0.0000	0.0000	0.0000	0.04137	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0003	0.0000	0.0001	0.0109	0.0215	0.1529	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0062	0.0076	0.0025	0.0062	0.0466	0.0656	0.2257	#DIV/0!	#DIV/0!	#DIV/0!	53.1%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.20	0.47	0.55	0.52	0.60	0.54	0.91	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.6E-07	7.3E-07	4.8E-08	3.8E-07	5.5E-05	6.4E-05	1.6E-03	0.0E+00	0.0E+00	0.0E+00	0.00171	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.03E+06	4.31E+06	9.50E+05	2.85E+06	2.96E+07	3.52E+07	1.04E+08	0.00E+00	0.00E+00	0.00E+00	185,225,747	Abundance

Appendix 4b: **Estimates for three readers of burrows (m^{-2}) by stratum and for the 1998 survey area between Cuvier Island and White Island**

Burrows, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	Stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0070	0.1130	0.1036	0.0234	0.0166	0.0983	0.0914	0.0375	0.0000	0.0000	0.0000	0.06208	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0046	0.0645	0.0293	0.0160	0.0155	0.0370	0.0209	0.0330	0.0000	0.0000	0.0000	0.00600	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0009	0.0003	0.0002	0.0014	0.0004	0.0011	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0027	0.0323	0.0131	0.0092	0.0089	0.0166	0.0093	0.0191	#DIV/0!	#DIV/0!	#DIV/0!	9.7%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.38	0.29	0.13	0.39	0.54	0.17	0.10	0.51	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	1.3E-05	2.2E-06	6.6E-07	7.9E-07	6.9E-06	1.3E-06	1.1E-05	0.0E+00	0.0E+00	0.0E+00	0.00004	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E+06	2.96E+07	2.76E+07	4.90E+06	3.93E+06	3.71E+07	2.65E+07	1.57E+07	0.00E+00	0.00E+00	0.00E+00	147,573,289	Abundance

Burrows, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0285	0.1316	0.1236	0.0562	0.0502	0.1176	0.0905	0.0067	0.0000	0.0000	0.0000	0.07298	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0237	0.0515	0.0576	0.0260	0.0446	0.0489	0.0382	0.0074	0.0000	0.0000	0.0000	0.00671	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0006	0.0027	0.0033	0.0007	0.0020	0.0024	0.0015	0.0001	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0137	0.0258	0.0257	0.0150	0.0257	0.0219	0.0171	0.0043	#DIV/0!	#DIV/0!	#DIV/0!	9.2%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.48	0.20	0.21	0.27	0.51	0.19	0.19	0.64	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E-06	8.1E-06	8.3E-06	1.7E-06	6.6E-06	1.2E-05	4.3E-06	5.6E-07	0.0E+00	0.0E+00	0.0E+00	0.00004	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.99E+06	3.45E+07	3.29E+07	1.17E+07	1.19E+07	4.45E+07	2.62E+07	2.80E+06	0.00E+00	0.00E+00	0.00E+00	173,469,663	Abundance

Burrows, reader 3

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0202	0.0096	0.0037	0.0091	0.0603	0.1061	0.2131	0.0000	0.0000	0.0000	0.06473	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0080	0.0102	0.0044	0.0082	0.0804	0.1303	0.3348	0.0000	0.0000	0.0000	0.03536	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0065	0.0170	0.1121	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0040	0.0046	0.0025	0.0047	0.0360	0.0583	0.1933	#DIV/0!	#DIV/0!	#DIV/0!	54.6%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.20	0.48	0.69	0.52	0.60	0.55	0.91	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-07	2.6E-07	5.0E-08	2.2E-07	3.3E-05	5.1E-05	1.2E-03	0.0E+00	0.0E+00	0.0E+00	0.00125	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.29E+06	2.55E+06	7.74E+05	2.17E+06	2.28E+07	3.08E+07	8.95E+07	0.00E+00	0.00E+00	0.00E+00	153,854,105	Abundance

Appendix 4c: **Estimates for three readers of scampi in holes (m^{-2}) by stratum and for the 1998 survey area between Cuvier Island and White Island**

Scampi in holes, reader 1

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0098	0.0055	0.0014	0.0020	0.0130	0.0036	0.0000	0.0000	0.0000	0.0000	0.00453	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0072	0.0041	0.0025	0.0035	0.0138	0.0026	0.0000	0.0000	0.0000	0.0000	0.00111	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0036	0.0018	0.0014	0.0020	0.0062	0.0012	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	24.5%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.37	0.33	1.00	1.00	0.47	0.32	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-07	4.1E-08	1.6E-08	4.1E-08	9.6E-07	2.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.56E+06	1.45E+06	2.99E+05	4.82E+05	4.92E+06	1.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	10,769,928	Abundance

Scampi in holes, reader 2

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0077	0.0050	0.0046	0.0031	0.0127	0.0041	0.0000	0.0000	0.0000	0.0000	0.00463	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0075	0.0049	0.0055	0.0053	0.0141	0.0036	0.0000	0.0000	0.0000	0.0000	0.00120	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0038	0.0022	0.0032	0.0031	0.0063	0.0016	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	26.0%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.49	0.44	0.69	1.00	0.50	0.39	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-07	6.0E-08	7.8E-08	9.3E-08	1.0E-06	3.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.01E+06	1.33E+06	9.63E+05	7.23E+05	4.79E+06	1.20E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	11,015,153	Abundance

Scampi in holes, reader 3

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0065	0.0020	0.0014	0.0020	0.0085	0.0025	0.0000	0.0000	0.0000	0.0000	0.00293	mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0019	0.0025	0.0035	0.0098	0.0039	0.0000	0.0000	0.0000	0.0000	0.00080	sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000		
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0020	0.0008	0.0014	0.0020	0.0044	0.0017	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	27.4%	c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.30	0.42	1.00	1.00	0.51	0.69	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-08	8.6E-09	1.6E-08	4.1E-08	4.9E-07	4.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E+06	5.20E+05	2.99E+05	4.82E+05	3.22E+06	7.26E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6,959,651	Abundance

Appendix 4d: **Estimates for three readers of scampi not in holes (m^{-2}) by stratum and for the 1998 survey area between Cuvier Island and White Island**

Scampi on surface, reader 1

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377 km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000	
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0046	0.0087	0.0000	0.0000	0.0090	0.0031	0.0000	0.0000	0.0000	0.0000	0.00329 mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0037	0.0079	0.0000	0.0000	0.0098	0.0049	0.0000	0.0000	0.0000	0.0000	0.00087 sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31 sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0018	0.0035	0.0000	0.0000	0.0044	0.0022	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	26.3% c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.40	0.40	#DIV/0!	#DIV/0!	0.49	0.70	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.1E-08	1.5E-07	0.0E+00	0.0E+00	4.9E-07	7.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000 var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E+06	2.32E+06	0.00E+00	0.00E+00	3.40E+06	9.01E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7,823,556 Abundance

Scampi on surface, reader 2

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377 km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000	
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0083	0.0000	0.0000	0.0062	0.0023	0.0000	0.0000	0.0000	0.0000	0.00290 mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0075	0.0000	0.0000	0.0075	0.0034	0.0000	0.0000	0.0000	0.0000	0.00076 sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31 sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0031	0.0033	0.0000	0.0000	0.0034	0.0015	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	26.2% c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.50	0.40	#DIV/0!	#DIV/0!	0.54	0.65	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-07	1.4E-07	0.0E+00	0.0E+00	2.9E-07	3.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000 var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.66E+06	2.22E+06	0.00E+00	0.00E+00	2.36E+06	6.71E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6,903,812 Abundance

Scampi on surface, reader 3

	Stratum 201	stratum 202	stratum 203	stratum 204	stratum 301	stratum 302	stratum 303	stratum 304	stratum 401	stratum 402	stratum 403	stratum 404	stratum 501	stratum 502	stratum 503	Results
Area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377 km^2
Rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000	
Mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	0.0050	0.0000	0.0000	0.0072	0.0046	0.0166	0.0000	0.0000	0.0000	0.00545 mean density
Sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0067	0.0000	0.0000	0.0074	0.0042	0.0288	0.0000	0.0000	0.0000	0.00302 sd mean
Var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000	
Count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31 sites
Sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0012	0.0030	0.0000	0.0000	0.0033	0.0019	0.0166	#DIV/0!	#DIV/0!	#DIV/0!	55.4% c.v.
Cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.60	0.60	#DIV/0!	#DIV/0!	0.46	0.40	1.00	#DIV/0!	#DIV/0!	#DIV/0!	
Calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-08	1.1E-07	0.0E+00	0.0E+00	2.8E-07	5.2E-08	8.6E-06	0.0E+00	0.0E+00	0.0E+00	0.00001 var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.43E+05	1.33E+06	0.00E+00	0.00E+00	2.74E+06	1.35E+06	6.99E+06	0.00E+00	0.00E+00	0.00E+00	12,950,436 Abundance

Appendix 4e: **Estimates for three readers of all visible scampi (m^{-2}) by stratum and for the 1998 survey area between Cuvier Island and White Island**

All visible scampi, reader 1

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0144	0.0142	0.0014	0.0020	0.0220	0.0067	0.0000	0.0000	0.0000	0.0000	0.00782	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0079	0.0063	0.0025	0.0035	0.0196	0.0061	0.0000	0.0000	0.0000	0.0000	0.00155	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0039	0.0028	0.0014	0.0020	0.0088	0.0027	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	19.8%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.27	0.20	1.00	1.00	0.40	0.41	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-07	9.8E-08	1.6E-08	4.1E-08	1.9E-06	1.1E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+06	3.77E+06	2.99E+05	4.82E+05	8.32E+06	1.95E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	18,593,483	Abundance

All visible scampi, reader 2

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0140	0.0133	0.0046	0.0031	0.0189	0.0065	0.0000	0.0000	0.0000	0.0000	0.00754	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0084	0.0068	0.0055	0.0053	0.0193	0.0067	0.0000	0.0000	0.0000	0.0000	0.00159	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0042	0.0030	0.0032	0.0031	0.0086	0.0030	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	21.1%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.30	0.23	0.69	1.00	0.46	0.46	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-07	1.1E-07	7.8E-08	9.3E-08	1.9E-06	1.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.00000	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.67E+06	3.54E+06	9.63E+05	7.23E+05	7.14E+06	1.87E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	17,918,965	Abundance

All visible scampi, reader 3

	Stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	stratum	Results	
	201	202	203	204	301	302	303	304	401	402	403	404	501	502		503	
area	0	0	0	0	315	262	266	209	237	378	290	420	0	0	0	2377	km^2
rel_A	0.0000	0.0000	0.0000	0.0000	0.1325	0.1102	0.1119	0.0879	0.0997	0.1590	0.1220	0.1767	0.0000	0.0000	0.0000		
mean	0.0000	0.0000	0.0000	0.0000	0.0000	0.0086	0.0070	0.0014	0.0020	0.0158	0.0071	0.0166	0.0000	0.0000	0.0000	0.00838	mean density
sd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0064	0.0057	0.0025	0.0035	0.0165	0.0066	0.0288	0.0000	0.0000	0.0000	0.00323	sd mean
var	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0008	0.0000	0.0000	0.0000		
count	0	0	0	0	3	4	5	3	3	5	5	3	0	0	0	31	sites
sem	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.0000	0.0032	0.0025	0.0014	0.0020	0.0074	0.0030	0.0166	#DIV/0!	#DIV/0!	#DIV/0!	38.5%	c.v.
cv	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.37	0.37	1.00	1.00	0.47	0.41	1.00	#DIV/0!	#DIV/0!	#DIV/0!		
calc	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-07	8.1E-08	1.6E-08	4.1E-08	1.4E-06	1.3E-07	8.6E-06	0.0E+00	0.0E+00	0.0E+00	0.00001	var mean
N	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25E+06	1.85E+06	2.99E+05	4.82E+05	5.96E+06	2.07E+06	6.99E+06	0.00E+00	0.00E+00	0.00E+00	19,910,087	Abundance