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Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1 (1998–2003) and QMA 2 (2003)

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Final Research Report for
Ministry of Fisheries Research Project
SCI2002/01 (Objectives 1–3)

National Institute of Water and Atmospheric Research

October 2003

Final Research Report

Report Title:	Indices of relative abundance for scampi, *Metanephrops challengeri*, based on photographic surveys in QMA 1 (1998–2003) and QMA 2 (2003)
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1. Date:	13 October 2003
2. Contractor:	National Institute of Water & Atmospheric Research Ltd
3. Project Title:	"Measuring the abundance of scampi"
4. Project Codes:	SCI 2002/01
5. Project Leader:	Martin Cryer
6. Duration of Project:	
Start date:	1 January 2003
Expected completion date:	30 September 2003

7. Executive Summary

The fifth photographic sampling voyage in the core area of the QMA 1 scampi fishery (Cuvier to White Island, 300–500 m depth) was completed in March 2003. From the five voyages, we analysed a total of 3513 images from 105 stations (many of them on fixed locations). The total area of the images was 26 937 m^2, an average of 7.67 m^2 each. Five readers applied a rigorous analytical protocol to all images collected since 1998 (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 and 2003, consistent with declines in commercial CPUE. Based on the most recent estimate of minimum biomass (509 t), the current catch limit of 120 t in QMA 1 is about 23% of total biomass. This estimate is very likely to be conservative because it can be expected that not all scampi will have been visible at the time of the survey. The density of major burrow openings in the same area had little trend between 1998 and 2003, although the 1998 index was highest, the 2000 index was the lowest, and the 2003 index was close to the 2000 index. This is not consistent with commercial CPUE or research trawl catch rates. The 1998 estimate was generated using a different camera and method of estimating image area, but sensitivity analysis suggests it is unlikely to be markedly biased high relative to subsequent estimates. Based on the most recent estimate of biomass from burrow counts (3600 t), the current catch limit of 120 t in QMA 1 is about 3%

of total biomass. This estimate may not be conservative because not all burrows may be occupied and unobserved animals may be smaller than those used to estimate the length frequency distribution and, hence, average weight. The first survey in QMA 2 was completed in March 2003, including 27 stations in strata 701, 702, 703, 801, 802, and 803. The total area accepted for screening was 5 157 m^2 from 788 images, an average of 6.54 m^2 per image (about 15% smaller than in QMA 1 because of lower water clarity, especially in shallow stations). Six readers applied a rigorous screening protocol to these images. The density of visible scampi (and, hence, minimum absolute biomass) in the core area of the QMA 2 scampi trawl fishery in 2003 was 0.004 m^{-2}, only about one-third of the 0.012 m^{-2} recorded in QMA 1. Based on this first estimate of minimum biomass, the current catch limit of 245 t in QMA 2 is about 70% of total biomass. This estimate may be conservative because it can be expected that not all scampi will have been visible at the time of the survey. However, the estimate of average weight (35.4 g) came from a QMA 1 photographic length frequency distribution and an analogous estimate has not yet been derived for QMA 2. The density of major burrow openings in QMA 2 in 2003 was 0.067 m^{-2}, about 20% lower than the 0.085 m^{-2} observed in QMA 1. Based on this density, an assumed occupancy of 100%, and the same average weight, biomass in QMA 2 from burrow counts was estimated to be about 5 800 t. The current catch limit of 245 t is about 4% of this biomass, but this estimate may not be conservative because not all burrows may be occupied and unobserved animals may be smaller than those used to estimate the length frequency distribution and, hence, average weight.

8. Objectives

Overall Objective:

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

Specific Objectives:

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 update the relative abundance index for scampi in QMA 1.

9. Methods

9.1 Field sampling:

In 1998, 2000, 2001, 2002, and 2003, 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 except the last one in 2003. Positions of stations within strata in 1998 were randomised using RAND_STN (v 1.7 for PCs; MAF Fisheries 1990) arbitrarily constrained to keep the midpoints of all stations at least 1 km 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. Cryer & Hartill (1998) found spatial autocorrelation at scales of 1 km or less in their preliminary analysis of the 1998 photographic survey, although more recent work on standardised counts over several surveys (Watson & Cryer 2003) has shown very little spatial autocorrelation. "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 in 1998 and low density in 2000. Only the 20 fixed stations were occupied in 2003. In 2003, we conducted a similar stratified random photographic survey of scampi burrows within the core area of the QMA 2 scampi fishery, Mahia to Castle Point, 200–500 m depth (Figure 2).

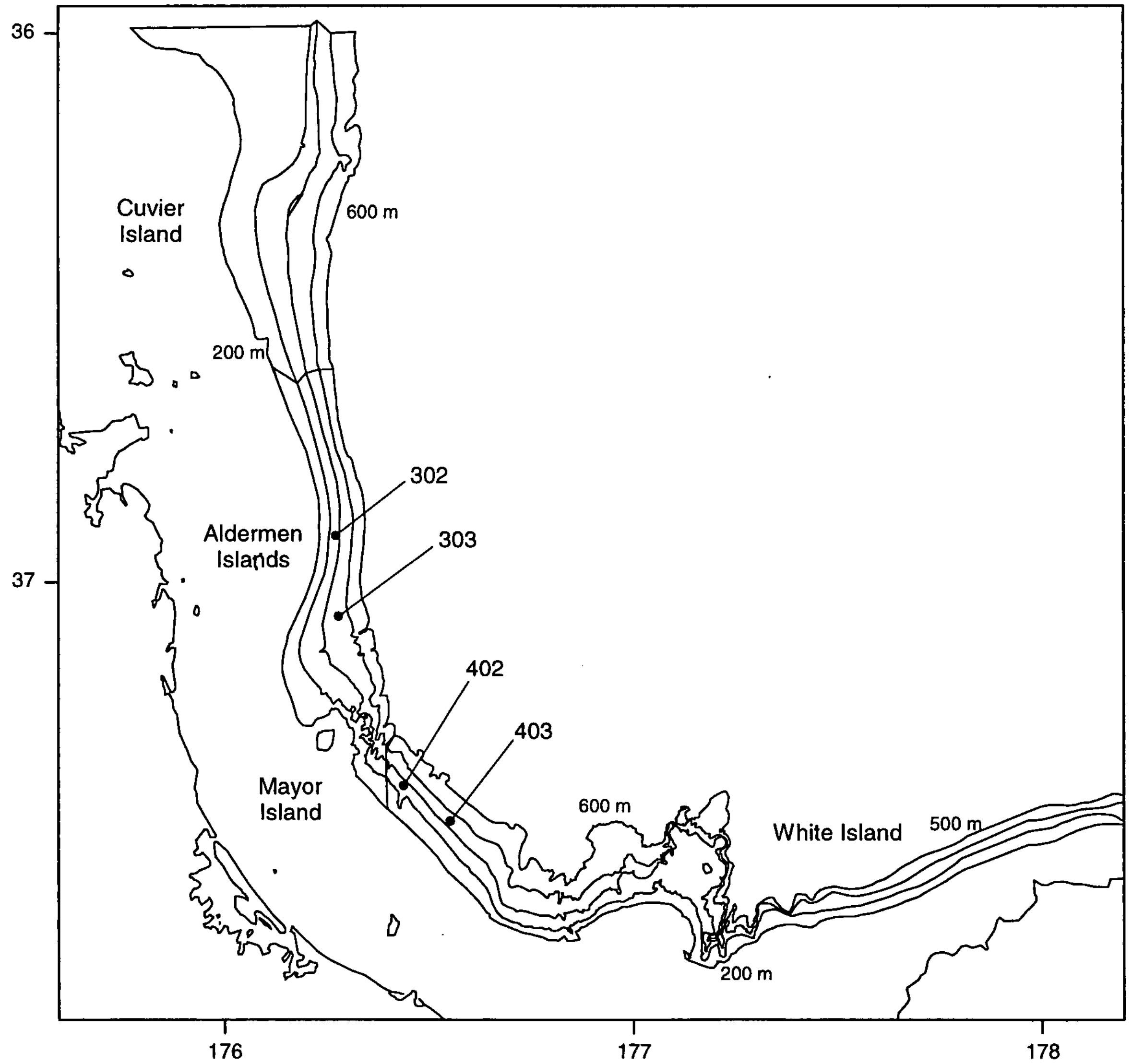

Figure 1: Sampling strata for photographic surveys of scampi and scampi burrows in the "core" area of the QMA 1 fishery, 1998–2003). Strata are grouped geographically (coded by the first numeral of the stratum code) and by depth (coded by the last numeral of the stratum code: 2 = 300–400 m; 3 = 400–500 m). Isobaths are shown at 100 m intervals from 200 to 600 m.

QMA 1 surveys between 1998 and 2002 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). In the 2003 survey of QMAs 1 and 2, a shortage of time and the preliminary results of a study of the effects of spatial distribution of scampi burrows on survey design and efficiency (Watson & Cryer 2003), led us to use a single transect of (nominally) 40 photographs at many of the stations, especially in QMA 1. 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 estimated 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).

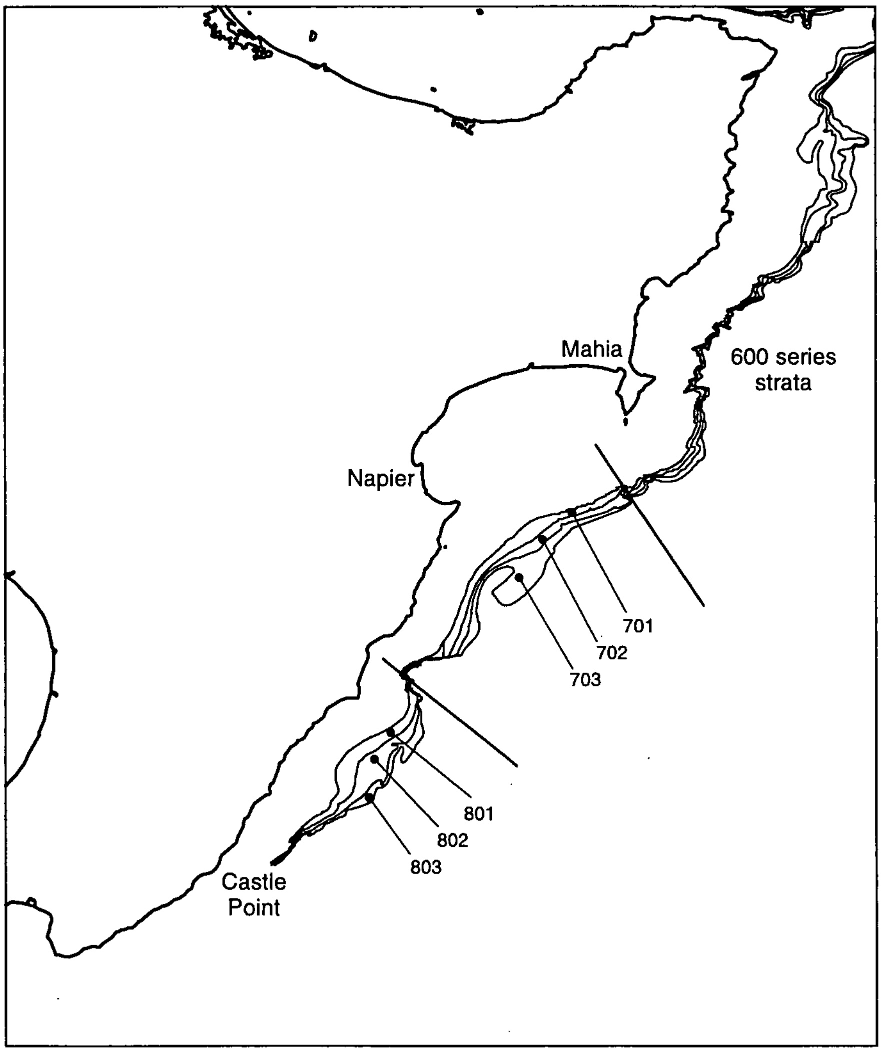

Figure 2: Sampling strata for photographic surveys of scampi and scampi burrows in the "core" area of the QMA 2 fishery (2003). Strata are grouped geographically (coded by the first numeral of the stratum code) and by depth (coded by the last numeral of the stratum code: 1 = 200–300 m 2 = 300–400 m; 3 = 400–500 m). Isobaths are shown at 100 m intervals from 200 to 500 m.

9.2 Image selection and scoring

Images were examined and scored using a standardised protocol (developed under Project SCI2000/02) applied by a team of six trained readers. For each image, the main criteria of usability are 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 in Cryer et al. 2002). The percentage of the frame within which the seabed is clearly and sharply visible is estimated and marked using polygons in "Didger" image analysis software. Each reader then assesses the number of burrow openings using the standardized protocol (Cryer et al. 2002). 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, "major" and "minor" openings each have their own characteristics and should be scored separately (Figure 3). 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 may, therefore, be conservative (assuming that burrow occupancy is high).

Many assessments of the similar *Nephrops norvegicus* 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 in Cryer et al. 2002). Using these descriptors as a guideline, each reader assesses each potential burrow opening (paying more attention to attributes with a high ranking such as surface tracks, a shallow descent angle, and sediment fans for major openings) and scores it only if it is "probably" (not "maybe") a scampi burrow.

Once the images from any particular stratum or survey have been scored by three readers, any images for which the greatest difference between readers in the counts of major openings 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.

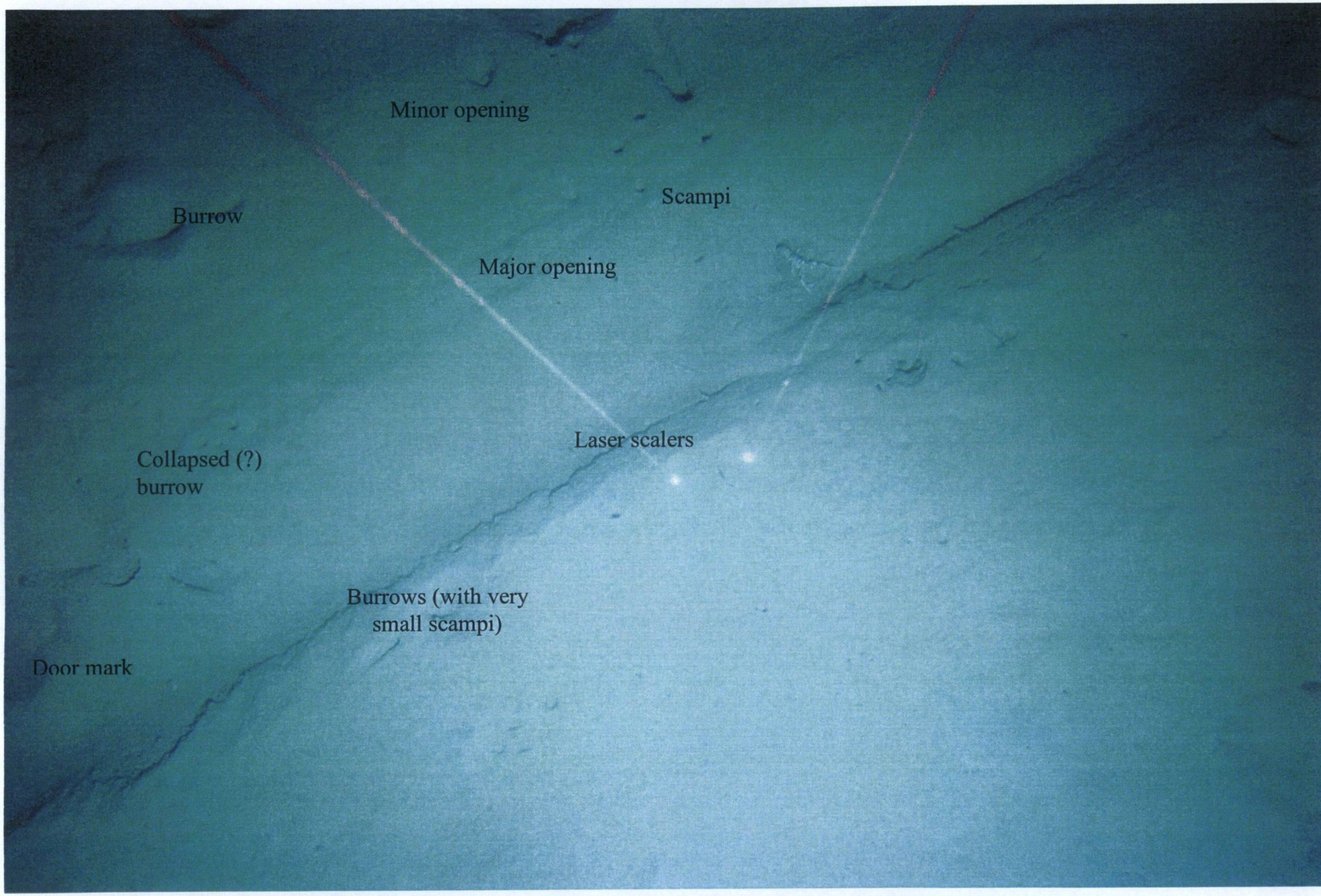

Figure 3: Sample image from April 2002 survey in QMA 1 showing laser scaling dots, several characteristic scampi burrows, one large and one very small visible scampi, and a seabed mark probably caused by a trawl door.

9.3 Data analysis

Counts from photographs were analysed using methods analogous to those in the *Trawlsurvey* Analysis Program (Vignaux 1994) for trawl surveys. To exclude a possible image size effect (burrows perhaps being more or less likely to be accepted as the number of pixels making up their image decreases) images with a very small (< 2 m^2) or very large (> 16 m^2) readable area were excluded. This was a small proportion (5%) of all images. 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, 2002, and 2003, and for QMA 2 in 2003. 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.

The sensitivity of the indices to the reader "bias" identified by Cryer et al. (2002) was assessed by "correcting" the counts made by each reader using (as a scalar) the inverse of their respective model effects in the general linear model developed and described by Cryer et al. (2002). These scalars describe the relative "bias" of each reader relative to the overall mean; three readers had a positive "bias" of about 10% and three had a negative "bias" of about 10%. After the counts had been corrected, the analysis was completed as described above. The same scalars were applied to both QMAs, thereby assuming that the relative biases are similar among areas.

10. Results

10.1 Images potentially available for indices of relative abundance

Excluding images with estimated areal coverage of less than 2 m^2 or more than 16 m^2 changed the three reported indices by 5% or less, and not always in the same direction, so we think it had very little effect on any trends. The mean number of photographs accepted for a station in QMA 1 was 33.4, with annual means ranging 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 26 937 m^2 for an overall average of 7.67 m^2 per image (Table 1). 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 1: Number of sites, number of usable photographs, and total screened area in each stratum in each of the surveys in 1998, 2000, 2001, 2002, and 2003 in the core area of the QMA 1 scampi trawl fishery, Cuvier to White Island, 300–500 m depth. Totals for 2002 include six sites initially selected based on their high density of putative scampi burrows in 1998 but subsequently found to be very similar to other sites in 2002.

	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
2002	8	7	6	5	26	288	273	180	172	913	2 360	2 035	1 395	1 340	7 130
2003	5	5	5	5	20	164	157	157	150	628	1 440	1 275	1 423	1 558	5 695

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.

In QMA 2, the mean number of photographs accepted for a station (again after excluding very small and very large images) was 29.2. This is lower than in QMA 1 largely because many images, especially shallower than 300 m, were hazy. It is not clear whether this is likely to be a persistent problem in QMA 2 (like it probably is in QMA 3) or whether the strong winds during the 2003 survey were part of the problem. 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 5157 m^2 for an overall average of 6.54 m^2 per image. This is within the range of annual means for QMA 1.

10.2 Indices of abundance and biomass in QMA 1

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 2, Figure 4). Estimates for 2003 were not exceptional but were towards the lower end of the observed range. "Correcting" the counts made by each reader by scaling by the inverse of their respective effects from Cryer et al's (2002) general linear model made little difference to the estimates of the density of major openings, increasing the estimates for 1998, 2000, and 2001 by 1–3%, decreasing those for 2002 by 5%, and hardly affecting those for 2003.

Table 2: 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 2003. Counts by each reader within "corrected" estimates have been scaled by the inverse of reader factors estimated from the linear model of reader "bias" described by Cryer et al. (2002). Estimates for 2002 include all 26 sites sampled in that year.

	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	134.5	8.0	128.2	8.1
2003	101.8	12.2	101.9	12.0

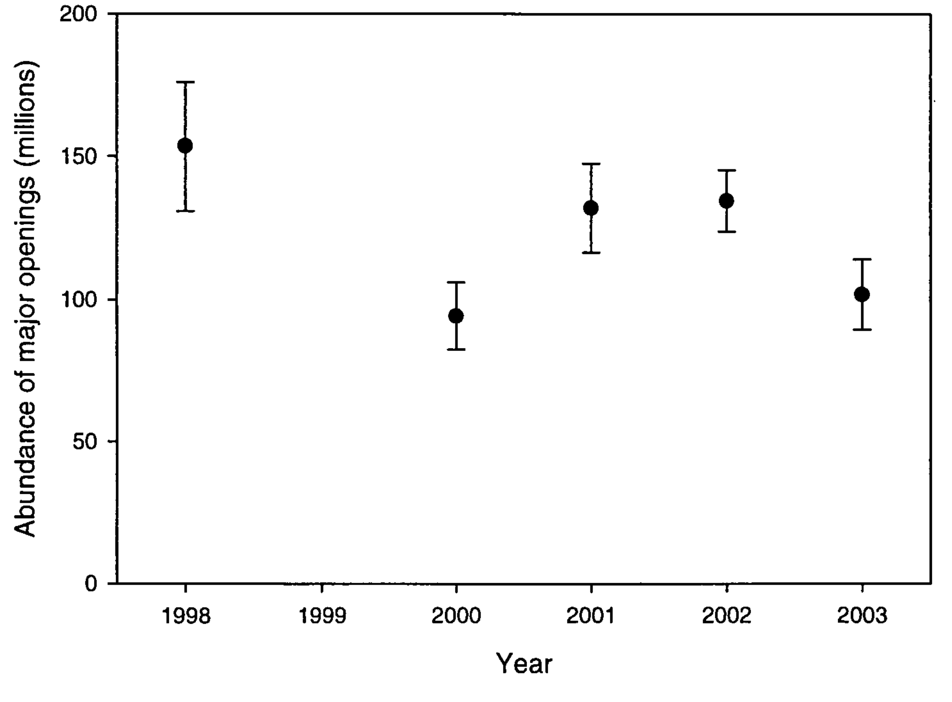

Figure 4: Estimated abundance (± one standard error) of major burrow openings in strata 302, 303, 402, and 403, 1998 to 2003. The estimate for 2002 includes all 26 sites occupied in that year.

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 3). Counting only the animals walking free on the sediment surface (i.e., those most susceptible to capture by trawl) greatly reduces the estimates of abundance (to 2–11 million animals, Figure 5) and greatly increases their c.v.s (to 25–62%).

Table 3: 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 2003. Scampi "not in burrows" were defined as those for which the telson was not obscured by a burrow. Estimates for 2002 include all 26 sites sampled in that year.

	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	16.7	21.3	2.4	61.6
2003	14.4	21.1	1.8	40.9

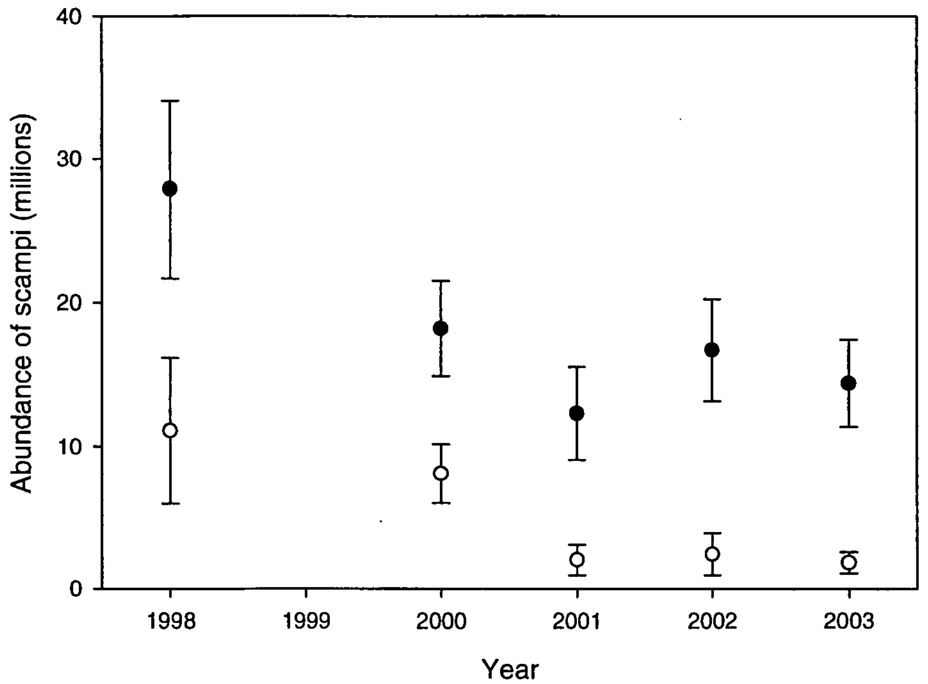

Figure 5: Estimated abundance (± one standard error) of visible scampi in strata 302, 303, 402, and 403, 1998 to 2003. Estimates for 2002 includes all 26 sites occupied in that year. Closed symbols indicate all visible scampi, open symbols include only those scampi out of their burrows.

No attempt was made to develop scalars for individual readers interpreting visible scampi, so these estimates cannot be corrected for reader "bias". However, there was very little difference among estimates of the number of visible scampi by different readers because animals are much less open to interpretation than burrow openings.

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). 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 4). These estimates are probably close to minimum estimates of biomass, although smaller estimates are conceivable (if, for instance, the average size were to be considerably smaller in 2003).

Making further assumptions (e.g., that each burrow identified as a scampi burrow is occupied by a single scampi of similar average size to those visible), the estimates of major burrow openings can be used to estimate current biomass (Table 5). 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 4: 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 2003 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 for 2002 include all 26 sites sampled in that year. 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	591	21.3	85	61.6
2003	509	21.1	62	40.9

Table 5: 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 2003 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 described by Cryer et al. (2002). Estimates for 2002 include all 26 sites sampled that year. 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	4 761	8.0	4 538	8.1
2003	3 605	12.2	3 606	12.0

10.3 Sensitivity of 1998 indices to assumptions and changes in method

The 1998 survey was conducted using a different camera (emulsion-based rather than digital) and a different method of estimating image areas (using an object in the field rather than parallel lasers). We assessed the extent to which these differences might affect the 1998 estimates of density and abundance relative to subsequent surveys by qualitative consideration of the implications of changing cameras and quantitative sensitivity analysis of the assumptions necessary for estimating image area.

Based on our qualitative analysis, we feel that the change of camera is unlikely to have biased the 1998 estimates relative to subsequent ones because:

- both cameras were set to look straight down
- the separation between camera and its obliquely-tilted flash unit was very similar for the two systems (Cryer et al. 2003, suggested that changing the lighting might have affected their burrow density estimates in QMA 3)
- the emulsion-based film stock may have had higher resolution than subsequent digital stills, but we negated this by scanning images at similar resolution before screening
- the difference between monochrome and colour images is unlikely to make a difference because colour images are effectively monochrome unless taken very close to the seabed
- identical screening and counting protocols were used by the same readers for all images used in the standardised indices (i.e., we did not use the original counts based on a description of *Nephrops* burrows reported by Cryer & Hartill, 1998)

The original assumption made by Cryer & Hartill (1998) when estimating average image size in 1998 was that the 450 mm-long weight used as a trigger had penetrated 100 mm into the (soft, silty) seabed by the time the camera was triggered (the distance from the camera to the top of the weight was 3.15 m). We cannot test this assumption, but the range of possible values is 0–450 mm (i.e., the camera was triggered the instant the weight touched the seabed, or the weight penetrated completely in the mud before the camera was triggered). The estimated seabed area would be greatest, relative to Cryer & Hartill's (1998) assumption, if penetration is assumed to be zero, and the distance of bottom, again relative to Cryer & Hartill's (1998) assumption, would be 3.6 m/3.5 m = 1.0286 (2.86% further off-bottom).

Because area increases with the square of distance, the sampled area would be 5.8% greater if penetration was zero, and estimates of burrow or scampi density would be 1/1.058 = 5.5% smaller. Similar logic dictates that, if the weight was completely buried by the time the camera was triggered, the camera would be 10% closer to the seabed, the sampled area would be 19% smaller, and the density estimates would be 23.5% larger (all relative to Cryer & Hartill's (1998) assumption).

Thus, the 1998 estimates are slightly sensitive to the assumptions used to estimate image and readable area, but any major bias of the 1998 indices relative to the others is much more likely to be negative than positive. Any bias greater than 6% is almost certain to be negative.

10.4 Indices of abundance and biomass in QMA 2 in 2003

The estimated overall density of major burrow openings in QMA 2 in 2003 was 0.067 m^{-2}, only about 80% of the density observed in QMA 1 (Table 6). The estimated density of burrows in the two shallowest strata (200–400 m depth) in Hawke Bay was particularly low (0.02 m^{-2}) compared with the other strata and with data from QMA 1 (0.06–0.14 m^{-2}). The estimated density of visible scampi (a much less equivocal estimate than that of burrow openings) was 0.004 m^{-2} in QMA 2, only about one-third of the 0.012 m^{-2} in QMA 1, and we did not observe any scampi shallower than 300 m in QMA 2.

Table 6: Comparison of estimated mean densities (m^{-2}) of major burrow openings, visible scampi, and scampi free of burrows in QMAs 1 and 2 in 2003. The reported ratio is the estimated density in QMA 2 divided by that in QMA 1.

	QMA 1		QMA 2		
Measure	Density	c.v.	Density	c.v.	Ratio
Major openings	0.0851	12.2%	0.0667	11.5%	0.784
All scampi	0.0120	21.1%	0.0042	38.6%	0.353
Scampi "out"	0.0015	40.9%	0.0004	74.3%	0.274

Scaling the estimated density of visible scampi by the combined area of the sampled strata (2363 km^2) leads to an estimated abundance of 10.04 million animals, and scaling this by the estimated average weight of 35.4 g (from QMA 1) leads to a "near-minimum" biomass estimate of 355 t. By similar arithmetic, the estimated density of major burrow openings suggests an abundance of 157.7 million, and a biomass of 5583 t, assuming 100% occupancy and the same average weight.

10.5 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, 23.6% for 2003). Conversely, biomass estimates made from burrow counts suggest that fishing takes a relatively small fraction of total biomass, (2.2–3.6%, with the 2003 estimate suggesting removals of 3.3%). In QMA 2, the current catch limit of 245 t could be a very large fraction (69.0%) of the QMA 2 biomass if the "minimum" estimates are used, although using an estimate based on major burrow openings reduces this to 4.4%, comparable with the estimate for QMA 1.

The decline in our indices of visible scampi between 1998 and 2001 in QMA 1 is consistent with the decline in commercial CPUE observed since about 1995 in QMAs 1 and 2 (e.g., Cryer & Coburn 2000, Hartill & Cryer 2002, 2003, Figure 6). Conversely, our indices of probable scampi burrows has remained relatively steady, a trend that is not consistent with commercial trawl catch rates (Figure 7). 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.

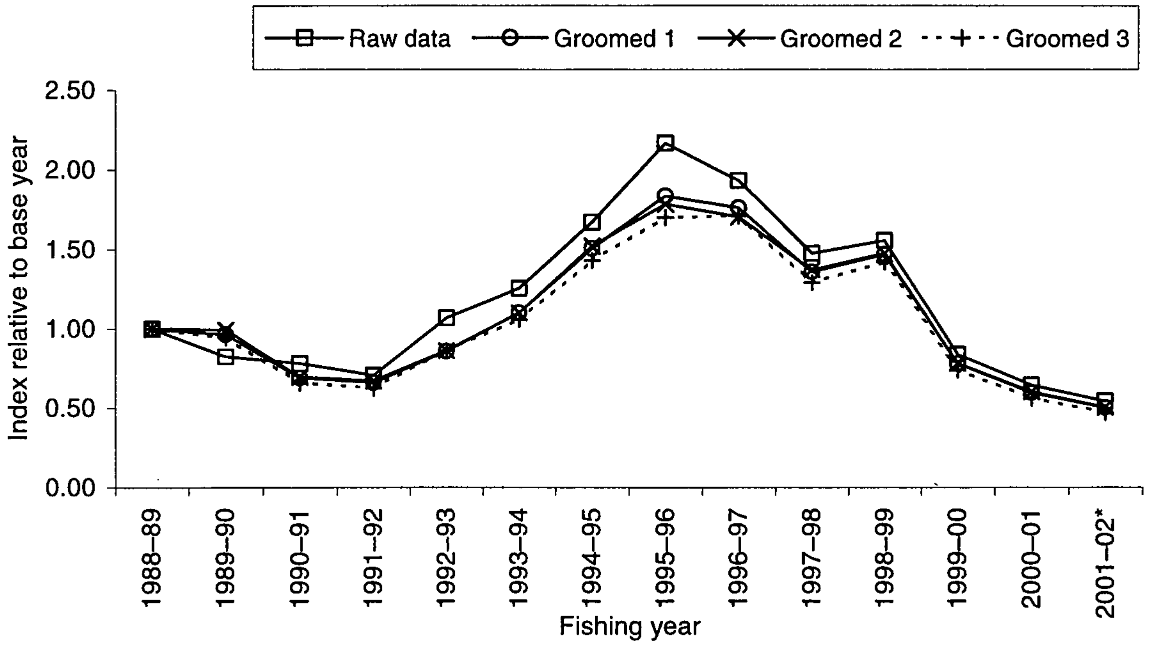

Figure 6: Unstandardised indices of trawl catch rates of scampi caught by all vessels fishing in QMA 1. Raw data are ungroomed, Groomed 1 = groomed data including irreconcilable errors, Groomed 2 = groomed data excluding irreconcilable errors, Groomed 3 = groomed data excluding irreconcilable records and zero scampi catches. Data for 2001–02 are based on the first six months of the fishing year (Hartill & Cryer 2002, 2003).

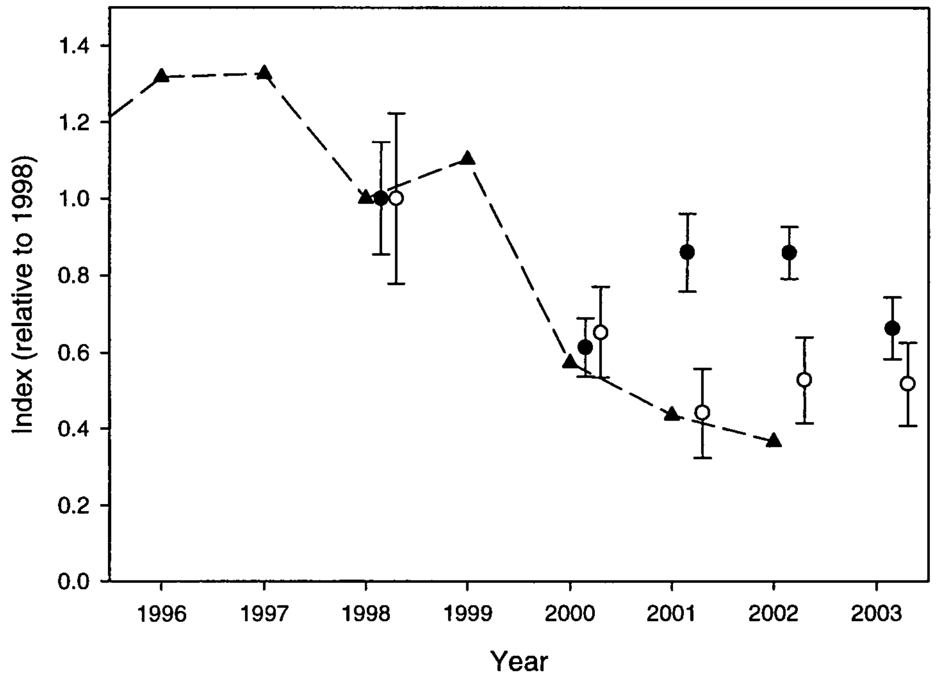

Figure 7: Comparison of possible indices of relative abundance for scampi in the core area of QMA 1 (Cuvier to White Island, 300–500 m depth) since 1995, all standardised to respective 1998 indices. Solid triangles and dashed line = commercial CPUE based on Groomed 3 from Hartill & Cryer (2003), solid circles = index of major burrow openings ± 1 standard error, and open circles = index of visible scampi ± 1 standard error. Commercial CPUE had not been updated with data from the 2002–03 fishing year at the time of reporting.

At this stage it is not possible to be certain which of these indices of abundance is the best for scampi. An index based on the density of characteristic burrows should not be affected by changes in emergence behaviour in scampi and can be estimated using photographs taken at any time of day (although it would be badly affected by changes in occupancy rate). Results from photographic surveys before and after the short fishing season in QMA 3 (Cryer et al. 2003), however, suggest that there may be major seasonal changes in the density or characteristics of burrows, as there is for *Nephrops norvegicus* ((ICES1998). This would militate against indices based on burrow densities estimated at different times of year. Indices of absolute abundance based on visible scampi are almost certainly negatively biased, and will also be affected by the seasonal and diel timing of photography (because emergence behaviour is likely to vary daily and seasonally, Cryer & Oliver 2001).

11. Conclusions

1. Five photographic surveys of scampi burrows in the core part of the QMA 1 scampi fishery were completed between 1998 and 2003. About 650 images were adopted for quantitative analysis from each survey, but about 900 from the one in 2002.

2. 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 but has remained similar since. This is consistent with commercial CPUE and research trawl catch rates.

3. The density of major burrow openings in the core area of QMA 1 had no obvious trend between 1998 and 2003, although the 1998 index was highest and the 2000 estimate was lowest. This is not consistent with commercial CPUE or research trawl catch rates.

4. 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 24% of the 2003 minimum biomass estimate. These estimates are likely to be conservative.

5. 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.

6. Sensitivity analysis suggests that any major bias in the 1998 estimates of density relative to subsequent ones is much more likely to be negative than positive. Any bias of 10% or more is almost certain to be negative relative to subsequent surveys.

7. The first photographic surveys of scampi burrows in the core part of the QMA 2 scampi fishery was completed in 2003. About 800 images were adopted for quantitative analysis.

8. The overall density of major burrow openings in the core area of QMA 2 was about 20% lower than in QMA 1, but this was strongly affected by very low density in most of Hawke Bay.

9. The current catch limit of 245 t for QMA 2 represents about 69% of our near-minimum estimate of 2003 biomass. This estimate is likely to be conservative.

10. Biomass estimates made by scaling estimates of burrow abundance by mean average size (from QMA 1) suggest that the current catch limit of 245 t in QMA 2 represents about 4% of total biomass. This estimate may not be conservative.

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12. Publications

There are no publications other than Voyage Programmes and Voyage Reports. A study of the relationship between the density of scampi burrows and acoustic signature (from fieldwork conducted between 2000 and 2003) is being documented separately.

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 NIWA 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 project.