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EXECUTIVE SUMMARY

Rowden, A.A.; Clark, M.R.; O'Shea, S.; McKnight, D.G. (2003). Benthic biodiversity of seamounts on the southern Kermadec volcanic arc.
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1) A research programme entitled "Seamounts: their importance to fisheries and marine ecosystems" is currently being carried out by NIWA with funding from the Foundation for Research, Science and Technology. Additional funding from MFish enabled a survey of seamounts of the southern Kermadec volcanic arc to be extended, and further research on biodiversity to be undertaken.

2) Three seamounts (Rumble V, Rumble III, and Brothers) were sampled using epibenthic sled and camera frame. This report describes the benthic macro-invertebrate assemblage on these seamounts, and quantifies and compares biodiversity between seamounts surveyed.

3) A total of 308 macro-invertebrate species were recorded from 52 epibenthic sled stations. At least 5.5% of the species are considered to be undescribed for the New Zealand region. Species were distributed among 10 phyla, with 5 of the phyla containing over 90% of the total number of taxa found. Taxonomic diversity varied within these major phyla.

4) The lack of an asymptote in the relationship between epibenthic sled sampling effort and the number of species recorded implies that the seamount assemblage was not fully sampled.

5) Differences between seamounts were evident in the mean number of species recorded for each feature: Rumble V had two and three times the number of species as Rumble III and Brothers respectively.

6) Analysis of photographic images confirmed the dominance of certain taxa as revealed by direct sampling, but also indicated some additional useful methodological and biodiversity information. In particular, it was possible to describe the discontinuous distribution of the seep/vent-specific bivalve "*Bathymodiolus*" sp.

7) Further sampling of other seamounts (using a combination of direct sampling and photographic techniques) and adjacent areas of hard substrate is required to improve assessments of biodiversity and endemism. In particular, further sampling of seamounts in the southern Kermadec volcanic arc is recommended in order to improve information concerning the composition and extent of assemblages associated with sites of active hydrothermal venting.

1. INTRODUCTION

1.1 Overview

Seamounts, features of significant elevated topography on the seafloor, are of considerable scientific interest, often hosting unusual or unique assemblages and a biodiversity disproportionate to their size/area (Probert 1999). Seamounts are not only widely recognised as areas of high productivity, but are also regarded as fragile habitat (Rogers 1994) susceptible to disturbance from fishing (e.g. Koslow et al. 2001) and mining (e.g. Grigg et al. 1987). In the New Zealand marine environment, seamounts are common and widely distributed features (Wright 1999), some of which are the focus of important commercial fisheries (Clark 1999). However, within the region very little ecological research has been undertaken, and only one study has addressed the effects that human activities may have on their physical and biological integrity (Probert et al. 1997). A research programme entitled "Seamounts: their importance to fisheries and marine ecosystems" is currently being carried out by the National Institute of Water and Atmospheric Research (NIWA) with funding from the New Zealand Foundation for Research, Science and Technology (FRST) and the Ministry of Fisheries (MFish). This programme aims to describe and build an understanding of the role and dynamics of seamounts in the marine environment (Clark et al. 1999).

Since the mid 1990s, NIWA scientists have studied a variety of seamount habitats, including those of the Kermadec volcanic arc. The extreme southern portion of the volcanic arc comprises a series (at least 12 major features) of active, mostly submarine, volcanoes associated with the Pacific-Australian plate convergence north of New Zealand (Wright 1994). Whilst aspects of their volcanism and hydrothermal venting are becoming better known (Wright 1996, Wright 2001, Wright et al. 1998, Wright et al. 2002, Wright & Gamble 1999, de Ronde et al. 2001), to date there have been few biological investigations. In November 2000, NIWA undertook a short still-camera and epibenthic sled survey of the seamount Rumble III, during which live hydrothermal vent faunas new to science, or at least to New Zealand waters, were recorded (Clark & O'Shea 2000). Vent assemblages are of interest to biologists worldwide who not only wish to understand how these chemosynthetic-based systems function, but also to elucidate the means by which the diversity of isolated habitats in the marine environment are maintained (Van Dover 2000). To date, investigations of vent assemblages are restricted to a few sites, mainly in the north Atlantic and eastern Pacific (Hessler & Kaharl 1995). Thus, understanding the composition of New Zealand's poorly known vent fauna is of both local and global significance.

The research undertaken during the present study was designed to extend the previous work of NIWA, and provide a comprehensive description of the seamount assemblages of the southern Kermadec volcanic arc, including those of the associated hydrothermal vents. Owing to the potential synergies between the FRST-funded NIWA seamount programme and the goals of the MFish biodiversity programme, additional objectives were supported by MFish to expand the biodiversity research undertaken during this survey. In this report, we present results from this work describing the benthic macro-invertebrate assemblage on three seamounts, two of which were afforded a degree of legal protection from anthropogenic disturbance immediately before the survey (Anon. 2001), and quantify and compare biodiversity among the seamounts surveyed. More detailed analyses are planned, once faunal identification is more complete, and will be reported in a future publication.

1.2 Objectives

There were four objectives in the project 'Supplementary Research on Biodiversity of Seamounts' (ZBD2000/04).

- To determine the biodiversity of seamounts of the southern Kermadec volcanic arc (Rumble V, Rumble III, Brothers).
- To describe the distribution of fauna, with an emphasis on mapping the nature and extent of biodiversity associated with hydrothermal vents.
- To compare the biodiversity of the three seamounts, and adjacent slope.
- To collect samples from near the vent sources (if possible, as these are thought to be very localised) to measure chemical and thermal aspects of the environment.

The results of the survey that relate to the first three objectives are the subject of this report. However, owing to the lack of suitable rocky seabed adjacent to the seamounts, no slope habitat was sampled as part of Objective 3. The fourth objective was met by the collection of water samples (using a water sample bottles attached to a CTD), and their provision to the New Zealand Institute of Geological and Nuclear Sciences for analysis. The results from Objective 4 are not included or discussed in this report.

2. METHODS

2.1 Study site

The study site was located on the southern end of the Kermadec volcanic arc. The three volcanic seamounts studied, Rumble V, Rumble III, and Brothers, are linearly arranged to the west of the Kermadec frontal ridge which extends northeastwards from New Zealand for 1000 km. Rumble V (the southernmost seamount) is 52 km from Rumble III, which is 110 km distant from Brothers (Figure 1). These seamounts are all volcanically active, with known hydrothermal venting. They occur between water depths (at feature base) of 2490–3506 m, and have different physical characteristics (Table 1).

2.2 Survey design

2.2.1 Epibenthic sled sampling

In order to allow for statistically valid comparisons between the associated fauna, a minimum of 10 random replicate epibenthic sled samples was desired for each of the three study seamounts. Sample stations were selected at random by a combination of random direction from the seamount peak and random depth down the slope. In addition, a few non-random epibenthic sled samples were planned to investigate particular regions of the seamounts.

2.2.2 Photographic image sampling

It was thought unlikely that all seamounts could be surveyed using images captured by a digital camera in the time available,. Thus, the following priority order for camera survey was established – Rumble III, Rumble V, Brothers. Rumble III was considered the preeminent target because it is a protected seamount of large area; Brothers was to be considered after Rumble V, for it occurs at water depths that would restrict the use of the camera to the seamount peak. The aim was to conduct at least eight photographic transects arranged in a starburst pattern centred on each seamount peak. Transects were to be aligned N–S, E–W, NE–SW, NW–SE, and extend as far as possible to the base of the seamount.

2.3 Field sampling

2.3.1 Epibenthic sled sampling

An epibenthic sled (overall size 155 cm long, 50 cm high, and 130 cm wide), similar in design to a SEBS sled (Lewis 1999), was used for sampling seamount fauna between 19 and 24 May 2001. Macro-invertebrates were sampled by the sled mouth (100 cm wide by 40 cm high) and were retained in a net of 30 mm stretched mesh size that was covered in an anti-chaffing net of 100 mm stretched mesh size. A depth sensor was attached inside the frame. Sleds were towed at each seamount station (Figure 2) up the slope at a speed of 2 knots for a target time of 15 minutes. Sled deployment was maintained as constant as possible between tows to enable robust comparisons of catch per tow. On recovery of each sled, the sample was sorted by hand and all macro-invertebrates recovered were identified (to at least major group), and retained (either fixed in formalin/alcohol or frozen) for subsequent analysis in the laboratory.

2.3.2 Photographic images

A still camera was mounted on the sled frame of the CREST acoustic system. The digital camera was a Minolta Dimage with wide-angle lens and zenon flash fitted 25 cm from and perpendicular to the base of the frame. The camera frame was towed down-slope (previous experience had identified up-slope tows as unsatisfactory) within 2–3 m of the seabed in order to achieve good-quality pictures. Camera frame height above bottom was monitored continuously using the CREST acoustic system, and supplied the information required to make the necessary adjustments to warp length. Tow speed was about 1 knot across the seabed. The camera was activated remotely at stations at about 1 minute intervals along the sample transects (Figure 2). The geographical location of the camera frame (and thereby the position of still camera stations) was recorded by the attached CREST acoustic system. The camera had limitations on numbers of shots taken, which necessitated its retrieval after four transects for the images to be downloaded from the camera's disk on to a computer.

A low-light video camera was also mounted in the sled frame and recorded continuously along each transect. The footage from the video system has not been analysed for inclusion in this report.

2.4 Laboratory analysis

2.4.1 Epibenthic sled samples

Macro-invertebrates were identified to species or putative species (i.e., apparently morphological distinct organisms, sometimes also called operational taxonomic units) with the aid of microscopy and taxonomic keys and enumerated when possible. After identification, samples were preserved in isopropyl alcohol/and or formalin and lodged in the biological collection, and records entered on to computer files at NIWA.

2.4.2 Photographic images

The locations of all still-camera stations (position of the camera frame, not the vessel) on the seamounts were calculated from the known depth of the frame at the time of each image capture and from the detailed bathymetric data collected along each transect. The digital image from each camera-frame station was analysed by eye and a standard assessment form detailing station information (station position, direction of transect, seabed depth, camera depth) was completed for image quality and organisms present. Digital images were viewed using Corel Photo-Paint and an initial assessment was made of image clarity, ranking each image as either 'good', 'poor', or 'blank'. Individual organisms or colonies visible in the images were enumerated (count or estimate of percent cover) and assigned to the following taxonomic groupings: Porifera, Scleractinia, Alcyonacea, Actiniaria, 'unidentifiable coral', Decapoda, Gastropoda, Bivalvia, "*Bathymodiolus*" sp., Ophiuroidea, Asteroidea, Crinoidea, Echinoidea, and 'other macro-invertebrates'. All data were transferred to computer spreadsheets for analyses.

2.5 Data analysis

2.5.1 Epibenthic sled samples

Owing to the time required to fully identify the macro-invertebrates, a compositional analysis of the seamount assemblage (for the three features combined) is necessarily restricted to a description based on those fauna identified to the taxonomic level of order. An analysis of variance (ANOVA) test was performed to test for statistically significant differences in the diversity of macro-invertebrate fauna between the seamounts sampled. The number of species sampled was the response variable, and 'seamount' was the random factor (significance level was set at $\alpha = 0.05$). In order to achieve a balanced design, data from 10 stations per seamount were used for the analysis, that is, the minimum number of successful stations achieved for a seamount. For those seamounts for which more than 10 effective samples were taken, stations omitted from analysis were those that reduced the sample size variability for a seamount to a minimum. Data were tested for departures from homogeneous variance before ANOVA to check that test assumptions were met. All analyses were conducted using the statistics software package NCSS.

2.5.2 Photographic image samples

Owing to the qualitative nature of the image record (seabed area of images not currently calculated), comparisons of taxonomic groupings between seamount assemblages were simply made by examining differences in the number of groupings recorded, and by noting those groupings unrepresented on each seamount. Photographic images were also used to describe the smaller-scale patterns of faunal distribution, in particular the relative occurrence of the seep/vent-specific mytiloid "*Bathymodiolus*" sp.

3. RESULTS

3.1 Sampling performance

3.1.1 Epibenthic sled samples

The epibenthic sled appeared to perform reasonably well for sampling seamount fauna. In order to effectively sample (i.e., sample not compromised by poor gear performance) each of the three study seamounts at least 10 times, 45 random epibenthic sled deployments were made: Rumble V (14), Rumble III (20), and Brothers (11). Eight non-random epibenthic sled deployments were also made. The plot of the species-accumulation curve for the 36 effective samples (Figure 3) reveals that the sampling effort was not sufficient to sample the whole of the macro-invertebrate assemblage of the seamounts studied. Thus, descriptions of the seamount assemblage of the southern Kermadec volcanic arc are incomplete. Attempts were made to standardise the time/speed for each epibenthic sled tow, but occasional deviations from the ideal occurred. The influence that such deployment variability might have on sample comparability was evaluated by relating the estimates of area sampled (distance along seabed x width of sled mouth) to the number of species sampled per effective epibenthic sled tow. Figure 4 shows the lack of significant relationship between number of species sampled and the sample area (mean sample area per tow = 349 m^2 ±19 1 SE). Hence variability in area sampled per sled tow will not invalidate comparisons of diversity between seamounts.

3.1.2 Photographic images

In the time available, it was possible to sample 214 camera stations along 13 transects, distributed on two seamounts from close to the feature peaks to a maximum of 1003 m water depth. Sampling effort was unequal between seamounts: Rumble III was sampled with 132 stations on 9 transects (total transect length, 12 900 m; water depth range, 194–1003 m), Rumble V by 82 stations along 4 transects (total transect length, 6800 m; water depth range, 373–1001 m). There was insufficient time to survey Brothers seamount. At times it proved difficult to maintain a steady flight of the camera frame at the desired height above the bottom. The quality of the photographic record varied; 76% of images were categorised as 'good', 18% as 'poor', and 6% as 'blank'. However, the quality of the still camera images was sufficient to recover seabed data from over 90% of the images.

3.2 Biodiversity of seamount macro-invertebrate assemblage

3.2.1 Taxonomic diversity of assemblage

3.2.1.1 Epibenthic sled samples

There were 308 species in the 52 samples of macro-invertebrates from the three study seamounts. Of the total number of species recorded, 223 are currently identified to putative taxon level only, of which at least 17 species (5.5% of the total species sampled) represent previously undescribed taxa (including 5 probable undescribed genera). Species were distributed among 10 phyla, with 5 of the phyla (Cnidaria, Polychaeta, Crustacea, Mollusca, Echninodermata) containing over 90% of the total number of taxa found. The number and distribution of classes, orders and species within the phyla (i.e., taxonomic diversity), varied considerably (Table 2). The most species-rich group, the Crustacea (81 species), was represented by two classes, one of which contained 85% of the total number of species recorded for this phyla. This class, Malacostraca, contained only two orders, of which one order (Decapoda) contained three-quarters (61 species) of the crustaceans recorded from the seamounts studied. In the next most speciose phylum, the Mollusca (59 species), the distribution of species among taxonomic sub-groupings was very different. Of the five classes that represented this phylum, one contained 71% of the species sampled for this group. This class, Gastropoda, contained seven orders of which the Neogastropoda and Vetigastropoda almost equally contributed to 69% of the species (16 and 13 respectively) recorded for the class. The next most order-rich molluscan class, the Bivalvia, contained 11 species distributed among five orders. The phylum Annelida (58 species) had a similar number of species to the Mollusca. However, the annelids were represented by only two classes of which one, the Clitellata, contained only one leech species. The remaining class, the Polychaeta, contained seven orders throughout which species were distributed. A large proportion of polychaete species sampled belonged to the order Phyllodicida (39%, 22 species), nearly half of the species were equally distributed in the Eunicida, Spionida, and Terebellida, whilst the remainder were distributed in another three orders. Like the Annelida, the phylum Cnidaria also had over 50 species represented by two classes, one of which (Anthozoa) contained the majority of species (45) distributed throughout a relatively high number of orders (6). The order Scleractinia alone contained almost a third of the species (14) of the taxonomically diverse Anthozoa. Half of the remaining anthozoans were represented in the orders Alcyonacea, Actiniaria, and Antipatharia (6, 8 and 7 species respectively), and just over 10% of the species between two orders. The other phyla well represented by sampling the study seamounts, the Echinodermata, contained 35 species in three classes. The class Ophiuroidea, represented by two orders, contained over half (19) of the species recorded for the phylum. The remaining two classes each contained four orders in which a relatively small number of species were distributed. Figure 5 illustrates the distribution of the seamount assemblage species within the most order-diverse or dominant classes of the major phyla.

3.2.1.2 Photographic images

From the 197 images that were of sufficient quality to observe the seabed, it was possible to identify and classify the macro-invertebrates into the chosen groupings for 144 photographic records (Table 3). Individuals belonging to the Echinodermata were the most frequently observed faunal organisms (occurring on 110 images), with the classes Asteroidea and Echinoidea (Figures 6 & 7) constituting the most numerous of all observations (45%, 43% of Echinodermata or 35%, 33% of total, respectively). Cnidarians were the next most frequently identifiable organisms, occurring in 34 images, of which the Actiniaria (Figure 8) and Alcyonacea constituted 50 and 18% (respectively) of the observations for this phylum. Mollusca belonging to the classes Gastropoda and Bivalvia were observed on 20 and 14 of the images. The latter class was singularly represented by the seep/vent-specific mytiloid "*Bathymodiolus*" sp. (Figure 9). For the Crustacea, records for only one sub-grouping were noted, that is individuals of the order Decapoda, which occurred in 12% of the images (Figure 10). The phylum Porifera was not subdivided into any taxonomic sub groupings and individual sponge colonies were observed in only five of the image samples. Not all the taxonomic groupings into which identifiable fauna were to be classified were represented in the photographic record of the seamount assemblage. No crinoids or scleractinian corals were observed.

3.2.2 Comparison of biodiversity between seamounts

3.2.2.1 Epibenthic sled samples

The mean diversity (expressed as number of species) for the three seamounts sampled on the southern Kermadec volcanic arc was 17.4 (± 2.52 1 SE). Mean diversity per seamount was 31.2 (± 3.49 1 SE) for Rumble V, 12.6 (± 1.61 1 SE) for Rumble III and 8.3 (± 2.52 1 SE) for Brothers (Figure 11). One-way ANOVA revealed that there was a significant difference in the number of species sampled between the seamounts studied (mean square = 1481.433, F-ratio = 21.05, $P < 0.0001$).

3.2.2.2 Photographic images

The number of images in which macro-invertebrates could be identified differed between the two seamounts, that is, sample size was 80 and 64 for Rumble III and Rumble V, respectively. Despite this, the number of taxon groupings observable in images was similar, and contrary to expectation, more groupings were observable on the seamount that received less sampling effort. Of the 15 faunal classifications utilised for the analysis, 10 were noted for Rumble III and 12 for Rumble V. The two taxa observed at the latter seamount, but not at the former, were individuals of the Alcyonacea (Figure 12) and Ophiuroidea. Of particular note is the observation that live "*Bathymodiolus*" mussels were recorded on eight images recovered from Rumble V (on three out of four transects) and on four of the images taken on Rumble III (on two out of nine transects). Such a record indicates that "*Bathymodiolus*" sp. has a patchy distribution on the two seamounts surveyed. "*Bathymodiolus*" sp. appeared on two, and one, isolated images on a single transect on Rumble V and Rumble III, respectively. However, consecutive images of "*Bathymodiolus*" sp. were also observed, indicating that 'patches' of this vent-specific taxon can span linear distances of at least 60 m and 220 m on Rumble V, and 160 m on Rumble III. Live "*Bathymodiolus*" sp. appear to occur towards the summit of both seamounts (Figure 13). Dead "*Bathymodiolus*" sp. were observed in two images from one transect on Rumble V, possibly indicating predation, transport of shells from elsewhere, or former sites of hydrothermal venting.

4. DISCUSSION

On the three studied seamounts of the southern Kermadec volcanic arc, sampled by 52 epibenthic sleds stations, 308 species of macro-invertebrate were recorded. At least 5.5% of the species recovered by the survey are considered to be undescribed for the New Zealand region. This estimate includes five genera new to science. However, because over a third of the taxa recorded have so far been identified to putative species only, the proportion of undescribed species/genera is probably much greater. Species were distributed among 10 phyla, with 5 of the phyla containing over 90% of the taxa found. Taxonomic diversity varied within these major phyla. Differences between seamounts were evident in the mean number of species recorded for each feature. The lack of an asymptote in the relationship between epibenthic sled sampling effort and the number of species recorded implies that the seamount assemblage was not fully sampled.

Rogers (1994) in his review of global seamount studies found that only 597 invertebrate species had been recorded since direct sampling began at the end of the nineteenth century. However, the review also noted that there had been relatively little sampling effort on seamounts and that seamount-targeted studies were very few. Therefore, comparison between studies of seamount fauna is difficult. However, a recent study in the southwest Pacific Ocean is similar in scope and methodology to the one reported here. Sampling of seamounts in the Tasman Sea and southeast Coral Sea recorded more than 850 macrofaunal species (*both* invertebrates and fish), of which 16–36% were deemed both new to science and potentially endemic to seamounts (Richer de Forges et al. 2000). A number of geographic seamount groupings were sampled; sampling of six seamounts on the Norfolk Ridge recorded 516 macrofaunal species, four seamounts on Lord Howe Rise produced 108 species records, and 297 species were found on 14 seamounts southeast of Tasmania. Different sampling effort was probably, in part, responsible for differences in species numbers observed between seamount groupings, and it is most likely that the number of species present on these seamounts is far greater than the number recorded (Richer de Forges et al. 2000).

The present evaluation of macro-invertebrate biodiversity for three seamounts of the southern Kermadec volcanic arc is broadly comparable with the study of Richer de Forges et al. (2000). However, whilst more species were recorded for the southern Kermadec seamounts than those of the Lord Howe Rise and Tasmania, sampling effort was also greater (52, 35, and 34 samples respectively). Seamounts of the Norfolk Ridge, which were found to have just over 200 more species recorded than seamounts in the present study, received over five times as much sampling effort. Estimates of seamount faunal endemism for the present study are at least half that of those made for seamounts of the Tasman and Coral Sea (Richer de Forges et al. 2000). However, caution should be attached to any such comparison; any interpretation of the uniqueness of the seamount assemblages of the southern Kermadec volcanic arc requires a study that compares species composition of seamounts and similar substrata of low-relief slope throughout the New Zealand region.

The only specifically seamount-targeted study available for making part of such a comparison is a recent survey of the macro-invertebrate biodiversity of a number of seamounts on the Chatham Rise, east of New Zealand (Rowden et al. 2002). A comparative compositional analysis of the faunas of that study and the present investigation has yet to be undertaken, but a comparison of the biodiversity descriptions is revealing in itself. A total of 414 macro-invertebrate species, distributed among 14 phyla (with 6 phyla containing over 90% of the total number of taxa), were recorded from 42 epibenthic sled stations on eight seamounts (Rowden et al. 2002). That is, the macro-invertebrate assemblage of the seamounts of the Chatham Rise is more speciose and taxonomically diverse than the assemblage sampled on the seamounts of the southern Kermadec volcanic arc. No difference in diversity (number of species sampled) between the eight relatively proximal seamounts (1.3–12.6 km apart) on the Chatham Rise was observed (Rowden et al. 2002).

The present study on the southern Kermadec volcanic arc clearly indicates that there is a statistically significant difference in the macro-invertebrate diversity (number of species sampled) between each of the three relatively distant study seamounts (52–160 km apart). Worthy of note is that the unprotected seamount has more species on average than the two features now protected from bottom fishing (Anon 2001). Rumble V has a mean number of species over twice that of Rumble III and over three times that of Brothers. Arguably, seamounts can be considered marine islands (*sensu* Hubbs 1959) and therefore, according to island-biogeography theory (*sensu* MacArthur & Wilson 1963), it would be reasonable to expect that large seamounts will support more species than smaller ones. However, although Rumble V is slightly larger in area than Brothers, Rumble III is over six times larger than the seamount with the greatest number of recorded taxa. Why there is such a striking difference in diversity between Rumble V and the other two seamounts is a question that warrants future investigation.

In addition to diversity being evaluated by direct sampling using the epibenthic sled, a camera frame was also used to assess diversity of taxonomic groupings observable on recovered images. Analysis of camera images confirmed the dominance of certain taxa as revealed by direct sampling, but also indicated some additional useful methodological and biodiversity information. For example, the high diversity of decapod crustaceans cannot be effectively indicated by photo image, whilst members of the Actiniaria are a dominant component of the seamount assemblage that appears to be proportionally under-sampled by epibenthic sleds. The diversity of the Echinodermata as revealed by the camera images compared reasonably well with that assessed by epibenthic sled samples. However, the generally smaller members of the Ophiuroidea were not so frequently observed on the recovered images. Sampling by camera image proved to be inappropriate for recording the diversity of the generally small and cryptic polychaetes. Epibenthic sled sampling revealed that the Polychaeta was one of the five major taxonomic components of the assemblage of the studied seamounts.

Photographs can be used to characterise the distribution of fauna on the seamounts. In the present study, such small-point area samples were particularly useful for mapping the nature and extent of the distribution of the mytiloid "*Bathymodiolus*" sp. Bivalves of the genus *Bathymodiolus* occur only near seep or hydrothermal vent activity because their nutrition is largely dependent upon symbiotic bacteria that metabolise a derivative of the sulphide emanating from seeps and vents (Fisher 1995). Previous studies in the southwestern Pacific, and elsewhere, have revealed that such bivalves are part of a distinct assemblage of vent-specific macro-invertebrates (Desbruyères et al. 1994, Van Dover 2000). Thus, the camera survey effectively indicates that vent assemblages are sparsely and patchily distributed on the seamounts studied. However, it should be noted that for only one seamount (Rumble III) was the target number of eight transects completed, and further photographic data would be necessary before any substantive statements can be made about the occurrence of vent fauna on the volcanoes of the southern Kermadec arc.

Despite concerns about the destructive nature of sampling using an epibenthic sled (particularly on protected seamounts), and the related attractiveness of using only camera/video-derived samples to study the biodiversity of seamounts, it should be remembered that the footprint of the direct sampling device used is relatively small (seamount:sample area km^2; Rumble V – 48:0.007, Rumble III – 315:0.013, Brothers – 34:0.008). In addition, it is currently not possible to identify even the major components of a macro-invertebrate assemblage from a photograph. When an assemblage is largely or partly undescribed, as for New Zealand seamounts, recovery of specimens by direct sampling is imperative for a full assessment of biodiversity. The usefulness of combining sled and photographic sampling methods has already been demonstrated by seamount studies elsewhere (e.g., Raymore 1982, Kaufmann et al. 1989), but this approach has infrequently been applied to studies of New Zealand's benthos. Although not reported here, video images were also taken using the camera frame, and these will provide additional data for evaluating aspects of the seamount environment (particularly the heterogeneity of substrate type) in relation to assessment of biodiversity by direct sampling.

In summary, the present study of the seamounts of the southern Kermadec volcanic arc revealed a diverse assemblage of macro-invertebrates, composed mainly of relatively few, taxonomically diverse phyla. The extent of endemism for the seamount assemblage studied is (after identifications are complete) likely to be relatively high and, like the high diversity, broadly comparable to that found in a previous study of seamounts in the southwestern Pacific Ocean. However, we emphasise that, considering the relatively low sampling effort and the lack of a study of assemblages from similar-substrate/low-relief habitats in the region, further sampling of seamounts and adjacent areas of hard substrata would be required to substantiate indications of high diversity and endemism for seamounts. Seamount assemblages are considered fragile and vulnerable to disturbance from fishing (Probert 1999, Koslow et al. 2001, Clark & O'Driscoll 2002), and to assess and manage the interactions of fishing with these communities we need to improve our understanding of the biodiversity of New Zealand's seamounts. Such studies should use a combination of sampling methods, including photographic techniques as well as direct sampling using epibenthic sleds. In particular, further sampling of seamounts in the southern Kermadec volcanic arc is recommended in order to improve information concerning the composition and extent of assemblages associated with sites of active hydrothermal venting.

5. ACKNOWLEDGMENTS

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Table 1: Physical characteristics of the three study seamounts of the southern Kermadec volcanic arc.

Seamount	Depth at peak (m)	Depth at Base (m)	Elevation (m)	Area (km^2)
Rumble V	367	2454	2087	48
Rumble III	200	3506	3306	315
Brothers	1197	2490	1293	34

Table 2: Taxonomic composition of the macro-invertebrate assemblage from three seamounts of the southern Kermadec volcanic arc (total of 52 epibenthic sled samples).

Phylum	Class	Order	Number of species
Porifera	Demospongiae	Astrophorida	2
		"Lithistida"	2
		Poecilosclerida	1
		Hadromerida	1
	Hexactinellida	Hexactinosa	5
		Lyssacinosa	1
Cnidaria	Anthozoa	Scleractinia	14
		Alcyonacea	10
		Actiniaria	8
		Antipatharia	7
		Pennatulacea	5
		Zoanthiniaria	1
	Hydrozoa	-	6
Annelida	Polychaeta	Phyllodocida	22
		Eunicida	9
		Spionida	9
		Terebellida	9
		Sabellida	5
		Scolecida	1
		Amphinomida	2
	Clitellata	-	1
Sipuncula	-	-	5
Crustacea	Cirripedia	Thoracica	12
	Malacostraca	Decapoda	61
		Isopoda	8
Pycnogonida	-	-	2
Mollusca	Aplacophora	-	1
	Polyplacophora	Ischnochitonina	3
		Lepidopleurina	1
	Gastropoda	Neogastropoda	16
		Vetigastropoda	13
		Neotaenioglossa	8
		Heterostropha	2
		Heterobranchia	1
		Cephalaspidea	1
		Neritopsida	1
	Bivalvia	Pterioida	5
		Arcoida	3
		Mytiloida	1
		Veneroida	1
		Nudibranchia	1
	Cephalopoda	Incirrata	1

Table 2: *(continued)*

Echinodermata	Ophiuroidea	Ophiurida	17
		Euryalinida	2
	Echinoidea	Cidaroida	3
		Echinoida	2
		Clypeasteroida	1
		Diadematoida	1
	Asteroidea	Forcipulatida	5
		Valvatida	2
		Spinulosida	1
		Paxillosida	1
Bryozoa	Gymnolaemata	Cheilostomata	2
		Ctenostomata	1
	Stenolaemata	Cyclostomata	1
Entoprocta	-	-	1

Table 3: Allocation of taxonomic groupings for photographic images recovered from three study seamounts of the southern Kermadec volcanic arc.

Phylum	Class	Order	Species	Number of images
Porifera	-	-	-	5
Cnidaria	Anthozoa	Actiniaria	-	17
		Pennatulacea	-	6
		Alcyonacea	-	3
		Scleractinia	-	0
		'unidentifiable coral'	-	8
Crustacea	Malacostraca	Decapoda	-	18
Mollusca	Gastropoda	-	-	20
	Bivalvia	-	-	0
		Mytiloida	"*Bathymodiolus*" sp.	14
Echinodermata	Asteroidea	-	-	50
	Echinoidea	-	-	47
	Ophiuroidea	-	-	13
	Crinoidea	-	-	0
'other macro-invertebrates'	-	-	-	11

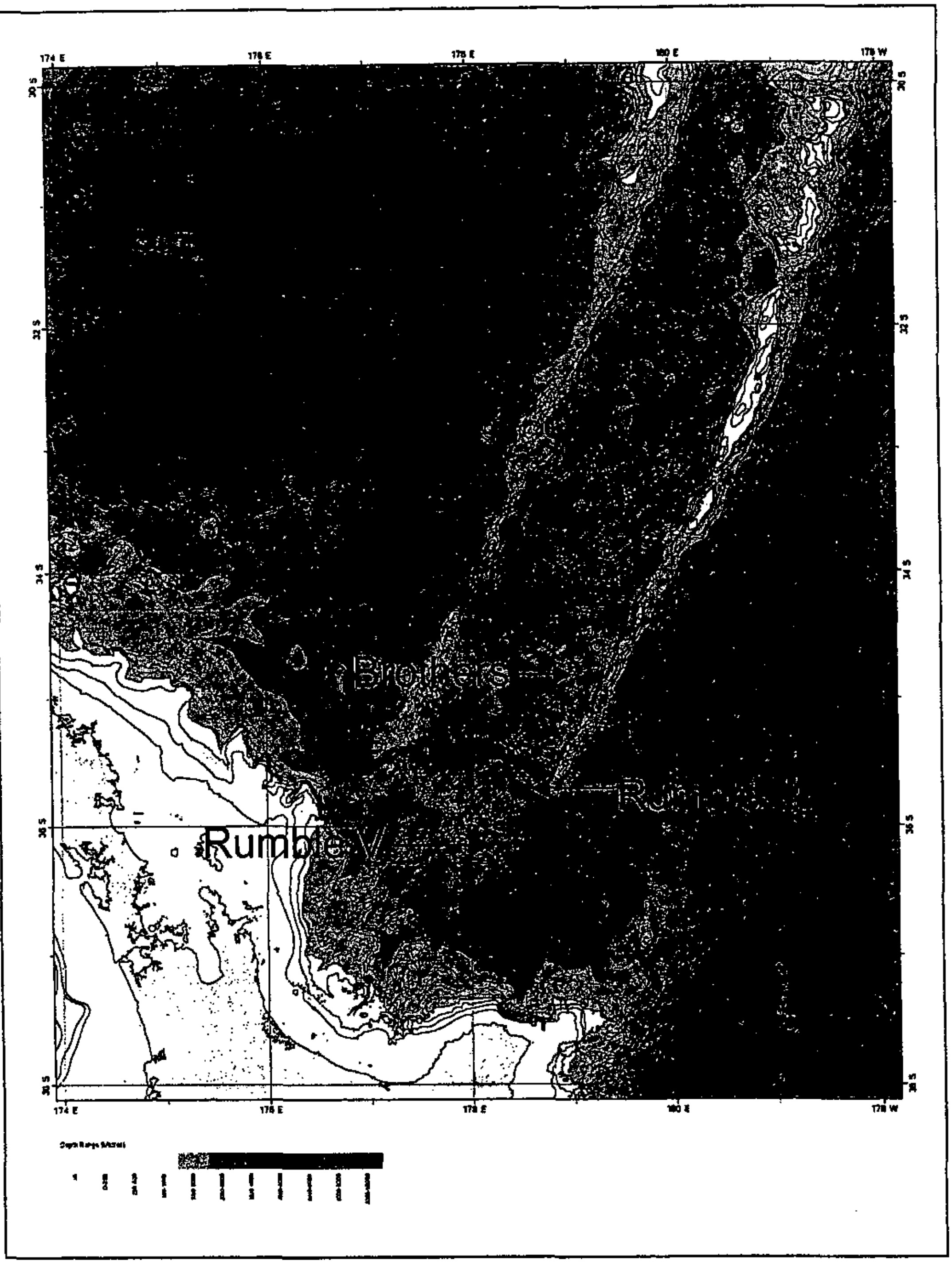

Figure 1: Location of the three study southern Kermadec volcanic arc seamounts northeast of New Zealand.

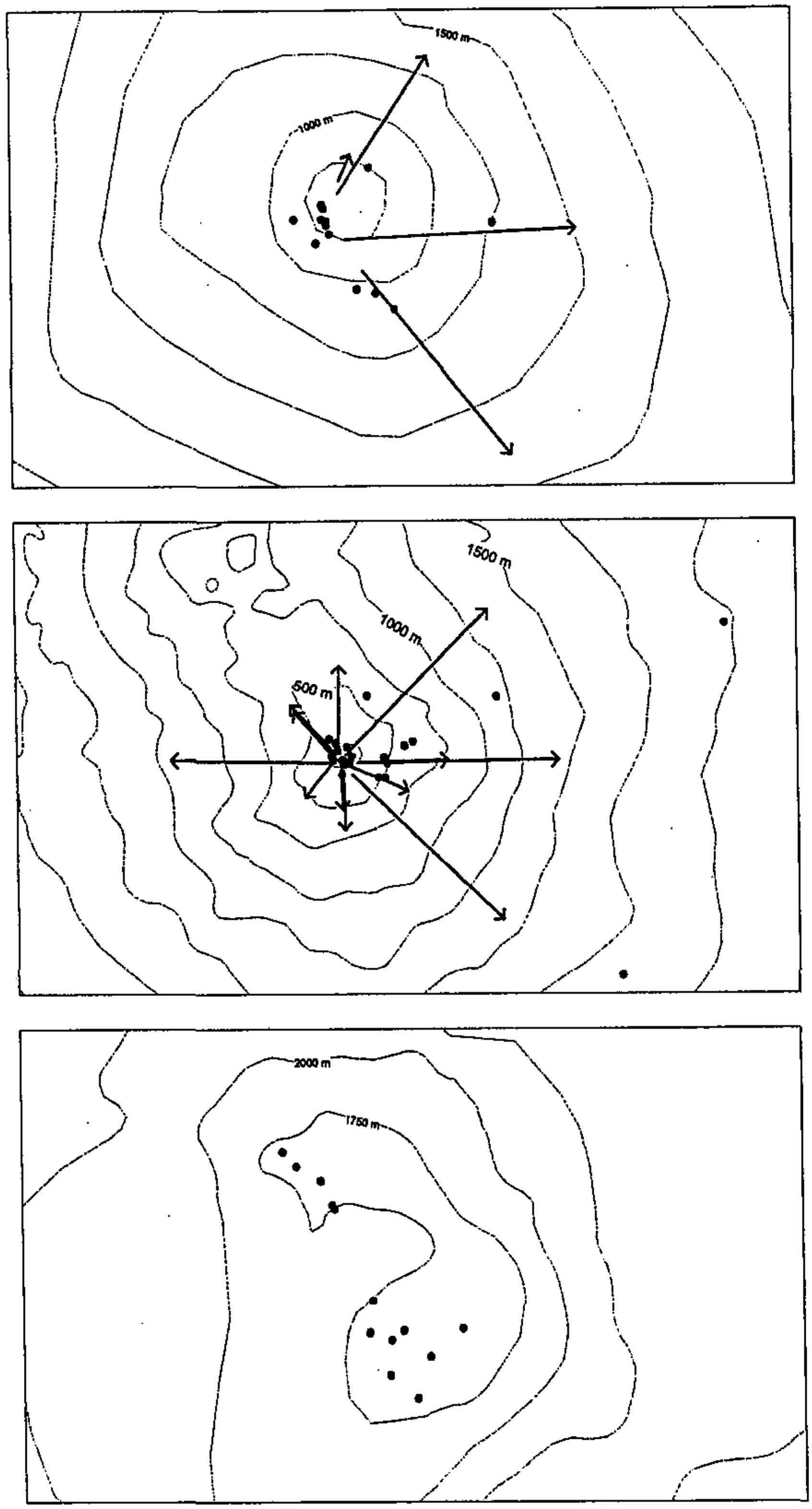

Figure 2: Distribution of epibenthic sled sample stations (filled circles) and camera frame transects (arrows) on Rumble V (top panel), Rumble III (middle panel), and Brothers (lower panel) seamounts.

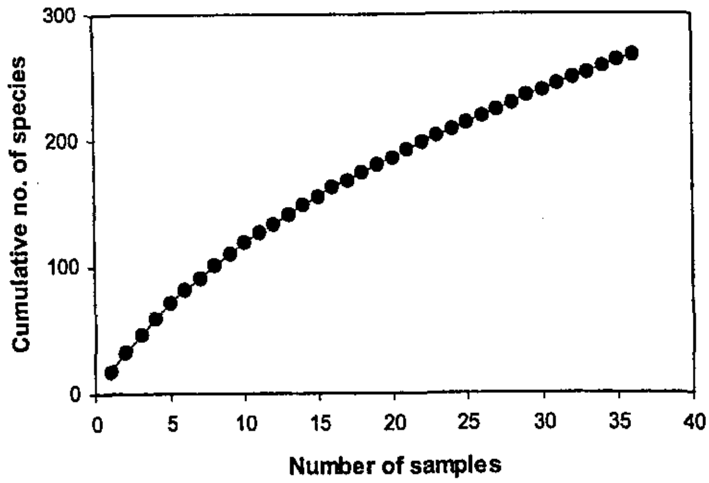

Figure 3: Species-accumulation curve for the effective epibenthic sled samples from the study seamounts of the southern Kermadec volcanic arc.

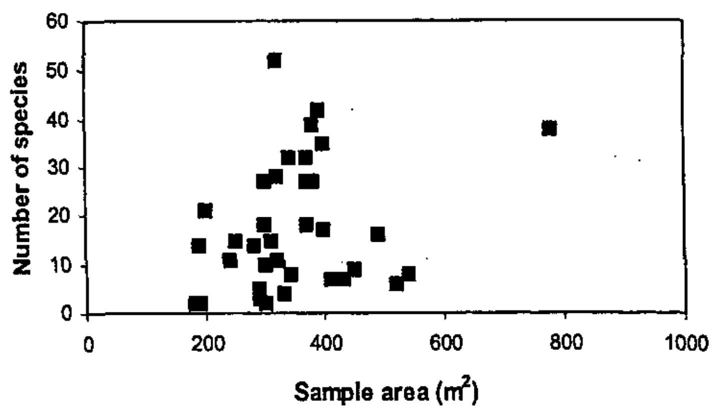

Figure 4: The relationship between the number of macro-invertebrate seamount species and the sample area of the epibenthic sled stations from the study seamounts of the southern Kermadec volcanic arc.

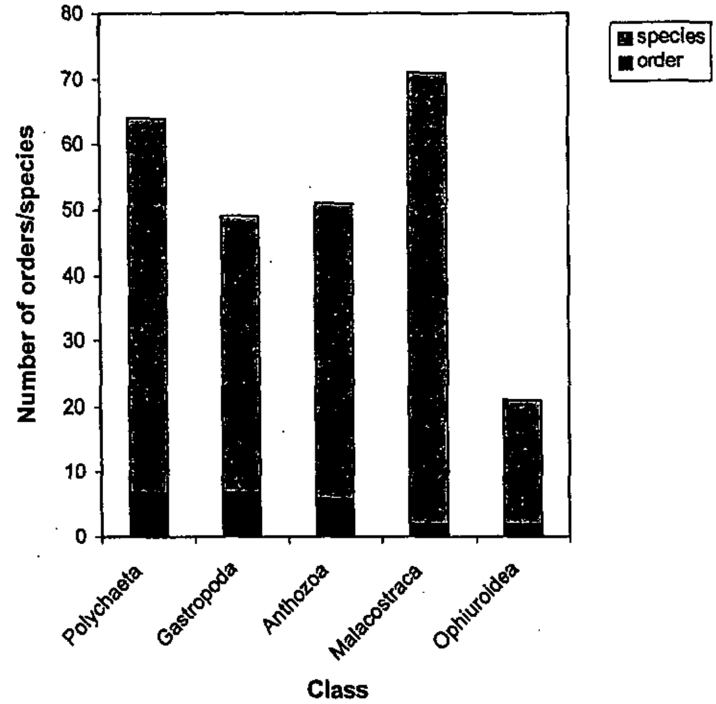

Figure 5: Taxonomic composition of the most order-diverse or dominant classes of the seamount macro-invertebrate assemblage sampled in the study seamounts of the southern Kermadec volcanic arc.

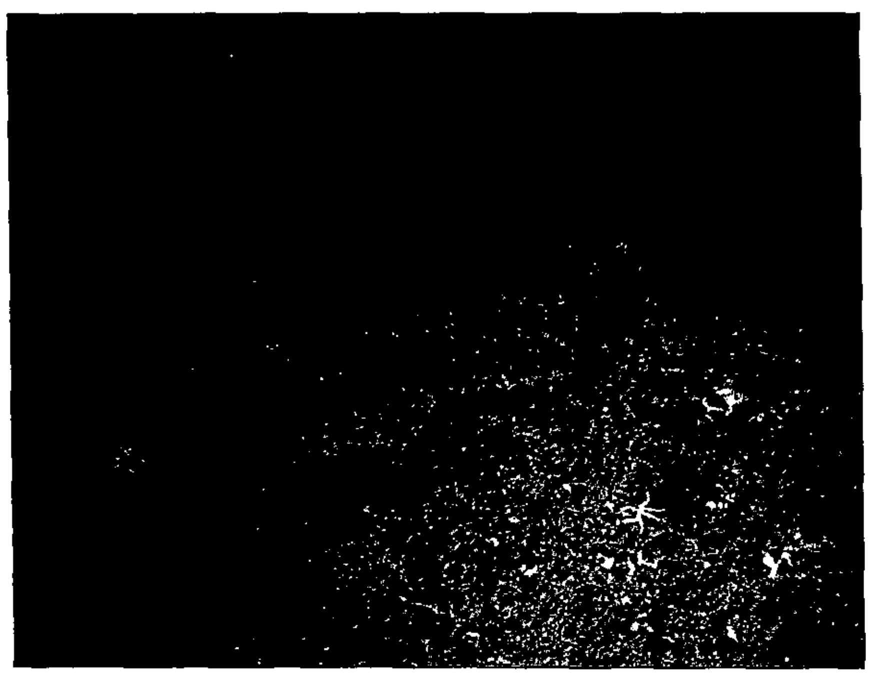

Figure 6: Photograph of seabed (Station 173) showing individuals of the class Asteroidea (white star-like organisms, left and right).

Figure 7: Photograph of seabed (Station 247) showing individuals of the class Echinoidea (e.g., a red and a white spiny organism, top and bottom right).

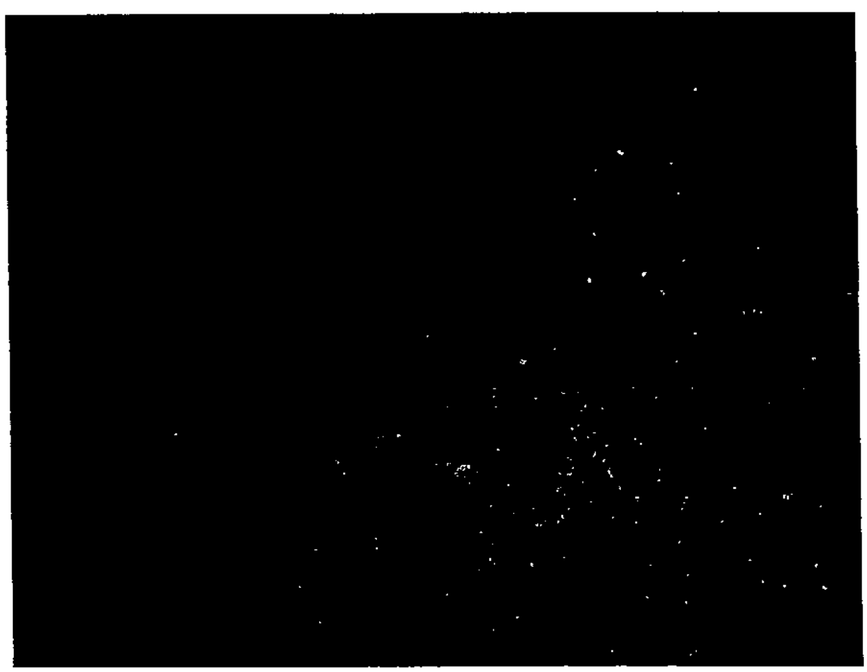

Figure 8: Photograph of the seabed (Station 298) showing individuals of the order Actiniaria (grouped lower right).

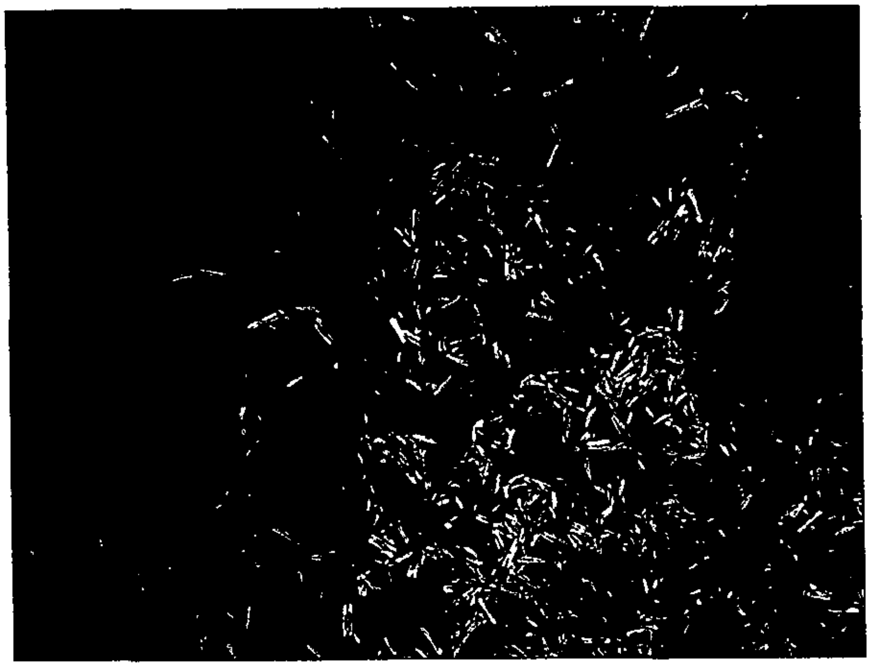

Figure 9: Photograph of the seabed (Station 150) showing individuals of "*Bathymodiolus*" sp.

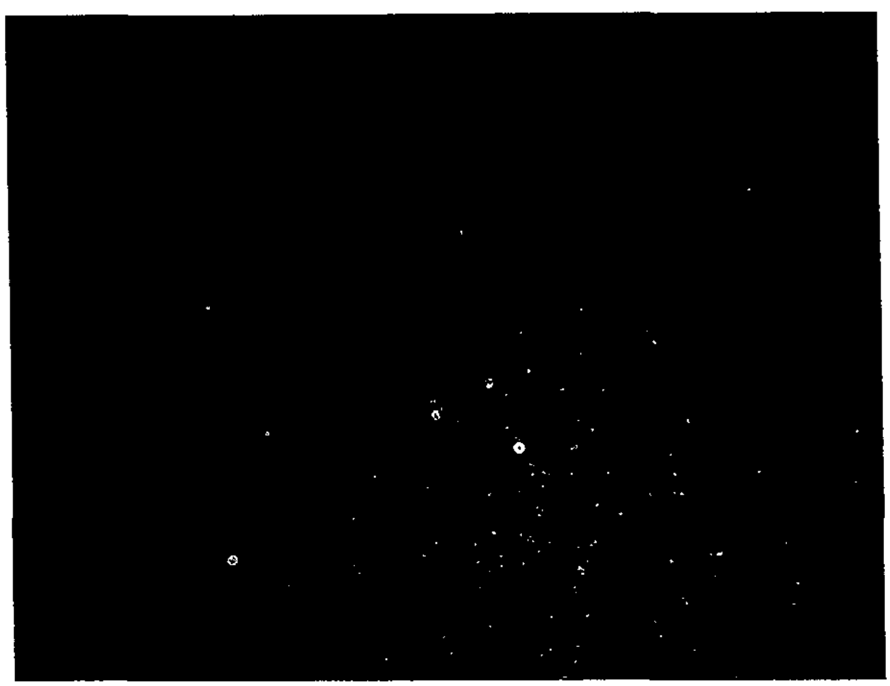

Figure 10: Photograph of the seabed (Station 269) showing individuals of the order Decapoda (orange-coloured organisms).

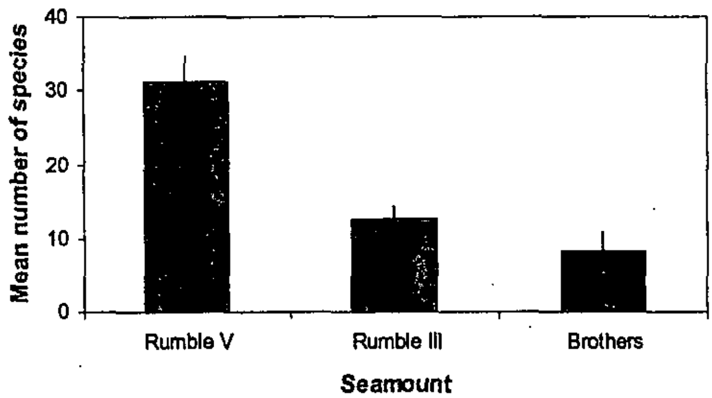

Figure 11: Mean number of macro-invertebrate species for each seamount sampled on the southern Kermadec volcanic arc (error bars = 1 SE).

Figure 12: Photograph of the seabed (Station 240) showing individuals of the order Alcyonacea.

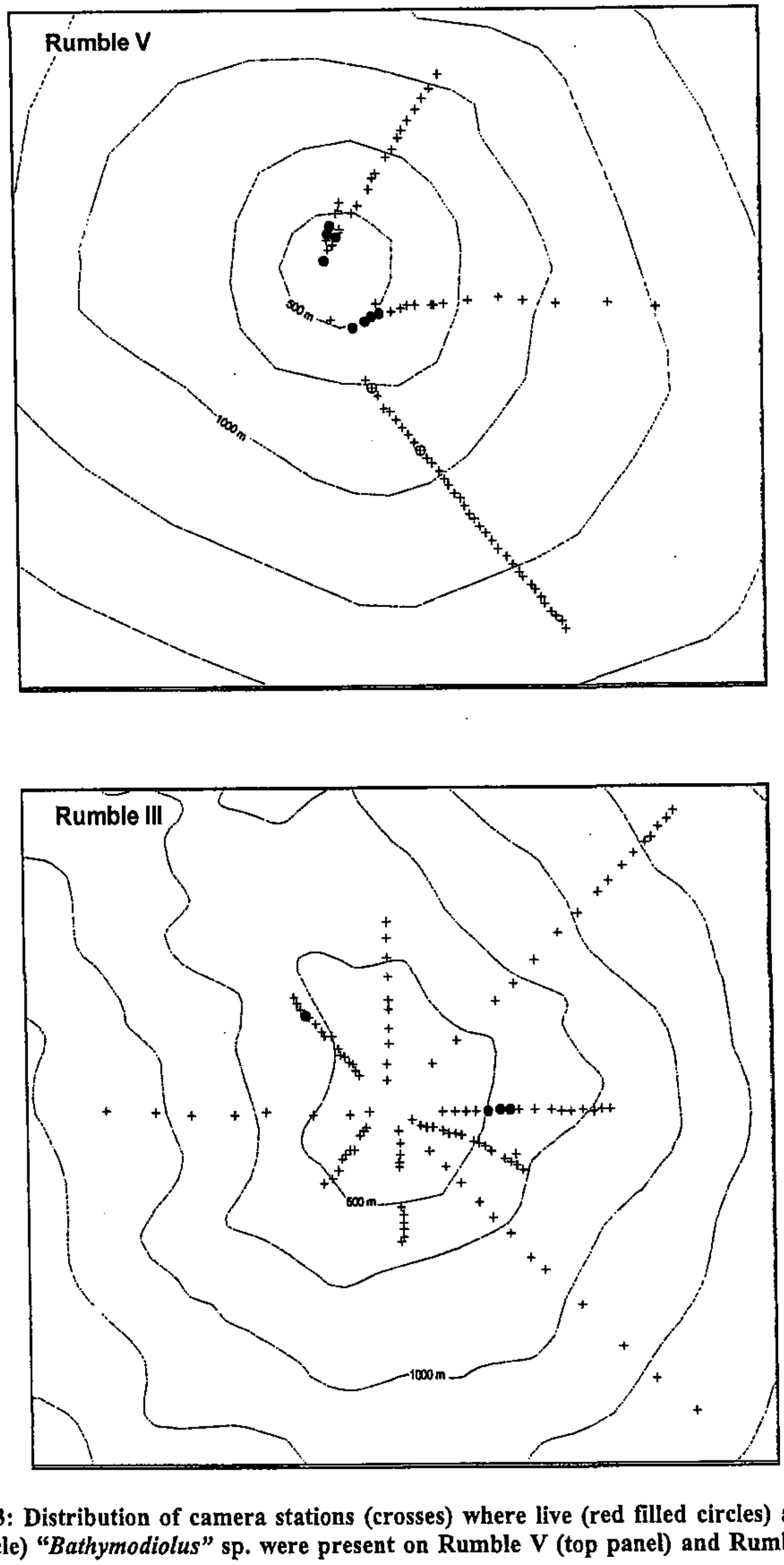

Figure 13: Distribution of camera stations (crosses) where live (red filled circles) and dead (cross and open circle) "*Bathymodiolus*" sp. were present on Rumble V (top panel) and Rumble III (lower panel) seamounts.