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Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1, 1998–2002

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Final Research Report for

Ministry of Fisheries Research Projects

SCI2000/02 (Objectives 1 & 2)

SCI2001/01 (Objectives 1 & 2)

National Institute of Water and Atmospheric Research

November 2002

Final Research Report

Report Title: Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1, 1998–2002

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1. **Date:** 29 November 2002

2. **Contractor:** National Institute of Water & Atmospheric Research Ltd

3. **Project Title:** "Monitoring the abundance of scampi" and "Measuring the abundance of scampi"

4. **Project Codes:** SCI2000/02 and SCI 2001/01

5. **Project Leader:** Martin Cryer

6. **Duration of Project:**
Start date: 1 December 2000
Expected completion date: 31 March 2003

7. **Executive Summary:**

The fourth photographic sampling voyage in the core area of the QMA 1 scampi fishery (Cuvier to White Island, 300–500 m depth) was completed in April 2002. From the four voyages, we initiated and screened 2885 images from 85 stations. The total area accepted for screening was 21 243 m^2 at an average of 7.36 m^2 per image. Using data from 1998 to 2001 in stratum 303 (Aldermen Islands, 400–500 m depth) we developed and tested a rigorous and repeatable screening and analytical protocol for estimating the density of scampi burrows; correlation between experienced readers consistently exceeded 0.95 at the site level. Based on this protocol, an expanded pool of six readers screened the remaining images with an average between-reader correlation of 0.96 at the site level General linear modelling at the transect level identified some consistent differences among readers; three readers tended to score about 10% higher than the overall average, the other three about 10% lower. Because images from different surveys and strata were spread relatively evenly among the readers, our final indices are not sensitive to this reader "bias". Based on images from all surveys in strata 302, 303, 402, and 403, the density of visible scampi (and hence minimum absolute biomass) in the core area of the QMA 1 scampi trawl fishery decreased by about 50% between 1998 and 2001 and remained relatively low in 2002. This is consistent with declines in commercial CPUE. Based on these estimates of minimum biomass, the current catch limit of 120 t in QMA 1 is about 12–28% of total biomass. This estimate is very likely to be conservative. The density of major burrow openings in the same area had little trend between 1998 and 2002, although the 1998 index was highest and the 2000 index was the lowest. This is not consistent with commercial CPUE or research trawl catch rates. Based on estimates of

biomass from burrow counts, the current catch limit of 120 t in QMA 1 is 2–4% of total biomass. This estimate may not be conservative.

8. Objectives:

Overall Objective for both projects:

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

Relevant Objectives for SCI2000/02:

1. To identify and minimise the effects of factors causing reader variation in the interpretation of photographic information.

2. To estimate the relative abundance of scampi using photographic techniques in QMA 1 between Cuvier Island and White Island at a depth of 300 to 500m.

Relevant Objectives for SCI2001/01:

1. To estimate the relative abundance of scampi using photographic techniques in QMA 1 between Cuvier Island and White Island at a depth of 300 to 500m.

2. To calculate comparable indices of relative abundance for scampi in the surveyed part of QMA 1 in 1998, 2000, 2001, and 2002.

9. Methods:

9.1 Field sampling

In 1998, 2000, 2001, and 2002, we undertook stratified random photographic surveys of scampi burrows within the core area of the QMA 1 scampi fishery, Cuvier Island to White Island, 300–500 m depth (Figure 1). In 1998, we used a *Benthos* emulsion based system loaded with Ilford FP4+ high resolution black-and-white film stock. In 2000 and subsequent years we used a custom built digital system based on *Minolta* D'Image EX1500 digital cameras. We conducted complementary trawling and acoustic sampling during all surveys. Positions of stations within strata in 1998 were randomised using RAND_STN (v 1.7 for PCs; MAF Fisheries 1990) constrained to keep the midpoints of all stations at least 1000 m apart. For subsequent surveys, the stations were on fixed stations established in 2000, originally randomised using RAND_STN constrained to keep the midpoints of all stations at least 1 km apart (the estimated range of spatial autocorrelation from the 1998 photographic survey, Cryer & Hartill 1998). "Permanent" stations were used to remove small scale variability as a possible cause of changes in apparent burrow density among surveys (Cryer et al. 2001). In 2002, the six stations with the highest estimated density of scampi burrows in 1998 were sampled in addition to the 20 fixed random stations. This was done to test the proposition that the large difference between the 1998 and 2000 estimates of abundance (Cryer et al. 2001) was a result of selecting, by chance, areas of high density on 1998 and low density in 2000.

Each survey consisted of 20 or more stations, each station of 2–5 (usually 3) transects, and each transect of (nominally) 12–15 photographs. Within a station, transects were spaced about 1000 m apart at roughly constant depth, such that each station mimicked a short trawl tow (the original intent of this design was to compare photographic and trawl methods of sampling scampi). Within a transect, photographs were taken as the ship drifted, using a time delay sufficient to ensure that adjacent photographs did not overlap (Cryer & Hartill 1998, Cryer et al. 2001). For both camera systems we took photographs 3–5 m from the seabed using custom-built steel cages suspended on a trawl warp. The camera was triggered using a bottom contact trigger or interval timer. Image sizes were determined using parallel lasers 200 mm apart on the camera frame; two red dots from the lasers are visible in almost all images, and these were used to estimate the linear dimensions of the image and its area. Laser scaling was not available in 1998, so we scaled image areas using the trigger weight (84 mm on its longer dimension) assumed to be 350 mm above the sediment surface (after a method by Cryer & Hartill 1998).

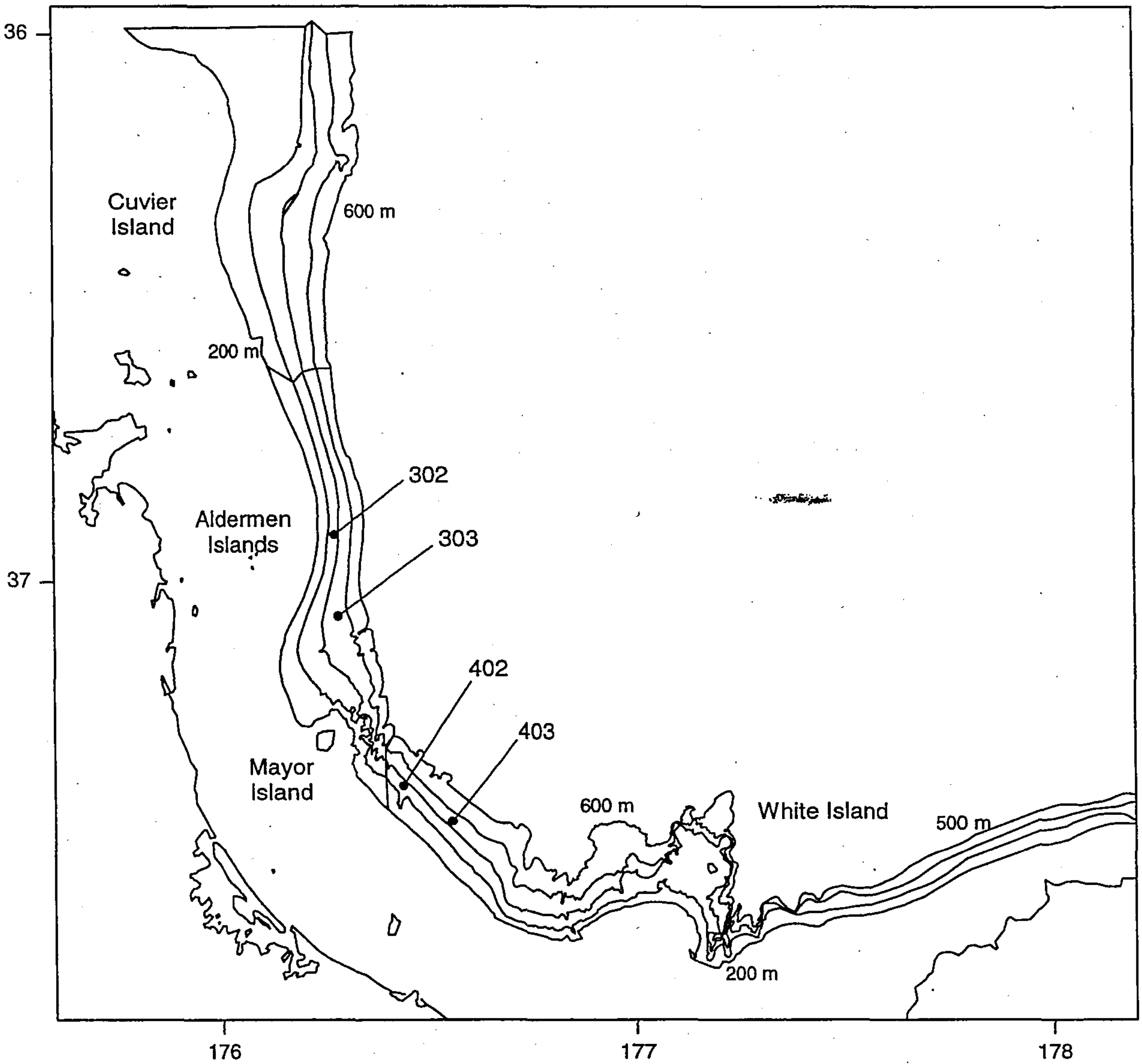

***Figure 1*: Sampling strata for photographic surveys of scampi and scampi burrows in the "core" area of the QMA 1 fishery, 1998–2002). Strata are grouped geographically (coded by the first numeral of the stratum code) and by depth (coded by the last numeral of the stratum code: 2 = 300–400 m; 3 = 400–500 m). Isobaths are shown at 100 m intervals from 200 to 600 m.**

9.2 Image selection and scoring

Until April 2002, images were examined and scored (either by committee or independently) by the three experienced readers who developed the standardised protocol now in use (project SCI2000/02). We now have a team of six trained readers. For each image, the main criteria of usability is the ability to discern fine seabed detail, and the visibility of more than 50% of the frame (free from disturbed sediment, poor flash coverage, or other features). If these criteria are met, the image is "adopted" and "initiated" (see Appendices). The percentage of the frame within which the seabed is clearly and sharply visible estimated and marked using polygons in "Didger" image analysis software. Each reader then assesses the number of burrow openings using the standardized protocol. We have defined "major" and "minor" burrow openings which are, respectively, the type of opening at which scampi are usually observed, and the "rear" openings associated with most burrows. Based on our examination of a large number of images of scampi associated with burrows, we suggest that "major" and "minor" openings each have their own characteristics and should be scored separately (Figure 2). We classify each opening (whether major or minor) as "highly characteristic" or "probable", based on the extent to which each is characteristic of burrows observed to be used by New Zealand scampi. Burrows and holes which could conceivably be used by scampi but which are not "characteristic" are not counted. Our counts of burrow openings are, therefore, probably conservative (assuming that burrow occupancy is high).

Many assessments of Nephrops in ICES areas are conducted using relative abundance indices based on counts of "burrows" (rather than burrow openings) (Tuck et al. 1994, 1997). We count burrow openings rather than assumed burrows because burrows are relatively large compared with the quadrat (photograph) size and accepting all burrows totally or partly within each photograph is positively biased by edge effects (e.g., Marrs et al. 1998).

The criteria used by readers to judge whether or not a burrow should be scored are, of necessity, partially subjective. We cannot be certain that any particular burrow belongs to a *M. challengeri* and is currently inhabited unless the individual is photographed in the burrow. However, after viewing large numbers of scampi associated with burrows, we have developed a set of descriptors that guide our decisions (see Appendices). Formalising and ranking these descriptors and using them as part of our scoring protocol is the means by which we have identified and minimised factors causing variation between readers; previously, different readers have been "keying in" on different burrow attributes. Using these descriptors as a guideline, each reader assesses each potential burrow opening (paying more attention to attributes with a high ranking such as surface tracks, a shallow descent angle, and sediment fans for major openings) and scores it only if it "probably" (not "maybe") a scampi burrow.

Once the files from any particular stratum or survey have been read by three readers, any differences are discussed. All images for which the greatest difference between readers in the counts of major openings is more than 1 are re-examined by all readers who may or may not change their score. During this process, each reader has access to the score and annotated files of all other readers and, after re-assessing their own interpretation against the original image, all are encouraged compare their readings with the interpretations of other readers. Thus, the re-reading process is a means of maintaining consistency among readers as well as refining the counts for a given image.

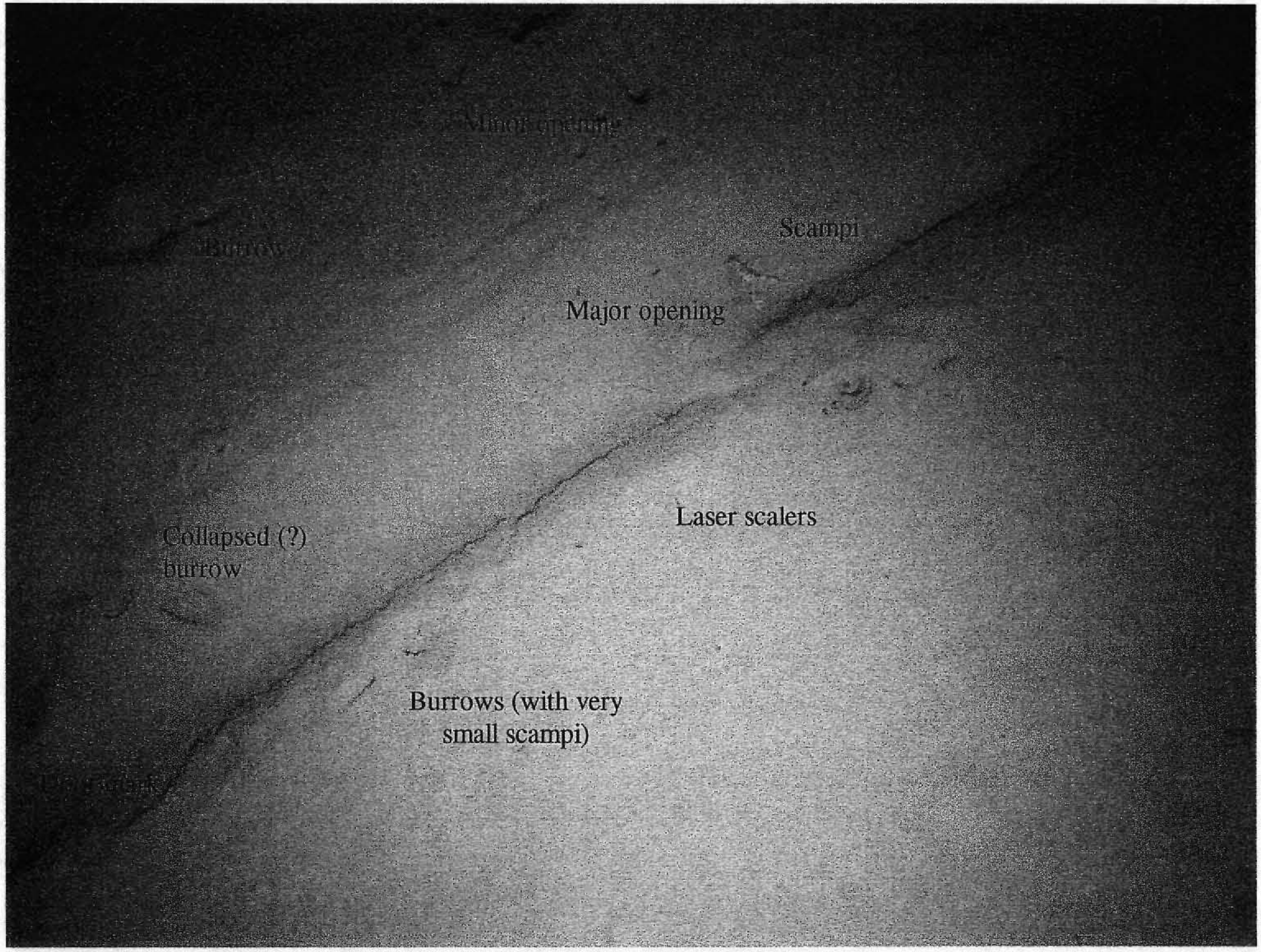

***Figure 2*: Sample image from April 2002 survey showing laser scaling dots, several characteristic scampi burrows, one large and one very small visible scampi, and a seabed mark probably caused by a trawl door.**

9.3 Data analysis

Counts from photographs 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 (major or minor openings or scampi) divided by the sum of all readable areas. For any given stratum, the mean density of openings and its associated variance were estimated using standard parametric methods, giving each station an equal weighting. The total number of openings in the stratum were estimated by multiplying the mean density by the estimated area of the stratum. The overall mean density of openings in the survey area was estimated as the weighted average mean density, and the variance for this overall mean was derived using the formula for strata of unequal sizes given by Snedecor and Cochran (1989):

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

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

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

Comparable estimates of relative abundance (with estimated c.v.s) were generated for surveys of the core area of the QMA 1 scampi fishery in 1998, 2000, 2001, and 2002. Separate indices were calculated for major and minor openings, for all visible scampi, and for scampi "out" of their burrows (i.e., walking free on the sediment surface). Only indices for major burrow openings and for visible scampi are presented here because the Shellfish Fishery Assessment Working Group has agreed that these are likely to be the most reliable indices.

10. Results:

10.1 Developing a protocol for screening and counting burrows

This was a major thrust of project SCI2000/02 (especially Objective 1, to identify and minimise factors causing variation between readers) but applies also to SCI2001/01 (especially Objective 2, calculating comparable indices for 1998, 2000, 2001, and 2002). A substantive presentation was made to the Ministry's Shellfish Fishery Assessment Working Group in late April 2002 describing the development of a rigorous, repeatable counting protocol for images from stratum 303 in 1998, 2000, and 2001 (see Appendices 1–3). After this meeting, we tested the generality of this protocol using data from stratum 302 in these same years, and then moved to assess all images from all four strata in all four years using an expanded team of six trained readers.

Data analysed by April 2002 suggested that we had developed a repeatable screening and counting protocol; at a site level, readings by three readers working blind of one another are correlated in the range r_{13} = 0.96–0.99 (Figure 3). This is of the same order as the repeatability of counts by individual readers, and shows that experienced readers have a very similar understanding of what constitutes a major burrow entrance that is likely to belong to New Zealand scampi.

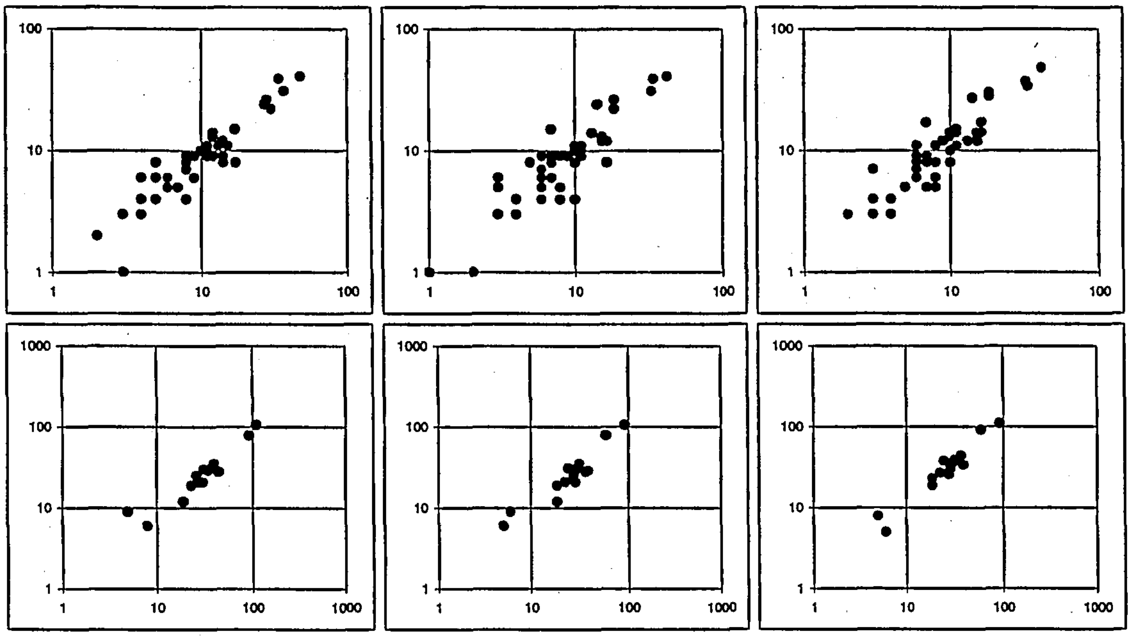

Figure 3: **Correlations among three readers in counts of major burrow openings from stratum 303, 1998 to 2001, at a transect level (top three panels) and a station level (bottom three panels).**

10.2 Differences and correlations among readers

Correlation among the six readers at a site level averaged 0.955 (range 0.885–0.996, with 8–27 degrees of freedom, Table 1). This is only slightly lower than correlations among the initial three readers and suggests that the standardised training and counting protocols we have developed result in relatively consistent interpretations of images; the system is rigorous and repeatable.

Correlation coefficients between individual readers can be used to estimate "scatter" about the relationship between the two sets of counts, but that there can also consistent bias in one reader's counts compared with another that might not be obvious from a correlation analysis (e.g., Figure 4). We examined this possibility using linear models using data pooled at a transect level (i.e., about 12 images combined, representing about 80 m^2 of seabed). Models testing the null hypotheses that there were no spatial or temporal trends in distribution and all readers behaved similarly detected highly significant year, stratum, and reader effects (all expressed as categorical effects Table 2). The reader effect was the weakest of the main effects tested.

Table 1: Correlations among readers at a site level (top) and number of sites that each pair of readers screened together (bottom).

Readers:	BH	CM	HC	JD	MC	MS
Correlation						
BH	1.000	–	–	–	–	–
CM	0.930	1.000	–	–	–	–
HC	0.959	0.968	1.000	–	–	–
JD	0.957	0.885	0.917	1.000	–	–
MC	0.953	0.996	0.990	0.976	1.000	–
MS	0.980	0.958	0.952	N/A	0.943	1.000
Number of sites						
BH	0	–	–	–	–	–
CM	14	0	–	–	–	–
HC	10	15	0	–	–	–
JD	29	10	10	0	–	–
MC	29	10	17	29	0	–
MS	24	19	22	0	17	0

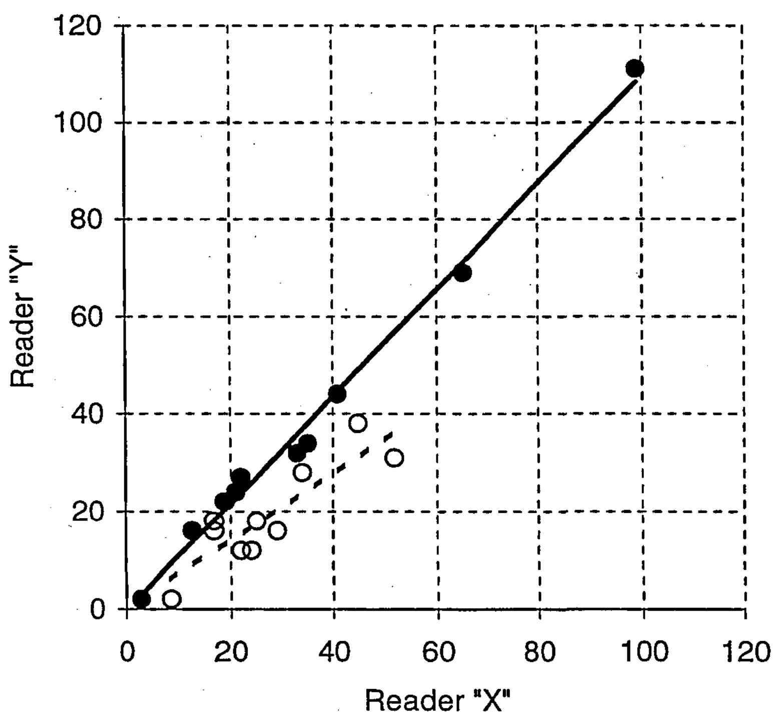

Figure 4: Scatterplots showing the highest (solid dots, r_s = 0.996) and lowest (open dots, r_s = 0.885) correlations between readers at a site level. Lines are ordinary least squares regressions. These plots show the effects of "random" variation as well as bias; the solid dots show the relationship between two readers who have, on average, very similar readings with little variability, whereas the open dots show a "noisy" relationship between two readers, one of whom also counts consistently less than the other.

Table 2: Analysis of variance for a general linear model relating the estimated density of major burrow openings on a transect to reader, year, stratum, and a first-order interaction between year and stratum. Other first-order interaction terms were examined but found not to be significant.

Source	SS	df	MS	F	P
READER	670.846	5	134.169	3.202	0.007
YEAR	1789.041	3	596.347	14.231	0.000
STRATUM	2178.207	3	726.069	17.326	0.000
YEAR*STRATUM	2502.109	9	278.012	6.634	0.000
Error	31303.35	747	41.905		

Exploration of first-order interaction terms (reader*year, reader*stratum, and year*stratum) showed that the year*stratum interaction was the strongest and remained significant in the model whatever other interactions and main effects were included. In contrast, interaction terms including reader, and a second-order year*reader*stratum interaction were included only sporadically. The model including only the main effects gave very similar results to those from the model including the year*stratum interaction (Table 3), the effects for readers MS, HC, and JD being the most sensitive to inclusion of the interaction term (changes of about 6–7%).

Table 3: Least squares mean effects for readers from a general linear model relating the estimated density of major burrow openings (on a transect) to reader, year, stratum, and a first-order interaction between year and stratum. Values for N are the number of transects (each of about 12 images) examined by each reader.

	With interaction		Without interaction		
	Mean (m^{-2})	SE	Mean (m^{-2})	SE	N
READER = BH	0.1024	0.0056	0.1020	0.0055	160
READER = CM	0.1198	0.0074	0.1191	0.0073	100
READER = HC	0.0995	0.0070	0.0927	0.0067	109
READER = JD	0.1006	0.0066	0.1077	0.0066	121
READER = MC	0.1212	0.0055	0.1250	0.0055	161
READER = MS	0.1226	0.0069	0.1140	0.0067	117

These results suggest that, although correlation between readers is generally very good, there are reasonably consistent differences among readers. Three of the current trained pool tend to read relatively high (about 10% more than the overall average, CM, MC, and MS) and the other three tend to read relatively low (about 10% less than the overall average, BH, HC, JD).

The year effects and their variances estimated using this model should not be interpreted as mean densities across the whole survey area because they include the repeat 1998 stations selected for their possible high density, and because the mean of transect densities takes no account of the stratification in our sampling design. In fact, the pattern in the year effects is very similar to the pattern in the relative abundance estimates derived later.

10.3 Images potentially available for indices of relative abundance in QMA 1

We initiated and screened 2722 images from the 79 randomly positioned stations covered during the four surveys (Table 4). Of these, we excluded 34 images because their estimated areal coverage was either less than 2 m^2 or more than 16 m^2, leaving 2688 valid images. A further 197 images were initiated and screened from the additional sites occupied in 2002, making a grand total of 2885 valid images. The average number of photographs accepted for a station was 33.9, and this was roughly constant among years (annual means ranged from 31.4 to 35.8). The total area accepted for screening (i.e., excluding all poor photographs and all parts of acceptable photographs occluded by silt or grossly over- or under-exposed) was 21 243 m^2 for an overall average of 7.36 m^2 per image. This varied (largely as a result of changes to exposure management among years) from a high of 8.65 m^2 in 2000 to a low of 5.61 m^2 in 2001.

Table 4: Number of sites, number of usable photographs, and total screened area in each stratum in each of the surveys in 1998, 2000, 2001, and 2002 (a) in the core area of the QMA 1 scampi trawl fishery, Cuvier to White Island, 300–500 m depth. In 2002, six additional sites were selected (2002b) for sampling based on their high density of putative scampi burrows in 1998.

	Sites					Photos					Area (m^2)				
Year	302	303	402	403	Total	302	303	402	403	Total	302	303	402	403	Total
1998	5	5	5	5	20	124	212	174	160	670	910	1 362	1 192	1 295	4 759
2000	4	5	5	5	19	150	177	188	160	675	1 117	1 350	1 805	1 564	5 836
2001	5	5	5	5	20	158	169	147	153	627	872	1 055	759	831	3 517
2002a	5	5	5	5	20	203	196	145	172	716	1 683	1 482	1 104	1 340	5 609
2002b	3	2	1	0	6	85	77	35	0	197	677	553	291	0	1 521

In 1998 and 2000 images were also collected in water shallower than 300 m, deeper than 500 m, north of Cuvier Island, and east of White Island. These areas are considered to be outside the core area of the QMA 1 fishery and have not been included in this analysis. There may be future implications of this decision if there are changes in the distribution of the fishery or of scampi, but all images and data have been electronically archived.

10.4 Assessing the "usability" of non-randomly selected sites from 2002

The six sites with the highest observed density of burrows in 1998 were spread among three of the four core strata (302, 303, 402, and 403). The mean density of major burrow openings at these sites in 2002 (estimated using transect means to estimate stratum and overall means) was not significantly different from sites selected at random (Table 5). Using all the data, the mean density at the selected 1998 "high density" sites was 0.115 m^{-2} compared with 0.117 m^{-2} for the random sites (now used as fixed sites). This suggests that the high estimate of the mean density of burrow openings in 1998 (e.g., Cryer & Hartill 2000) was not a result of choosing, by chance, sites in areas with a particularly high density of burrows. If that were the case, we would expect these sites to have a high density in 2002 (relative to randomly chosen sites). In fact, 2002 burrow densities were, on average, lower than "ambient" at the specially selected sites in strata 302 and 303 (11 transects from 5 stations), higher in stratum 402 (three transects at one station), and remarkably similar overall. These results suggest that using the five additional (non random) sites occupied in 2002 to estimate average burrow density is not likely to lead to much bias. Relative abundance estimates are, therefore, presented with and without these additional stations (section 10.5).

Table 5: Differences in the estimated mean density of major openings at the 20 fixed sites (which were randomly selected) and at 6 sites selected for re-sampling in 2002 because they had particularly high densities of burrows in 1998 (i.e., they were not randomly selected). Densities were estimated by pooling all data up to the transect level; numbers in parentheses show the number of transects used to estimate each mean density.

Stratum	Mean density at random sites (m^{-2})	Mean density at 1998 high density sites (m^{-2})	T	P
302	(15) 0.0889	(6) 0.0693	1.51	0.15
303	(15) 0.1460	(5) 0.1386	0.25	0.81
402	(16) 0.1065	(3) 0.1686	1.70	0.11
403	0.1286	–	–	–
Overall	(60) 0.1171	(14) 0.1153	0.10	0.92

10.5 Indices of abundance and biomass

The estimated mean density of scampi burrows (as indexed by their major openings) throughout the core area of the QMA 1 scampi fishery, 300–500 m depth, varied from 0.08 m^{-2} in 2000 to 0.13 m^{-2} in 1998 (with c.v.s of 8–15% of the mean). Scaling to the combined area of these four strata (1196 km^2) leads to abundance estimates of 94–154 million burrows or, assuming 100% occupancy, an identical number of animals (Table 6, Figure 5).

Table 6: Estimates of the abundance (millions) of major burrow openings within the core area of the QMA 1 scampi fishery (strata 302, 303, 402, and 403) between 1998 and 2002. Counts by each reader within "corrected" estimates have been scaled by the inverse of reader factors estimated from the linear model in Table 3. Estimates annotated "2002+" were made using all 26 sites sampled in 2002, the 20 fixed sites (sampled 2000, 2001, and 2002) plus repeats of the 6 sites sampled in 1998 that had the highest estimated density of scampi burrows.

	Uncorrected		Corrected	
	Abundance (x 10^{-6})	c.v.	Abundance (x 10^{-6})	c.v.
1998	153.5	14.7	155.1	14.7
2000	94.2	12.5	96.7	12.7
2001	132.0	11.8	135.9	11.8
2002	131.8	7.9	125.6	7.8
2002 +	134.5	8.0	128.2	8.1

"Correcting" the counts made by each reader by scaling by the inverse of their respective effects from the general linear model (Table 6) makes little difference to the estimates of the density of major openings, increasing the estimates for 1998, 2000, and 2001 by 1–3% and decreasing those for 2002 by 5% (whether or not the additional stations are included).

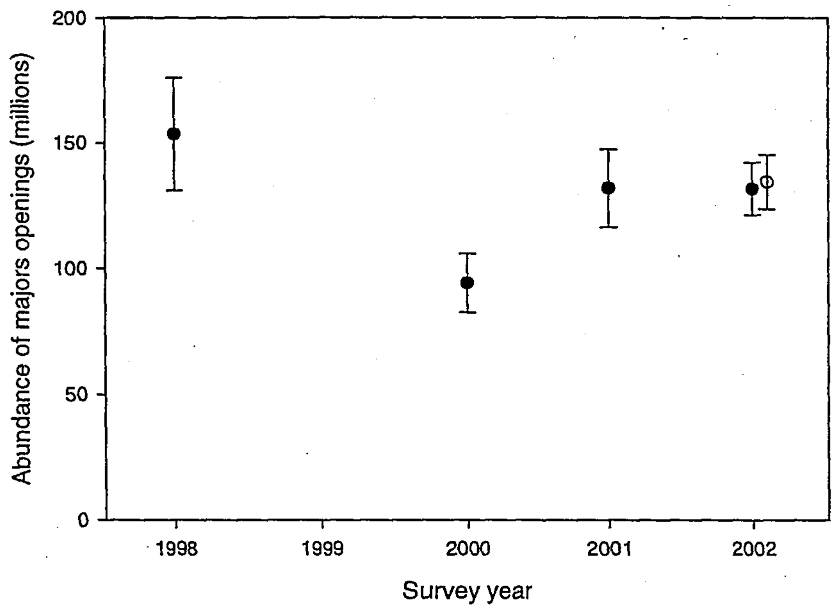

Figure 5: **Estimated abundance (± one standard error) of major burrow openings in strata 302, 303, 402, and 403, 1998 to 2002. Closed symbols represent estimates made using randomly-selected sites (these being fixed sites since 2002) and the open symbol represents a revised estimate for 2002 including 6 sites selected for survey on the basis that they had the highest estimated density of burrows in 1998.**

Table 7: Estimates of the abundance (millions) of visible scampi within the core area of the QMA 1 scampi fishery (strata 302, 303, 402, and 403) between 1998 and 2002. Scampi "not in burrows" were defined as those for which the telson was not obscured by a burrow. Estimates annotated "2002+" were made using all 26 sites sampled in 2002, the 20 fixed sites (sampled 2000, 2001, and 2002) plus repeats of the 6 sites sampled in 1998 that had the highest estimated density of scampi burrows.

	All visible scampi		Scampi not in burrows	
	Abundance (x 10^{-6})	c.v.	Abundance (x 10^{-6})	c.v.
1998	27.9	22.3	11.1	45.8
2000	18.2	18.2	8.1	25.4
2001	12.3	26.3	2.0	53.5
2002	14.7	21.5	0.8	51.8
2002 +	16.7	21.3	2.4	61.6

The estimated mean density of all visible scampi (i.e., including those in burrows and those walking free on the sediment surface) varied from 0.010 m^{-2} in 2001 to 0.025 m^{-2} in 1998 (with c.v.s of 18–26% of the mean). Scaling these counts to the sampled area leads to abundance estimates of 12–28 million animals (Table 7). Counting only the animals walking free on the sediment surface greatly reduces the estimates of abundance (to 1–11 million animals, Figure 6) and greatly increases their c.v.s (to 25–62%).

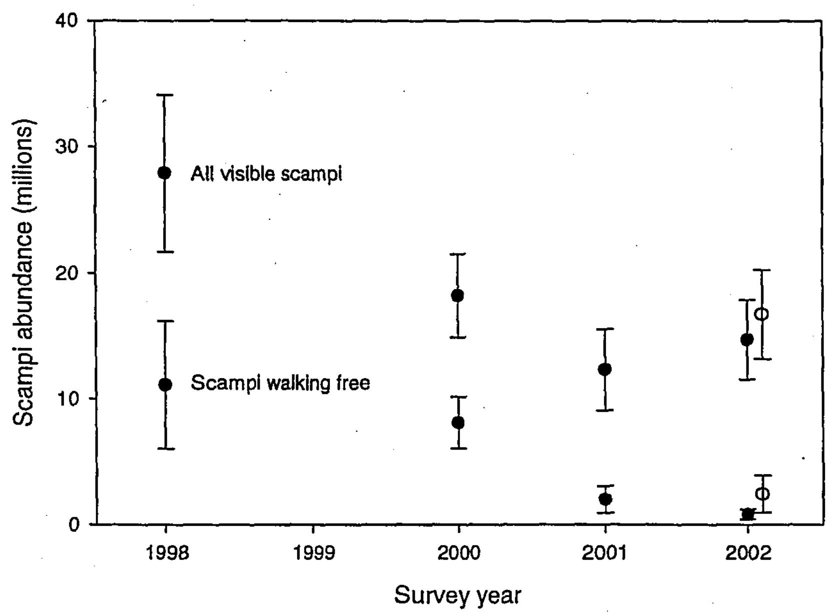

Figure 6: **Estimated abundance (± one standard error) of visible scampi in strata 302, 303, 402, and 403, 1998 to 2002. Closed symbols represent estimates made using randomly-selected sites (these being fixed sites since 2002) and open symbols represents revised estimates for 2002 including 6 sites selected for survey on the basis that they had the highest estimated density of burrows in 1998.**

No attempt was made to develop scalars for individual readers interpreting visible scampi, so these estimates cannot be corrected for reader "bias".

Moving to estimates of (relative or absolute) biomass from estimates of abundance requires an estimate of the mean weight of individuals. Cryer et al. (2001) estimated the length frequency distribution of visible scampi in 2000 and applied length-weight regressions to estimate average weight. They used 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. Their estimate of average weight for measurable scampi in the 2000 survey was 38.3 g, similar to the 1998 estimate of 35.4 g (Cryer & Hartill 1998). Work is still underway to make comparable estimates for 2001 and 2002, but scaling the abundance estimates for visible scampi by the smaller of these two estimates of mean weight leads to an estimate of (absolute) biomass (Table 8). These estimates are probably close to minimum estimates of biomass, although smaller estimates are conceivable (for instance, if the average size were to be considerably smaller in 2001 and 2002).

Making further assumptions (e.g., that each burrow identified as a scampi burrow is occupied by a single scampi of average size similar to those visible), the estimates of major burrow openings can be used to estimate current biomass (Table 9). These estimates may be conservative (because we score only those burrows that are characteristic of scampi and we know that scampi are sometimes seen in other types of burrows), but they may be optimistic (because not all burrows may be currently occupied or because hidden scampi are, on average, smaller than visible scampi). It is not currently possible to assess whether estimates of biomass made using our estimates of the density of major burrow openings are positively or negatively biased estimates of actual abundance.

Table 8: Estimates of the biomass of visible scampi within the core area of the QMA 1 scampi fishery (strata 302, 303, 402, and 403) between 1998 and 2002 made using a mean average weight of 35.4 g. These estimates are probably close to estimates of "minimum biomass". Scampi "not in burrows" were defined as those for which the telson was not obscured by a burrow. Estimates annotated "2002+" were made using all 26 sites sampled in 2002, the 20 fixed sites (sampled 2000, 2001, and 2002) plus repeats of the 6 sites sampled in 1998 that had the highest estimated density of scampi burrows. The specified c.v.s are underestimates because they do not include variance associated with conversions from observed cheliped length to individual weight.

	All visible scampi		Scampi not in burrows	
	Biomass (t)	Min. c.v.	Biomass (t)	Min. c.v.
1998	988	22.3	393	45.8
2000	644	18.2	287	25.4
2001	435	26.3	71	53.5
2002	520	21.5	28	51.8
2002 +	591	21.3	85	61.6

Table 9: Estimates of biomass (t) of scampi within the core area of the QMA 1 scampi fishery (strata 302, 303, 402, and 403) between 1998 and 2002 made by multiplying the estimated abundance of major burrow openings by a mean average weight of 35.4 g. Counts by each reader within "corrected" estimates have been scaled by the inverse of reader factors estimated from the linear model in Table 3. Estimates annotated "2002+" were made using all 26 sites sampled in 2002, the 20 fixed sites (sampled 2000, 2001, and 2002) plus repeats of the 6 sites sampled in 1998 that had the highest estimated density of scampi burrows. The specified c.v.s are underestimates because they do not include variance associated with conversions from observed cheliped length to individual weight.

	Uncorrected		Corrected	
	Biomass (t)	Min. c.v.	Biomass (t)	Min. c.v.
1998	5 434	14.7	5 491	14.7
2000	3 335	12.5	3 423	12.7
2001	4 673	11.8	4 811	11.8
2002	4 666	7.9	4 446	7.8
2002 +	4 761	8.0	4 538	8.1

10.6 Comparison of indices with other data

Our "minimum" biomass estimates suggest that current landings of scampi from QMA 1 (120 t) could represent a substantial fraction of the QMA 1 biomass (12.1–27.6%, depending on the year, 20.2–23.1% for 2002). Conversely, biomass estimates made from burrow counts suggest that fishing takes a relatively small fraction of total biomass, (2.2–3.6%, with the 2002 estimate suggesting removals of 2.5–2.6% (including or excluding the 6 "non-random" repeat sites)).

The decline in our indices of visible scampi is consistent with the decline in commercial CPUE observed since about 1995 in QMA 1 (e.g., Cryer & Coburn 2000, Hartill & Cryer 2002, Figure 7). Conversely, our indices of probable scampi burrows has remained relatively steady, a trend that is not consistent with commercial trawl catch rates (Figure 8). This divergence might be expected because the light, "skimming" trawl gear used to catch scampi is most unlikely to be able to catch scampi that are hidden from view in burrows. Critical in this interpretation is the implicit assumption that the proportion of burrows occupied by scampi is constant among years. If burrows last a long time after they are vacated by a scampi, then this assumption may not hold; the density of burrows could remain constant even while the population was declining rapidly. We have no information on burrow longevity and this could be a fruitful area for future research.

At this stage it is not possible to be certain which of these indices of abundance is the best for scampi, although we currently favour a relative index based on the abundance of major burrow openings. This index should not be affected by any changes in emergence behaviour in scampi and can be estimated using photographs taken at any time of year or day (although it would be badly affected by changes in occupancy rate). Indices of absolute abundance based on visible scampi are almost certainly negatively biased, and indices of relative abundance will be affected by the seasonal and diel timing of photography.

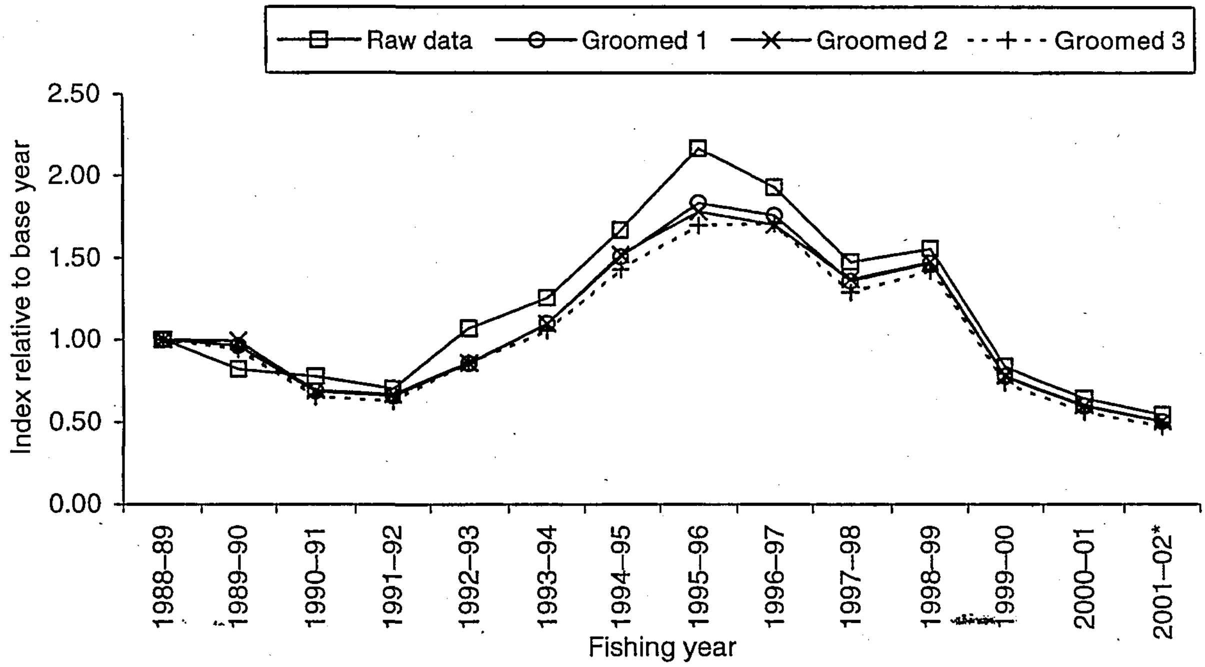

Figure 7: Unstandardised indices of trawl catch rates of scampi caught by all vessels fishing in QMA 1. Raw data are ungroomed, Groomed 1 = groomed data including irreconcilable errors, Groomed 2 = groomed data excluding irreconcilable errors, Groomed 3 = groomed data excluding irreconcilable records and zero scampi catches. Data for 2001–02 are based on the first six months of the fishing year (after Hartill & Cryer 2002).

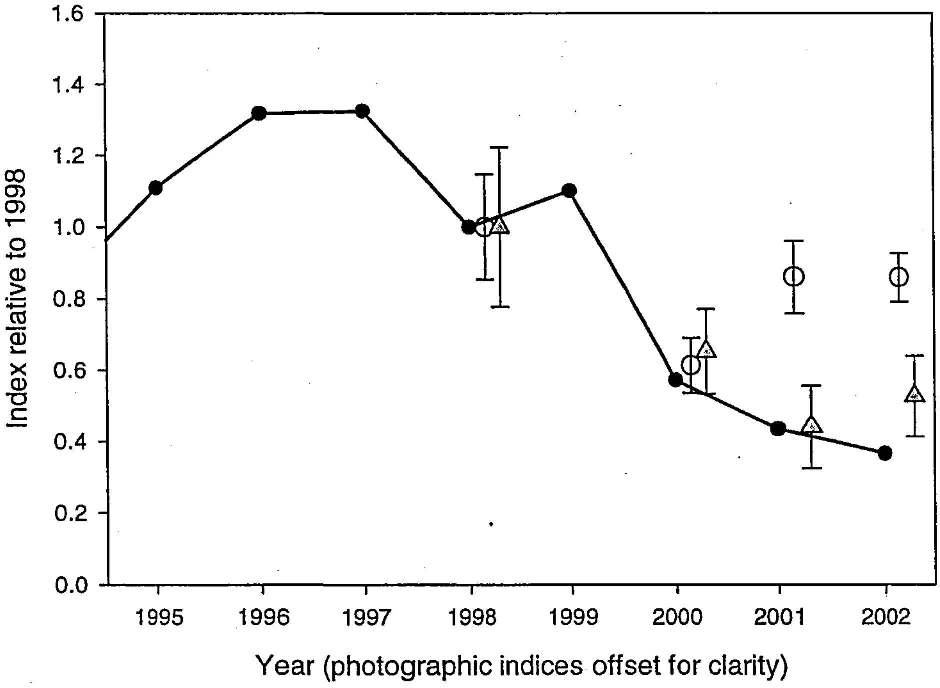

Figure 8: Comparison of possible indices of relative abundance for scampi in the core area of QMA 1 (Cuvier to White Island, 300–500 m depth) since 1995, all standardised to respective 1998 indices. Solid dots and line = commercial CPUE based on Groomed 3 from Hartill & Cryer (2002), open circles = index of major burrow openings ± 1 standard error, and grey triangles = index of visible scampi ± 1 standard error.

11. Conclusions:

1. Four photographic surveys of scampi burrows in the core part of the QMA 1 scampi fishery were completed in 1998, 2000, 2001, and 2002. Almost 3000 images were adopted for quantitative analysis from the four surveys combined.

2. We have developed a rigorous and repeatable screening and analytical protocol for estimating the density of scampi burrows; correlations among the three most experienced readers consistently exceeded 0.95 at the site level, and the average correlation among all six trained readers was 0.96. General linear modelling suggested significant differences among readers at a transect level, with three readers tending to read slightly high and three tending to read slightly low.

3. The density of visible scampi (and hence minimum absolute biomass) in the core area of QMA 1 (Cuvier to White Island, 300–500 m depth) decreased by over 50% between 1998 and 2001 and was also low in 2002. This is consistent with recent declines in commercial CPUE and research trawl catch rates.

4. The density of major burrow openings in the core area of QMA 1 had no obvious trend between 1998 and 2002, although the 1998 index was highest and the 2000 estimate was lowest. This is not consistent with commercial CPUE or research trawl catch rates.

5. Recent average landings of scampi from QMA 1 represent about 12–28% of our minimum estimates of biomass, and the current catch limit of 120 t is about 20–23% of the 2002 minimum biomass estimate. These estimates are likely to be conservative.

6. Biomass estimates made by scaling estimates of burrow abundance by mean average size suggest that the current catch limit of 120 t in QMA 1 represents about 2–4% of total biomass. These estimates may not be conservative.

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12. Publications:

There are no other publications other than Voyage Programmes and Voyage Reports.

13. Data Storage:

Data from trawl and photographic stations are in the Empress database *trawl*. Original and annotated 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. Copies have also been provided for the Ministry's Data Manager at Greta Point. Image details and records of readings are centralised in a formal MS-Access database on a secure, backed-up server at NIWA Auckland. Various analytical files in MS-Excel and presentations in MS-PowerPoint reside on the same server. These will be copied to the Ministry's Data Manager at Greta Point on completion of the projects.

Appendix 1: **Criteria for screening and counting burrows of *Metanephrops challengeri* from still images**

Background

The development of a robust index of relative abundance for New Zealand scampi, *Metanephrops challengeri*, will depend on consistent screening, counting, and analytical protocols. Developing such a protocol is likely to be complicated by the fact that we cannot make many practical tests of what is and what isn't a *Metanephrops* burrow, and must rely instead on inferences made mostly on the basis of seeing scampi associated with particular types of burrow. Three surveys of the main fishery areas of QMA 1 have been conducted since 1998, but each was scored in a different way as we have increased in experience. We think it is now time to standardize a protocol and this document describes the development of what we consider to be an appropriate set of guidelines, rules, and criteria.

Developing descriptions and criteria

The first quantitative photographic survey for *Metanephrops challengeri* was conducted in February 1998 (Project SCI9701) and screened by a single reader (M. Cryer) using the dichotomous key for burrows on European *Nephrops norvegicus* grounds published by Marrs et al. (1996, 1998). 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, and sparsely distributed burrows are usually more distinctive than those that are crowded close together. The 1998 survey was scored on the basis that a burrow opening was counted if it was thought more likely than not to be part of a scampi burrow. This led to an estimate of the density of burrow openings, not burrows; we used European estimates of the average number of openings in *Nephrops* burrows to convert the estimate of the density of burrow openings to the density of putative burrows. We acknowledged that this direct estimate of burrows using any of their constituent opening was likely to be positively biased by edge effects (Cryer & Hartill 1998).

After the 1998 survey, M. Cryer visited several scientists involved in European visual assessment surveys and assessments in the U.K. and spent some time at sea viewing *Nephrops* grounds. M. Cryer's performance at recognizing and counting *Nephrops* burrows increased markedly during his time at sea, to the extent that his counts were closely comparable with those of local experienced readers after about 4 days. These counts were made using a video sledge rather than still cameras, however, and we knew even then that *Metanephrops* burrows were not exactly the same as those of *Nephrops*. This prompted our decision that developing a rigorous protocol for *Metanephrops* would require better knowledge of the precise characteristics of their burrows.

After the U.K. trip, therefore, a "library" of about 100 images in which *M. challengeri* could be seen associated with burrows was developed using images from the 1998 survey. These images were examined for consistent burrow features and a summary was drawn up (Table 1). The summary was used as a description of what might be considered a *Metanephrops* burrow, and was used as a basis for a preliminary screening of the second QMA 1 survey (Project SCI1999/02, February 2000). This survey was screened separately by three readers in different orders and blind from one another. As in the 1998 survey, burrow openings were counted if they were thought more likely than not to belong to scampi. In retrospect, one of the readers was much less likely to than the other two to count openings; this was probably caused at least partly by our lack of formalized decision tree at that time.

Table 1: Metanephrops **burrow description as at October 2000 (based on 74 scampi photographed in association with burrows in February 1998)**

- Entrance ways tend to be shallow and can be but are often not crescent shaped.
- 83% of the burrows had two entrances with most of the remaining having only one visible entrance.
- Burrows with two entrances appeared to be simple tunnels up to four scampi lengths long, and probably contain only one scampi. If this is so, however, it does not explain where small scampi may be found.
- The back entrance of these tunnels is often slit like.
- When single entrances were observed they often appeared to be related to sunken burrows. There were sometimes small holes associated with the back of these deep burrows but they did not appear to be regularly maintained nor large enough for use as an actual entrance way.
- 80% of burrows had either sediment fans and/or runs associated with them.
- Tunnel shapes and sediment fans or runs are the most reliable features which can be used to describe a burrow.

Although there was reasonable correlation among counts made by the three readers overall, there were some very marked discrepancies. Even the two readers whose counts correlated most closely had markedly different counts for some stations, most especially in peripheral strata. We presented the results and comparisons to the Ministry of Fisheries Shellfish Fishery Assessment Working Group and sought guidance as to the best way to proceed. The working group agreed to the following actions to examine the issue:

- Expansion 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

Following the meeting, we re-read a selection of 400 images from the stations causing most of the variance among readers. Because the variance among readers came partly from the different levels of "certainty" required by each of the readers before counting a burrow, we adopted a graduated counting protocol under which burrow opening could be accepted as "definitely" or "probably" being part of a *Metanephrops* burrow. These "labels" cannot be taken literally because we have no means of assessing whether a burrow is definitely inhabited unless a scampi is visible, and there is good reason to suppose that the visibility of scampi is volatile. Further, we scored "major" and "minor" openings separately, major openings being those at which any visible scampi would be observed.

At about the same time (and based on the recommendations of their working group), the Ministry of Fisheries commissioned further research to identify and minimize factors causing variations in counts among readers, to generate a third index for QMA 1 in February 2001, to calculate comparable indices for the core areas of QMA 1 sampled during all three surveys, and to generate indices before and after expected heavy fishing in October 2001 in QMA 3 (Project SCI2000/02).

By the time we had scored the images from the February 2001 survey in QMA 1, we were starting to develop a consensus (albeit implicit) about burrow structure in *Metanephrops challengeri* that was codified in a set of "agreed" characteristics (Table 2). We did not codify any sort of decision rule to guide categorisation as "definite" or "probable", but it was implicit that a "definite" burrow opening should have most of the characteristics described in Table 2 or a clearly-resident scampi.

***Table 2*: "Agreed" characteristics of *Metanephrops* burrows as at March 2001 (based on the original description in Table 1 and knowledge accumulated during blind reading, analysis, and semi-blind re-reading of the 2000 the survey).**

- "Major" and "minor" openings to burrows are almost always different and separately characteristic. The major opening is defined as the one where any visible scampi would be expected to be seen.

- Major openings tend to be shallow and can be, but sometimes are not, crescent-shaped. The minor opening is often slit-like.

- Most burrows have two openings. Burrows that do not have two visible openings probably have only one. Burrows with multiple openings (i.e., more than two) seem to be rare.

- Burrows with two openings are usually simple tunnels, usually 2–4 scampi lengths long. These tunnels probably contain only one mature scampi (because the width of the burrow is highly correlated with the size of visible scampi).

- Burrows with single openings are often deep or "sunken". Small, steep holes can often be seen to the rear of these deep burrows but these holes are often not characteristic slit-like openings and may not appear to be regularly maintained nor large enough for use as an opening.

- Most burrows have "fans" of excavated sediment in front of the major opening. Most also have runs (tracks) on the sediment surface which may lead to or from the major or minor opening, or both.

- A linear tunnel with distinct major and minor openings, combined with a sediment fan at the major opening and runs on the sediment surface seems to be the most reliable combination of features to identify the burrows of *M. challengeri.*

Several indices are calculable using the data we had started to record by the start of 2001; we could count all openings or just major openings, and by counting openings probably belonging to scampi or just those thought "definitely" belonging to scampi. Consistency among readers for the subsample of 400 images was greatest for the most constrained count, that of "definite, major openings". Because the size of even major openings is small compared with the size of photographs, this count should also be an unbiased index of the number of burrows (it is not biased by edge effects).

In October 2001, we started to score images from the first survey of QMA 3. Quite soon we had disagreements about what should and should not be counted as a "definite" burrow opening. We decided to cease counting until we had developed a written scoring protocol upon which we could base a consistent approach. We decided that we would involve Dr Ian Tuck (leader of the *Nephrops* Group at the FRS Marine Laboratory, Aberdeen) in this process, to ensure that we were at least as rigorous as European workers who have had considerable success with visual assessment methods for *Nephrops norvegicus.*

Table 3 defines a set of criteria for defining and counting animals and burrow openings of *Metanephrops challengeri* accepted by all three initial readers on 17 October 2001. It will be used as a basis for scoring images from all voyages, those in QMA 1 in 1998, 2000, and 2001, and those in QMA 3 before and after the 2001 fishing season. It should also be used to train any new readers and for all future surveys (until a new protocol is adopted).

***Table 3*: Summary of characteristics of "highly characteristic" and "probable" burrows of *Metanephrops* as at October 2001 (based on all previous work and discussions).**

- "Major" and "minor" openings to burrows are almost always different and separately characteristic. The major opening is defined as the one where any visible scampi would be expected to be seen.

- Most burrows seem to be linear, have two openings, and have covered tunnels 100–700 mm long. Burrows with more than two openings are rare. The width and length of the tunnel are only loosely correlated.

- Major openings tend to have the following characteristics (in approximate rank order):
  - well-maintained "tracks" on the sediment; the most characteristic of which lead away at right angles.
  - shallow rather than vertical tunnels
  - "fans" of excavated sediment (that may be a different colour or texture from surrounding sediments)
  - crescent-shaped entrance way
  - part of a linear system with an associated minor opening
  - smooth, flat bottoms
  - usually 50–180 mm wide at the base (increasing with occupant size)

- Minor opening tend to have the following characteristics (in approximate rank order):
    - often slit- or trench-like
    - lie directly in line with a major opening
    - well-maintained linear "tracks" on the sediment
    - smooth (not necessarily flat) bottoms
    - clean, linear sides (especially in highly characteristic burrows)
    - shallow rather than vertical tunnels (though many seem to be steep)
    - usually about half as wide as the major opening

- Burrows with single (major) openings are often deep or "sunken". One to several small, steep holes can often be seen to the rear of these deep burrows but these holes are often not characteristic slit-like openings and may not appear to be regularly maintained nor large enough for use as an opening by an adult scampi.

- A linear tunnel with distinct major and minor openings, combined with a sediment "fan" at the major opening and runs on the sediment surface (especially if these run at a wide angle from the major opening and almost in line with the axis of the burrow from the minor opening) seems to be the most reliable combination of features to identify the burrows of *M. challengeri.*

- To be classed as "highly characteristic", an opening should have most of the characters (especially those that are ranked highly) of a specified opening type (major or minor) and should be in a good to excellent apparent state of repair. State of repair is inferred from smooth, flat floors, and sharp edges to tunnels, openings, and tracks.

- To be classed as "probable", an opening should seem more likely than not to be a scampi burrow, have some of the characteristics (especially those ranked highly) but may lack several. They may be in a moderate, but not poor, state of repair (as defined above).

- To avoid volatility in the burrow indices caused by changes in emergence or other behaviour, the presence of a scampi or other animal in or near a burrow should not influence the decision to count a burrow nor its characterization as highly characteristic as opposed to probable.

- All openings and scampi within a defined "countable area" are included in counts. Excluded from the countable area are areas too dark, too burnt out, or too occluded by suspended sediment to discern whether the apparent state of repair of a putative burrow (e.g., whether there is a fan of sediment or the bottom of the tunnel is flat and smooth).

- To account for edge effects, partly-visible scampi on the bottom and left edges of the image are ignored, those on the top and right edges are included. All partly-obscured burrow openings are ignored. Animals are treated differently from openings because counts of animals are used to calculate absolute (minimum) estimates of abundance and biomass whereas openings are used only to calculate relative indices.

The finalized protocol (March 2002)

In March 2002, the original three readers met to discuss progress with the protocol and the results of the first experimental blind reading. The following process was agreed.

1. Digital images are archived on the project (o:\) drive on the Auckland server (which is accessible to all project team members and is backed-up regularly). Backup copies on CD-ROM will be held in the fireproof safe and elsewhere, as appropriate.
2. Images are allocated, station by station, to specific readers who selects usable images, marks the readable portion of each, estimates the relative and absolute

readable areas (using parallel lasers or other cues), and creates a new high-quality "A" image annotated with the readable area. We have called this process "initialization". The area estimates are stored on a spreadsheet on the project drive.

3. Images are "screened" for burrow openings and visible scampi by this reader and two others, blind from one another. The results are stored (using numbers and comments only — no alphanumerics such as "1??" or "maybe", please) on spreadsheets unique to the reader (but still on the project drive), and annotated on new low-quality "reader" images.

4. Once a pre-determined "block" of images have been initialized and screened, the analyst consolidates the three reader-generated files into a single spreadsheet and examines the readings for consistency. The degree of consistency among readers is assessed through correlation coefficients and comparisons of aggregate counts.

5. Images where the difference between the highest and lowest count of major openings is 0 or 1 are accepted as "finalized". Images where the difference is two or more major openings are highlighted in a "re-read" section of the consolidated spreadsheet and made available to all readers.

6. Each reader "re-reads" all images highlighted in the consolidated analysis and considers their initial score in the light of interpretations recorded by the other two readers on their "reader" images. Scores may be revised at this stage, but this is not mandatory. Any changes are recorded in the "re-read" consolidated spreadsheet and annotated on the "reader" image using a contrasting colour.

7. Once all re-reads are complete for a given block of images, the consolidated spreadsheets are finalized by the analyst, keeping separate the results of the initial (completely blind) and the revised (moderated) screenings. All "A" and "reader" image files are archived for future audit or training purposes.

8. A timetable with strict target dates for the completion of "initialization", "screening", and "re-reading" stages for each image is necessary to coordinate the activities of the several readers involved. Keeping to the timetable is clearly important, a delay by one person will have implications for several.

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Appendix 2: **Rankings of criteria (1 being most important) nominated by each of the three readers for initial identification of major (top) and minor (bottom) openings of burrows of *Metanephrops challengeri*.**

Character	Reader 1	Reader 2	Reader 3	Mean rank
Major openings:				
Surface tracks leading from opening	1	2	1	1.3
Shallow descent angle	6	1	2	3.0
Sediment fan	2	3	4	3.0
Crescent shape	4	4	3	3.7
Part of linear system with minor opening	3	7	5	5.0
Smooth tunnel floor	5	5	7	5.7
50-180mm wide at base	8	6	7	7.0
Well-maintained appearance	7	8	7	7.3
Minor openings:				
Narrow trench with long sides	1	1	1	1.0
Part of linear system, major <800mm distant	4	2	2	2.7
Long, straight surface track	2	3	4	3.0
Near to highly characteristic major opening	3	7	3	4.3
Smooth tunnel floor	5	5	6	5.3
Well-maintained appearance	7	4	6	5.7
Shallow descent angle	7	7	6	6.7
Half as wide as an associated major opening	7	7	8	7.3

Appendix 3: **Image and file management using Didger 3.0, MS-PhotoEditor, and MS-Excel.**

A: To define readable area and screen images for burrow openings:

1. Open *Didger* software, the appropriate *Excel* spreadsheet, and *PhotoEditor.*

2. In *Didger*, under file>project settings>general, set the file locations (using "Browse") to the location of your image files (e.g., o:\sci200002\working\new protocol\photodata), and set the text properties to 18pt Arial, text to some bright colour and the line properties to blue with a thickness of 0.05 inches.

3. For each image file, establish a new raster project and import the jpeg without resetting any of the options.

4. Select the polygon tool from the toolbar and mark out the extreme corners of the image by clicking just outside the image, finishing the polygon with a double click. You can either click the mouse button once every time the line changes direction or just hold the button down to trace around an unreadable area and double click at the end. If you then double click on the completed polygon it will give you its area. Copy this value (CTRL-INS, CTRL-C, or CTRL-X) and paste it into the appropriate square in the *Excel* spreadsheet. If you are working with digital camera images the area of the image should not change, if so then you can ignore this step and just repeat the value in the spreadsheet with occasional verification from time to time.

5. Mark out YOUR interpretation of the overall readable area, finishing the polygon with a double click. If there is an "island" of unreadable area in the middle of the image (i.e. caused by silt clouds, burnout, or large fish) connect it to the outer boundary of the readable area with a very thin bridge to save you having to paste more than one area value. If you double click on the completed polygon it will give you its area. Copy this value (CTRL-INS, CTRL-C, or CTRL-X) and paste it into the appropriate square in the *Excel* spreadsheet.as those in *PhotoEditor.*

6. Create a data summary view by pressing CTRL-D, then access the data for each of the polygons in turn by double clicking on the wee box at the extreme left of each row; this will allow you to select and copy (CTRL-INS, CTRL-C, or CTRL-X) the estimate of area for each polygon. Paste

these values into the appropriate square in the *Excel* spreadsheet. If you have more than one "island", paste-special-add the values on top of one another to acquire their sum in *Excel*.

7. Once the polygon areas have been defined and copied, save the revised image as a new jpg using the file-export command. Specify JPEG format, use the same name as the original file in the same directory, but replace "P" with "A" (thus, P0005450.jpg becomes A0005450.jpg). Ensure that, for photos taken using digital cameras, the image is 1344*1008 pixels, check the "maintain aspect ratio" option, and set "quality" to 100% (***most important***). These will be the new working files from which others will score each image to a standardized readable area.

8. You may prefer just to repeat the last 7 steps which gets the area estimation and "A" file creation tasks out of the way. If you prefer to do everything all at once, you can do the next 2 steps at the same time.

9. Open the "A" file in *PhotoEditor* and score it according to the agreed protocol, noting that protocols developed to account for edge effects must now apply to the defined readable area and not to the extreme edges of the image (unless these coincide). Note your scores in the *Excel* spreadsheet. Mark all openings and scampi that you adopt on the *Didger* version of the image using the annotate tool and the following conventions: 1 = major opening, 2 = minor opening, d = highly characteristic ("definite"), p = probable, A = scampi in, B = scampi out. Thus, a highly characteristic major opening would be marked "1d", and a scampi walking free with the telson in clear view would be marked "B".

10. Once you've completed your annotations, save the revised *Didger* image as a new jpg using the file-export command. Specify JPEG format, use the same name as the original file in the same directory, but replace "A" with "M" (Martin), "B" (Bruce), "J" (Jim) or other agreed letter if you are not one of the original three readers. Ensure that, for photos taken using digital cameras, the image is 1344*1008 pixels, the "maintain aspect ratio" option is checked, and that "quality" is set to 65%. These will be much smaller files used to record the details of individual scorings. They will allow audit and cross-checking.

B: To screen images for burrow openings when readable area has already been defined:

1. Open *Didger* software, the appropriate *Excel* spreadsheet, and *PhotoEditor.*

2. In *Didger*, set the file locations (using "Browse") to o:\sci200002\rawdata (or wherever your image files are located), and set the text properties to 18pt Arial, text colour red.

3. Open each "A" file in turn in *PhotoEditor* and *Didger* (in a raster project), and score it according to the agreed protocol, noting that protocols developed to account for edge effects must now apply to the defined readable area and not to the extreme edges of the image (unless these coincide). Note your scores in the *Excel* spreadsheet. Mark all openings and scampi that you adopt on the *Didger* version of the image using the annotate tool and the following conventions: 1 = major opening, 2 = minor opening, d = highly characteristic ("definite"), p = probable, A = scampi in, B = scampi out. Thus, a probable minor opening would be marked "2p", and a scampi at a burrow "entrance" with the telson obscured within the burrow would be marked "A".

4. Once you've completed your annotations, save the revised *Didger* image as a new jpg using the file-export command. Specify JPEG format, use the same name as the original file in the same directory, but replace "A" with "M" (Martin), "B" (Bruce), "J" (Jim) or other agreed letter if you are not one of the original readers. Ensure that, for photos taken using digital cameras, the image is 1344*1008 pixels, the "maintain aspect ratio" option is checked, and that "quality" is set to 65%. These will be much smaller files used to record the details of individual scorings. They will be hopeless for scoring purposes, but will allow audit and cross-checking. The naming protocols and pixel counts for the 1998 files will be different, but the files will be established in analogous directory structures and those already scaled for area will start with a "A".