Benthic biodiversity of seven seamounts at the southern end of the Kermadec volcanic arc, northeast New Zealand

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EXECUTIVE SUMMARY

Rowden, A.A.; Clark, M.R. (2010). Benthic biodiversity of seven seamounts on the southern end of the Kermadec volcanic arc, northeast New Zealand.
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1) This report documents the biodiversity of seven seamounts (Whakatane, Otara, Nukuhou, Tuatoru, Rungapapa, Mahina, Tumokemoke) that were surveyed as part of a broader NIWA project "Seamounts: their importance to fisheries and marine ecosystems". The seamounts were sampled using an epibenthic sled, grab, beam trawl, still-camera, and video. This report describes the benthic macro-invertebrate assemblages on these seamounts, and provides a preliminary assessment of biodiversity among the seamounts surveyed.

2) A total of 554 macro-invertebrate species was recorded from 110 samples (483 species from 69 epibenthic sled stations). At least 17% and 20% of bryozoan and sponge species, respectively, are undescribed for the New Zealand region. Species were distributed among 12 phyla, with 7 of the phyla containing over 99% of the taxa found. Taxonomic diversity varied within these major phyla.

3) Differences were evident in the estimated number of species recorded for each seamount: Mahina and Nukuhou had the highest estimated number of species, Tumokemoke the lowest, while the species number estimates for the other study seamounts were similar and midway between the two extreme estimates of diversity. There were no obvious reasons for this pattern of difference.

4) Analysis of photographic images confirmed the dominance of the same taxa revealed by direct sampling. It also indicated compositional differences in taxonomic diversity between the study seamounts.

5) Samples taken during the study will augment data already obtained from seamounts elsewhere on the Kermadec volcanic arc, and provide for an analysis of macro-invertebrate assemblage composition along the seamount chain.

1. INTRODUCTION

1.1 Overview

The term “seamount” as used in this report is synonymous with the term “underwater topographic feature” and refers to all underwater features with a vertical elevation greater than 100 m. See Rowden et al. (2005) for further discussion on what is considered a seamount in the New Zealand context.

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, Clark et al. 2010). Seamounts are not only widely recognised as areas of high productivity, but are also regarded as fragile habitat susceptible to disturbance from fishing (e.g., Clark & Koslow 2007) and mining (e.g., Grigg et al. 1987). In the New Zealand marine environment, seamounts are common and widely distributed (Rowden et al. 2005) and some are the focus of important deepwater fisheries (Clark 1999). Since the mid 1990s, NIWA scientists have studied a variety of seamount habitats, including some of those of the Kermadec volcanic arc. The southern portion of the Kermadec arc comprises a series of active, mostly submarine, volcanoes associated with the Pacific-Australian plate convergence north of New Zealand (Wright 1994). While aspects of their volcanism and hydrothermal venting are becoming better known (e.g., de Ronde et al. 2001, Wright et al. 2002), to date there have been few biological investigations.

Since 1999, NIWA has undertaken biodiversity surveys of 13 seamounts linearly arranged along the Kermadec volcanic arc from approximate latitudes 36° to 30° S (Rumble V to Giggenbach, Figure 1). Preliminary results from some of this sampling effort have indicated differences in the macro-invertebrate diversity between adjacent seamounts and the presence of hydrothermal vent faunas (Clark & O’Shea 2001, Rowden et al. 2003). Among vent assemblages sampled, a number of species new to science have been described (Buckeridge 2000, von Cosel & Marshall 2003, Glover et al. 2004, Smith et al. 2004, Webber 2004). Ultimately the biological data from these surveys will allow analysis to address a persistent question in seamount and vent ecology: by what means is the diversity of potentially isolated habitats in the marine environment maintained? In particular, there are issues of whether seamounts provide stepping-stones for dispersal of biota, to what degree has isolation on seamounts led to speciation (Hubbs 1959); and have deep-sea vent faunas evolved from shallow water faunas (Jacobs & Lindberg 1998)? Findings that provide partial answers to these particular questions are beginning to emerge from recent scientific research (Richer de Forges et al. 2000, Little & Vrijenhoeck 2003, Samadi et al. 2006, O’Hara 2007). The seamounts and vents of the Kermadec volcanic arc, owing to their linear arrangement (which encompasses a water depth gradient) and because their age/origin is known, offer an ideal study site for a more complete examination of questions pertaining to the maintenance of biodiversity on seamounts and vents.

To date there has been very little sampling of relatively shallow-water seamounts (and associated vents) of the southern end of the Kermadec volcanic arc (in the Bay of Plenty) that would complement the surveys of seamounts/vents undertaken further north in deeper water. There have been shallow-water samples taken around White Island (e.g., Kamenev et al. 1993) and some from Rungapapa Knoll (NIWA unpublished data), but this effort is very limited. A number of seamounts in the Bay of Plenty have been extensively fished since the 1990s for orange roughy and cardinal-fish, and the modification of the seabed and associated faunal assemblages that bottom trawling brings about (Clark & O’Driscoll 2003) could affect the pattern of biodiversity along the seamounts of the Kermadec volcanic arc. To evaluate the influence of such anthropogenic disturbance on benthic biodiversity in the area, it would therefore be useful to include localities that have been the subject of bottom trawling in any examination of seamounts of the volcanic arc.

In October 2004 NIWA was planning to undertake an extensive multibeam acoustic survey of the seabed in the Bay of Plenty, mapping bathymetry and substrate type for the purpose of understanding the geological processes of the area. It was thought likely that the swath mapping/interpretation exercise would reveal not only the more precise extent and form of known seamounts, but also the presence of additional seamounts and the location of possible vent sites. Thus, there existed an ideal opportunity to add biological value to physical data that would be obtained for seamounts in the Bay of Plenty area, and thereby significantly complement biodiversity research of seamounts in the New Zealand region.

To make the most of this opportunity, NIWA undertook a biodiversity research voyage as part of its FRST-funded programme "Seamounts: their importance to fisheries and marine ecosystems" (C01X0028) which would also build on results of past Ministry of Fisheries (MFish) projects, "Supplementary research on the biodiversity of seamounts" (ZBD2000/04) and "Additional research on the biodiversity of seamounts" (ZBD2001/10). The present project is part of MFish's programme on "Baseline information on the diversity and function of marine ecosystems" (Ministry of Fisheries 2004). This project complements NIWA's FRST-funded seamount programme and a NIWA non-specific outcome funded project (NRAM053). Resulting data will be analysed to provide a description of the biodiversity of, and between, the seamounts sampled. The results will ultimately contribute to planned analyses and reporting of all comparable data so far obtained from the seamounts of the New Zealand region. Such analyses will include a multivariate statistical examination of macro-invertebrate and environmental data from all seamount-specific sampling undertaken between 1999 and 2004. The preliminary results of the research are presented here in a similar manner to previous reports provided by NIWA to MFish on the benthic biodiversity of seamounts (i.e., Rowden et al. 2002, 2003, 2004).

1.2 Objectives

The overall objective of the project was to assess macrobenthic biodiversity on the seamounts of the southern Kermadec volcanic arc. There were two specific objectives:

1. To quantify, and compare, the macro-invertebrate assemblage composition of a number of seamounts at the southernmost end of the Kermadec volcanic arc.

2. To compare the macro-invertebrate diversity of the southernmost end of the Kermadec volcanic arc with that of seamounts already sampled and reported on.

2. METHODS

2.1. Study site and seamounts

The study site was located in the Bay of Plenty (off the North Island, New Zealand), in an area of the continental slope between about 250 m and 2000 m water depth. Seven seamounts at the southernmost end of the Kermadec volcanic arc were sampled (Figure 1). The seamounts sampled were (from south to north) Whakatane, Otara, Nukuhou, Tuatoru, Rungapapa, Mahina, and Tumokemoke, and represented a range of sizes and occupied a range of water depths (Table 1). All the seamounts are volcanic in origin, and Whakatane and Nukuhou are known to be hydrothermally active (NIWA SEAMOUNT v2 database, Rowden et al. 2008). Three of the seamounts, Whakatane, Nukuhou, and Tomokemoke, belong to the same group (Group 9) of the classification of New Zealand seamounts (Rowden et al 2005). Insufficient data were available for the other study seamounts to be included in the classification of Rowden et al. (2005), but it is likely that they are in the same group as the other seamounts on this part of the Bay of Plenty slope. Two of the seamounts, Whakatane and Nukuhou, have been the subject of commercial bottom trawling – with the latter seamount having received by far the most fishing effort (Table 1). Mahina and Tumokemoke have been subjected to about 20 research trawls in the past. The remaining seamounts are either relatively small (Rungapapa, Tuatoru) or too deep (Otara) to have been fished. None of the study seamounts are closed to bottom fishing.

2.2 Survey Design

2.2.1 Epibenthic sled sampling

To allow for statistically valid comparisons between the associated fauna, between four and six random replicate epibenthic sled samples were planned for each of the study seamounts. Sample stations were selected by a combination of random direction from the seamount peak and random depth down the slope.

2.2.2 Grab and beam trawl sampling

In order to extend the assessment of the types of fauna present, in addition to the standard use of the epibenthic sled, two other types of sampling gear were deployed: a grab that would improve sampling of the infauna of soft substrates, and a beam trawl to improve sampling of larger, more sparsely distributed epibenthic fauna. Grab stations were allocated at random, as per the epibenthic sled, while the beam trawl was used to target relatively smooth seafloor (as indicated by multibeam backscatter data, photographic images, or the contents of the grab/sled samples).

2.2.3 Photographic image sampling

The plan was to conduct at least four still-camera photographic transects arranged in a cross-shape centred on each seamount peak. Transects were to extend from the peak down the flanks of the seamounts. The still camera's operational limit of 1000 m water depth precluded the sampling of Otara and Whakatane seamounts. Photographic images were also to be taken using a video camera attached to the grab.

2.3 Field sampling

The survey took place between 8 and 16 November 2004 (see Clark 2004).

2.3.1 Epibenthic sled samples

An epibenthic sled (overall size 150 cm long, 50 cm high, and 130 cm wide), similar in design to a SEBS sled (Lewis 1999), was used for sampling seamount fauna. 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 to give both an accurate depth of the tow, and to help determine when the gear was on the bottom. Sleds were towed at each seamount station (Figure 2) up the slope at 1–1.5 knots for a target time of 10 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 Grab and beam trawl samples

A van Veen grab was mounted in a frame to which a video camera was attached. The video was oriented to take an oblique view of the surface of the seabed that would be sampled by the grab (surface area of 0.25 m^2). The 'grab-camera' was lowered to about 1–3 m above the seabed (determined by a Furuno CN22 acoustic transponder mounted on the side of the frame), video footage was taken for about 3 minutes, and then the gear was dropped to the bottom for the grab to take a sample. At times the order of operation was reversed with the grab-camera 'hovering' to take video after the grab had obtained a sample.

A beam trawl with a 4 m beam, a light chain and rubber disk ground rope, and a main net mesh of 25 mm with a cod-end liner of 10 mm was used. The beam trawl was towed in the same manner as the epibenthic sled. Samples retained by the grab and beam trawl were sorted by hand (after being sieved on a 1 mm mesh in the case of the grab samples) 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.

2.3.3 Photographic images

As well as the video images taken by the grab-camera a 'still camera' was mounted in a separate platform. The digital camera with a wide-angle lens and flash was fitted 25 cm from and perpendicular to the base of the frame. The camera platform was towed down-slope within 2–3 m of the seabed in order to achieve good-quality pictures. Camera platform height above bottom was monitored continuously using a Furuno CN-22 acoustic transponder, 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 pre-set to take shots at 1 minute intervals along the sample transects (Figure 2). The camera had limitations on numbers of images taken and stored, which necessitated its retrieval after 150 shots for the images to be downloaded from the camera's disk on to a computer. The imaging system had a maximum working depth of 1000 m water depth.

2.4 Laboratory analyses

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 exception of the Actinaria and Ascidiacea, which to date are undifferentiated to putative species), 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 into databases at NIWA.

2.4.2 Grab and beam trawl samples

Samples of macro-invertebrates recovered from the grab and beam trawl were treated as per the epibenthic sled samples.

2.4.3 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 camera platform at the time of each image capture and from the detailed bathymetric data collected along each transect. The location of grab-camera stations was allocated to the entire video record collected at these stations. For the video record, non-overlapping frame grabs were secured from the footage. Digital images from each still camera station and video frame grab were viewed and processed using the freeware *ImageJ*.

First an initial assessment was made of the images to determine whether they met the required standard for analysis based on the following criteria: both scaling lasers could be seen (or discerned after image modification), over 80% of the seabed was well lit, and resolution was such that organisms over 5cm could be reliably identified to the taxonomic level required. Only images meeting all criteria were processed and analysed further. The frame grab images were scaled (using the two laser marks 20 cm apart) and a 50 x 50 cm 'child' image was extracted for the analysis out of the original image, at the location on the image where the van Veen grab would sample the seabed. The images from the still camera were not scaled.

For all images, individual organisms were counted by eye and the percentage cover of colonial organisms was determined using tools within *ImageJ*. Visible macro-invertebrate fauna were assigned to the following taxonomic groupings: Porifera, Scleractinia, Gorgonacea, Antipatharia, Actiniaria, Anthothecata, Decapoda, Gastropoda, Ophiuroidea, Asteroidea, Crinoidea, Echinoidea, Holothuroidea, and Polychaeta. Still images were examined for evidence of the passage of trawl gear (pieces of wire/netting, gouges from trawl doors or bobbins). For the video images, any 'lebenspurren' or faunal traces were also enumerated using the following descriptive categories: craters (ragged edges), depressions (smooth edges), burrow holes, small mounds, small paired indentations. All data were transferred to computer spreadsheets for analyses. (Percent cover was also determined for the substrate types present, but these data are not reported upon here.)

2.5 Data analysis

2.5.1 Epibenthic sled samples

The assemblage compositional description here is for all seamounts sampled and is based on fauna identified to the taxonomic level of order. More detailed identification and assemblage compositional analysis (including between seamount comparisons) is beyond the scope of this project. A preliminary assessment of the differences in diversity (using preliminary putative species level identifications) between the seamounts sampled by the epibenthic sled was made using the species estimator of Ugland et al. (2003), the so-called "UGE" estimator (calculated using the analysis software PRIMER v6, Clarke & Gorley (2006). Presence-absence species estimators, such as UGE, which use aspects of the species accumulation curve to predict the number of taxa possessed by a sampled assemblage, are a useful means by which to compare the diversity of assemblages subject to different sampling effort and/or when an assemblage is expected to be undersampled (Magurran 2004).

2.5.2 Grab and beam trawl samples

For the overall assemblage compositional analysis, data from the grab samples were treated as per the epibenthic sled samples, as was the less extensive data from the beam trawl sampling. The limited data from the grab and beam trawl were deemed unsuitable for an examination of differences in diversity between the study seamounts using the species number estimator method.

2.5.3 Photographic images

Owing to the qualitative nature of the image record from the still camera transects (seabed area of images not currently calculated), an assessment of the taxonomic composition of the seamount assemblages was made by comparing the number of images in which the taxonomic groupings were present, and by noting differences in the representation of groupings between each seamount. Although data obtained from the video were quantitative, records from the video frame grab images were treated as per the still photographic images (quantitative video-derived data are to be reported elsewhere along with the fully processed still-camera data).

3. RESULTS

3.1 Sampling performance

3.1.1 Epibenthic sled samples

The epibenthic sled appeared to perform well for sampling seamount fauna, with 81 deployments to recover 69 satisfactory samples. The planned 4–6 sled samples per seamount was met or exceeded, with 6 samples being recovered from Whakatane, Otara, and Nukuhou, 8 from Tuatoru, 9 from Rungapapa, and 18 and 16 from Mahina and Tumokemoke, respectively. Samples were taken on the last two seamounts to provide data that could be used in an assessment of sampling efficiency (not reported here).

Attempts were made to standardise the time/speed for each epibenthic sled tow, but occasional deviations occurred. The influence this 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 3 shows that there is no significant relationship between number of species sampled and the sample area (mean sample area per tow for these samples = 425 m^2). Hence variability in area sampled per sled tow is deemed not to invalidate comparisons of diversity between the study seamounts.

3.1.2 Grab and beam trawl samples

The grab is designed to take samples of unconsolidated substrates, and where this sort of seabed was encountered on a seamount the grab performed as expected and the desired number of replicates were obtained without the need for additional deployments (4 samples from Tumokemoke, 5 samples from

Nukuhou, Mahina, and 6 from Rungapapa). Where hard substrates were encountered that sometimes prevented the successful operation of the grab, additional deployments were required (7 deployments for 4 satisfactory samples from Whakatane, 8 for 4 for Otara, and 8 for 5 from Tuatoru). Seafloor appropriate for the deployment of the beam trawl was not much in evidence on the study seamounts and only 11 deployments were made to obtain 8 satisfactory samples (1 satisfactory sample recovered from Otara and Rungapapa, 2 from Whakatane, Nukuhou, and Tuatoru, and none from Mahina or Tumokemoke).

3.1.3 Photographic images

A total of 2114 still images was taken of the seabed along a total of 35 transects on five of the study seamounts, from the peaks to 1000 m water depth down the flanks of the features (ranging from 0.5 to 2.2 nautical miles in length). Sampling effort was somewhat unequal between seamounts: Mahina was sampled by 562 images (8 transects), Nukuhou by 503 images (7 transects), Rungapapa by 443 images (8 transects), Tuatoro by 379 images (8 transects), and Tumokemoke by 227 images (4 transects). Generally, it was possible to maintain a steady flight of the camera frame at the desired height above the bottom. However, some photographs were taken too near, or far from the bottom to clearly image the seabed, and at other times the camera malfunctioned resulting in images from two transects being out of focus. Overall, 70% of images were suitable for analysis, with the quality of the photographic record varying between deployments on the different seamounts (52–81% of images categorised as being of sufficient quality).

The video attached to the grab recorded footage of the seabed from all study seamounts apart from Otara. Useable video record was recovered from the camera at 3 stations on Nukuhou, 4 on Whakatane, Mahina and Tumokemoke, 5 from Rungapapa and 7 stations from Tuatoru. The number of frame grabs from the video record at each station that were suitable for image analysis varied from 1 to 15, with an overall median of 6 frame grab images per station.

3.2 Biodiversity of seamount macro-invertebrate assemblages

3.2.1 Taxonomic diversity of assemblages

Overall there were 554 putative species in the 110 samples of macro-invertebrates from the seven study seamounts taken by the three direct sampling gears. Taxa were distributed among 12 phyla, with 7 of the phyla (Bryozoa, Crustacea, Echniodermata, Porifera, Cnidaria, Annelida, Mollusca) containing over 99% of the total number of taxa found. The number and distribution of classes, orders, and putative species within the phyla (i.e., taxonomic diversity), varied considerably within and between gear types (Table 2).

3.2.1.1 Epibenthic sled samples

There were 483 putative species in the 69 samples of macroinvertebrates from all seven of the study seamounts taken by the epibenthic sled (Table 2). Of the Bryozoa and Porifera species identified, 17% and 20% represent previously undescribed taxa, respectively. The most species-rich group, the Bryozoa (110 species), was represented by two classes, one of which contained 85% of the total number of species recorded for this phylum. This class, Gymnolaemata, contained only one order, as did the other bryozoan class Stenolaemata. In the next most speciose phylum, the Porifera (81 species), the distribution of species among taxonomic sub-groupings was somewhat different. While the Porifera were represented by two classes, and one of these classes (Demospongiae) contained the majority of the species for the phylum, this class comprised 7 orders and the other class (Hexactinellida) was represented by only 8 species distributed among 2 orders. There were 78 species of echinoderm sampled, which were distributed among 5 classes. Most echinoderm species sampled were either asteroids, ophiuroids, or echinoids (28, 21, and 16 species, respectively). The classes Echinoidea and Asteroidea and were particularly order-rich (8 and 7 orders, respectively), while the Ophiuroidea and the remaining classes, Holothuroidea (8 species) and Crinoidea (5 species), were represented by taxa distributed among relatively few orders (2, 3, and 1, respectively).

Seventy-three species of arthropod were sampled and the vast majority (93%) of these belonged to the order Decapoda. The malacostracan orders Amphipoda and Isopoda together were represented by only 4 species, while the arthropod class Maxillopoda was represented by one species in one order (Pedunculata). The Cnidaria possessed 70 species, 56% of which were distributed among 5 orders of the Anthozoa and the remainder among 2 orders of the class Hydrozoa. Of these orders, the Leptothecatae (Hydrozoa) and Gorgonacea (Anthozoa), contained a relatively large number of cnidarian species sampled (24 and 20 species, respectively).

The other two phyla relatively well represented (each 7% of the total number of taxa) by sampling the study seamounts, the Annelida and the Mollusca, showed quite different distribution of species among the taxonomic sub-groupings. The annelids were represented by one class, the Polychaeta, comprising representatives of 7 orders, with 2 orders (Eunicida and Phyllodocida) together containing 67% of the polychaete species sampled. The Mollusca comprised 5 classes, one of which (Bivalvia) was relatively order-rich, although the order Neogastropoda of the class Gastropoda contained the majority of the molluscan taxa sampled (17 species). All other molluscan orders sampled contained either only one or two species.

3.2.1.2 Grab and beam trawl samples

There were 57 putative species in the 33 samples of macro-invertebrates recovered by the grab on the seven study seamounts and 90 species sampled by eight beam trawl deployments on five of the study seamounts. The assemblage composition of the study seamounts sampled by the grab and beam trawl were both less taxonomically diverse than those taken by the epibenthic sled (Table 2). Some of this difference in taxonomic diversity most likely reflects the fact that a far greater number of sled samples were taken. However, some of the difference will relate to the component of the faunal assemblage that each type of gear most efficiently samples.

The most speciose phylum sampled by the grab, the Annelida (21 species, 37% of the total number of species sampled by this gear type) was represented by 5 polychaete orders, 4 of which contained a similar number of species (either 4 or 6). The next most speciose phylum was the Mollusca (12 species) represented by only 2 classes. Four orders in the class Bivalvia each possessed 1 species, while 4 orders of the Gastropoda were either represented by 1 or 3 species. There were 10 species belonging to 3 orders in the arthropod class Malacostracea, the majority (7 species) belonging to the order Amphipoda. Six species were sampled for each of the Cnidaria and Echinodermata; however, these species were distributed among 4 orders of the class Anthozoa and 1 order in class Hydrozoa for the former phylum, and among 1 order in each of 4 classes of the latter phylum. Only 2 species of Porifera, each belonging to a single order in different classes were sampled by the grab. No bryozoan fauna were sampled by the grab.

The 33 species of the most speciose phylum sampled by the beam trawl, the Echinodermata (37% of the total number of species sampled by this gear type), were distributed relatively evenly among 15 orders within 5 classes. The exception was the order Ophiurida (class Ophiuroidea) which alone contained 10 species. The Cnidaria and Arthropoda were represented by a similar number of taxa (20 and 17 species, respectively), but species were primarily (over 85%) contained within 6 orders and 3 orders in one class for the former and latter phylum, respectively. The order Decapoda dominated the records for the arthropods (15 species) and the Gorgonacea had the most species (6) within the Cnidaria. The 9 species of Porifera sampled by the beam trawl were distributed among two orders within two classes, with one order in each class having the majority of species (Lithistida in the Demospongiae, and Lyssacinosida in the Hexactinellida). Only individuals belonging to the class Gastropoda (two orders) represented the phylum Mollusca in samples taken from the study seamounts using the beam trawl. The other 'major' taxonomic groups were very poorly sampled by the beam trawl, with only 2 species of Annelida and 1 species of Bryozoa being recovered.

3.2.1.3 Photographic images

From the 1479 still 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 750 photographic records (Table 3). Individual colonies belonging to the phylum Cnidaria (Figure 4a) were the most frequently observed faunal organisms (occurring on 246 images, 16.6% of the total analysed images). Records of individual colonies of the cnidarian class Anthozoa belonged, in order of frequency, to the orders Alcyonacea (27.6% of Cnidaria), Antipatharia (20.3%), Pennatulacea (17.9%), Scleractinia (15.9%) and Actinaria (7.3%). Individual colonies of the orders Stylastridea and Anthothecata, belonging to the cnidarian class Hydrozoa, were seen on only 17 and 10 images, respectively. Individuals of the phylum Echinodermata (Figure 4b) were the next most frequently identifiable organisms, occurring on 186 images (12.6% of the total), with the class Echinoidea constituting by far the most numerous of all observations for this group (74.2% of Echinodermata or 9.3% of the total). The other four echinoderm classes were less well represented in the images (less than 10% of the Echinodermata or 1.2% or less of the total). Individual colonies of the phylum Porifera (Figure 5a) occurred in 180 images (12.2% of the total), while individuals of the Polychaeta (Figure 5b), Decapoda (Figure 6a) and Gastropoda (Figure 6b) were observed on 62, 39, and 35 images, respectively (4.2%, 2.6%, and 2.4% of the total analysed images, respectively). No trawl marks were observed in any of the images.

A total of 174 images of sufficient quality was analysed from the video footage recovered from six of the study seamounts (Table 4). Overall, Porifera were the most frequently observed live faunal group, although this taxon was viewed on only 7 images. Scleractinian corals were observed on 4 images, while the other 7 faunal groups noted were each only viewed on 1 or 2 images in total. The sparse distribution of each of the epifaunal groups observed is not surprising given the relatively small area encompassed by the image and that the video was deployed in conjunction with the grab, a gear designed to sample soft substrates (where relatively large epifauna are generally less common). The relative density of lebenspurren testifies to this bias, with burrows of undetermined infauna being observed on 57 or a third of all images. Other relative large and obvious traces, depressions, and craters, of presumably different infauna were also observed (8 and 7 images, respectively). Smaller features such as mounds and paired indentations were rarely viewed. Interestingly, accumulations of presumably dead and/or dying members of the Thaliacea (salps) were observed on the seabed surface on 13 images, most of these on one seamount (see below).

3.2.2 Comparison of biodiversity between seamounts

3.2.2.1 Epibenthic sled samples

The results of the analysis to determine the estimated number of macro-invertebrate species for each assemblage of the study seamounts are shown in Figure 7. None of the trajectories of the estimate curves reached an asymptote, meaning that it is not possible to estimate total species richness for the seamounts. However, using the species richness estimates for a standardised number of samples (n = 4) it is possible to make a comparison of relative species richness among the seamounts sampled. At this level of sampling effort, the seamount Tumokemoke has the lowest estimated number of species (30), a somewhat lower diversity than that similarly estimated for the seamounts Whakatane, Otara, Rungapapa, and Tuatoru (42, 45, 46, and 49, respectively). The macro-invertebrate assemblage of the seamounts Nukuhou and Mahina have the highest estimated number of species for a total of four samples (74 and 75, respectively).

3.2.2.2 Grab and beam trawl samples

As noted in the Methods, considering the limited distribution of sampling effort among the study seamounts by the other direct sampling gears, it was not deemed useful to estimate the number of species using data obtained by the grab and beam trawl.

3.2.2.3 Photographic images

The number of images in which macro-invertebrates could be identified differed between the five of the study seamounts sampled by the still camera (Table 4). That is, the sample size varied from being the lowest on Tumokemoke (n=147) to the highest on Nukuhou (n=379), with Rungapapa (n=358) receiving a similar degree of sampling effort to the latter seamount, and Tuatoru and Mahina having a similar number of images per seamount to one another (n=305 and 291, respectively). Thus even comparisons of the number of images on which the noted faunal groupings were observed have to be made with a deal of caution. Nonetheless, it is reasonable to note that the composition of the assemblages on seamounts from which about 300 images have been analysed appear to be somewhat different. Representatives of the Alyconacea, Echinoidea, and Porifera were relatively similarly imaged on Tuatoru (6.6%, 6.2%, and 7.2%, respectively), while other taxa were generally seen on less than 2% of the analysed images from this seamount. The Porifera and Echinoidea most frequently occurred on images from Rungapapa (the shallowest seamount) and Mahina (about 20% and 15% of images, respectively); however images from the latter seamount more frequently illustrated representatives of the Polychaeta (16.8% versus 0.3%), Antipatharia (11.3% versus 0.6%), Alyconacea (8.6% versus 1.7%) and Scleractinia (8.6% versus 0.3%). Images from the deepest study seamount, Nukuhou, were not particularly dominated by any one taxonomic group, although relatively more decapods and gastropods were seen in the images (5% and 4%, respectively, versus less than about 2.0%) than from the other seamounts on which a similar number of images had been taken. Analysis of the 147 images from Tumokemoke seamount suggests that the assemblage of this feature has a similar taxonomic composition to that of Mahina seamount (that occurs at a similar water depth range). That is, representatives of the Porifera, Echinoidea, Scleractinia, Alyconacea, and Polychaeta appear in a relatively high and similar number of the images. However, rather than antipatharians being imaged relatively frequently (as they are on Mahina), individuals of the Pennatulacea occur more often (9.5%) in the images taken on Tumokemoke.

The number of video-derived images in which macro-invertebrates could be identified differed between the six of the study seamounts sampled by the grab-camera. That is the sample size varied from 11 to 42 images per seamount, although over 20 images were recovered from all but one of the seamounts (Table 5). Thus even comparisons of the number of images on which the recorded faunal groupings were observed should be made with caution. Nonetheless, it is reasonable to note that the composition of the assemblages on seamounts from which a similar number of images have been analysed appear to be somewhat different. No live epifauna was observed on images from Tumokemoke (only lebenspurren), while on the similarly sampled Whakatane (22 versus 24 images in total) live Gorgonian corals and decapods were observed (as well as salps and craters on the seabed surface). Tuatoru, Rungapapa, and Mahina (38, 42, and 37 images respectively) also appear, as evidenced by the video record, to have quite different assemblages. Representatives of the Porifera, Crustacea, Gastropoda, Echinoidea, and Holothuroidea were each observed on 1 or 2 images taken of seabed on Tuatoru. These groups were not as frequently observed as infaunal burrow holes (15 images). Burrow holes were also seen on images (8) taken from Rungapapa, where other infaunal traces were observed (including craters on 4 images) along with sponges and Scleractian corals (4 images each). Images from Mahina frequently presented evidence of burrowing fauna (70% of images for this seamount), and depressions (6 images) possibly made by large macrofauna that once resided on the part of the seabed imaged (or inhabited the substrate beneath?). Live anemones (Actinaria) were noted on 1 image, and 10 images (27% of images for this seamount) recorded the presence of dead and/or dying salps that appeared to have accumulated on the seabed (curious because salps are pelagic).

4. DISCUSSION

Five hundred and fifty-four putative species of macro-invertebrates were recorded from the seven seamounts in this study. Many of the species recovered by the survey are considered to be undescribed for the New Zealand region. For the Bryozoa and Porifera, 17% and 20% of the species identified, respectively, are considered to be new to science. However, because over half of all the taxa recorded have so far been identified to putative species only, the total proportion of undescribed species is currently unknown. Species were distributed among 12 phyla, with 7 of the phyla containing over 99% of the taxa found. Taxonomic diversity varied within these major phyla. Differences between the assemblages of some of the seamounts were evident in the number of species estimated for each feature, and the taxonomic composition revealed by analysis of the images from the still camera survey and grab-camera deployments.

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. The review also noted that there had been relatively little sampling effort on seamounts and that seamount-targeted studies were very few. In recent years sampling levels on seamounts have increased, and a public database Seamounts Online (http://seamounts.sdsc.edu) in 2007 contained records of over 3000 taxa (both invertebrate and vertebrate) from 250 seamounts (Clark 2009).

A study in the southwest Pacific Ocean was broadly 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, 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 seamounts on the Norfolk Ridge recorded 516 macrofaunal species, 4 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 these 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 seven seamounts on the southernmost end of the Kermadec arc appears to be broadly comparable with the study of Richer de Forges et al. (2000). However, the meaningfulness of making any direct comparisons is questionable, for diversity estimates for the Tasman/Coral Sea area were for two macrofaunal components (both invertebrates and fish) and these surveys used different sampling gears and strategies (and sampling effort) from the present study.

Three surveys of the macro-invertebrate biodiversity of seamounts in New Zealand waters (Rowden et al. 2002, 2003, 2004), however, enable a useful preliminary comparison of variation in seamount biodiversity. 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 8 seamounts on the Chatham Rise (Rowden et al. 2002); a total of 308 species (10 phyla, 5 phyla containing over 90% of the total number of taxa) were recorded from 52 samples on 3 seamounts on a more northerly portion of the Kermadec arc (Rowden et al. 2003), while 396 species (13 phyla, 6 phyla containing over 90% of the total number of taxa) were recorded from 25 samples on 2 seamounts on the Northland Plateau (Rowden et al. 2004). In the present study, 483 macro-invertebrate species were identified from 69 epibenthic sled samples taken on 7 seamounts. Thus, the macro-invertebrate assemblage (in total) of the study seamounts on the southern end of the Kermadec volcanic arc is similarly speciose and as taxonomically diverse as the assemblage of the seamounts of the Chatham Rise. The overall assemblage of seamounts from both these areas appear more diverse than the assemblages of the seamounts further north on the Kermadec volcanic arc and the Northland Plateau. However, it should be noted that, because of the greater sampling effort/extent of the present and Chatham Rise surveys, the diversity of seamounts elsewhere on the Kermadec volcanic arc could be similar, while the diversity on the Northland Plateau seamounts appears to be relatively high.

The proportion of undescribed species sampled by the epibenthic sled, and therefore an estimate of the species possibly endemic to study seamounts, was at least 5%, 15%, and 17% for the seamounts of the previously sampled portion of the Kermadec volcanic arc, the Chatham Rise, and Northland Plateau respectively. Estimates of seamount faunal endemism for the present study (17% for Bryozoa and 20% for Porifera) are thus similar to those made from the Chatham Rise and Northland Plateau surveys and to 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 on the southern end of the Kermadec volcanic arc requires a study that compares species composition of seamounts and similar substrata of low-relief slope throughout the New Zealand region (O'Hara 2007).

There was an observable difference in the estimated number of species between for Mahina and Nukuhou (highest) and for Tumokemoke (lowest). The four other study seamounts had similar estimates of species richness, all between the highest and lowest estimates for the aforementioned seamounts. There was no obviously discernible reason for this pattern of difference, for Mahina and Tumokemoke occur at the same water depths, while Mahina and Nukuhou occur at quite different depths (and the latter seamount is fished). The seamounts with similar mid-range estimates of macrobenthic species richness occur over a relatively wide range of water depths, encompass a range of areas (see Table 1), and include seamounts nearest and furthest from the continental shelf edge. No significant difference in diversity (defined as mean number of species per sample) was detectable between seamounts on the Northland Plateau (Rowden et al. 2004), nor between the eight study seamounts of the Chatham Rise survey (Rowden et al. 2002). The three seamounts previously sampled further north on the Kermadec volcanic arc were different from each other in terms of number of species (one seamount had a much higher species number than the other two) (Rowden et al. 2003), which in part supports the findings of the present study that there are at least some differences in the diversity of macro-invertebrate assemblages on the seamounts of the southern portion of the Kermadec volcanic arc.

In addition to diversity being evaluated by direct sampling, still and video images of the seabed were also used to assess diversity of taxonomic groupings observable on recovered images. Analysis of still 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 diversity of relatively large-bodied or colonial forms, such as members of the orders in the phyla Cnidaria and Echinodermata, compared reasonably well with that assessed by epibenthic sled samples. The proportion of the Porifera in direct samples was also apparent in the recovered images. Mobile and smaller-bodied organisms are not so readily observable on photographs of the seafloor, and indeed the apparently diverse (as revealed by the sled samples) mollusc taxa and decapod crustaceans were poorly sampled by the camera. The most striking limitation of the camera to assess the biodiversity of the study seamounts was its inability to effectively quantify the dominance and diversity of the Bryozoa, partly because of their smaller size, and partly because of a preference for living on the underside of rocks. Another notable difference was in the ability of the images to possibly better reflect the occurrence of echinoids, a group of relatively fragile organisms that can be damaged by the epibenthic sled past a point were they can be identified (and thus recorded). However, analysis of the still camera images did prove useful for revealing compositional differences in the macro-invertebrate assemblages on each of the seamounts. Of particular note were differences in the occurrence frequency of the coral orders Scleractinia, Gorgonacea, and Antipatharia on Mahina seamount (overall, higher than other seamounts). Images of this seamount also revealed the abundance of polychaetes residing on the surface of soft substrate (primarily the ‘quill worm’ *Hyalionoecia* sp.). Overall, the taxonomic diversity of macro-invertebrate assemblage of Mahina seamount was notable, as was that of Nukuhou. In this regard the analysis of the still images supports the result of the species estimation analysis.

5. CONCLUSIONS AND RECOMMENDATIONS

In summary, the present study of the seamounts on the southern end of the Kermadec volcanic arc has revealed a diverse assemblage of macro-invertebrates, composed of a number of relatively taxonomically diverse phyla. Samples taken during the study will augment data already obtained from seamounts elsewhere on the Kermadec volcanic arc, and provide for an analysis of macro-invertebrate assemblage composition along a seamount chain. The extent of *apparent* endemism for the seamount assemblage studied (after identifications are complete) could be higher than already indicated 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 on the seamounts and similar-substrate/low-relief habitats in the region, further sampling would be required to substantiate indications of high diversity and endemism for these and other seamounts in the New Zealand region (see conclusions of Samadi et al. 2006 and O’Hara 2007). We recommend that, whenever possible, future seamount-related research voyages include sampling of similar non-seamount habitat on a nearby slope.

Despite concerns about the destructive nature of sampling using an epibenthic sled (particularly on protected seamounts), and the related (and time-saving) attractiveness of using only camera/video-derived samples to study the biodiversity of seamounts, the footprint of the direct sampling device used is relatively small. In addition, it is often not possible to identify the major numerical components of a macro-invertebrate assemblage from a photograph (in this instance, the small and cryptic Bryozoa). 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), and we recommend the approach continue to be applied to studies of New Zealand's benthos.

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6. REFERENCES

Buckeridge, J.S. (2000). *Neolepas osheai* sp. nov., a new deep-sea vent barnacle (Cirripedia: Pedunculata) from the Brothers Caldera, south-west Pacific Ocean. *New Zealand Journal of Marine and Freshwater Research 34:* 409-418.

Clark, M. (2004). Voyage report of a survey of seamounts in the Bay of Plenty and on the Hikurangi Plateau (TAN0413). 27 p. (Unpublished report available from NIWA, Private Bag 14901, Wellington)

Clark, M.R. (1999). Fisheries for orange roughy (*Hoplostethus atlanticus*) on seamounts in New Zealand. *Oceanologica Acta 22*: 593–602.

Clark, M.R. (2009). Seamounts: Biology. Pp. 818–821 *In*: Gillespie, R.G.; Clague, D.A. (eds). Encyclopaedia of Islands. University of California Press. 1074 p.

Clark, M.R.; Koslow, J.A. (2007). Impacts of fisheries on seamounts. Chapter 19. pp. 413–441 *In*: Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. (eds). Seamounts: ecology, fisheries, and conservation. Blackwell Fisheries and Aquatic Resources Series 12. Blackwell Publishing, Oxford.

Clark, M.R.; O'Driscoll, R.L. (2003). Deepwater fisheries and their impacts on seamount habitat in New Zealand. *Journal of Northwest Atlantic Fishery Science 31*:441–458.

Clark, M.R.; O'Shea, S. (2001). Hydrothermal vent and seamount fauna from the southern Kermadec Ridge, New Zealand. *Interidge News 10*: 14–17.

Clark, M.R.; Rowden, A.A.; Schlacher, T.; Williams, A.; Consalvey, M.; Stocks, K.I.; Rogers, A.D.; O'Hara, T.D.; White, M.; Shank, T.M.; Hall-Spencer, J. (2010). The ecology of seamounts: structure, function, and human impacts. *Annual Review of Marine Science 2*: 253–278.

Clarke, K.W.; Gorley, R.N. (2006). *PRIMER v6*: User Manual/Tutorial. PRIMER-E: Plymouth.

von Cosul, R.; Marshall, B.A. (2003). Two new species of large mussels (Bivalvia: Mytilidae) from active submarine volcanoes and a cold seep off the eastern North Island of New Zealand, with description of a new genus. *The Nautilus 117*: 31–46.

Glover, E.A.; Taylor, J.D.; Rowden, A.A. (2004). *Bathyaustriella thionipta*, a new lucinid bivalve from a hydrothermal vent on the Kermadec Ridge, New Zealand and its relationship to shallow-water taxa (Bivalvia: Lucinidae). *Journal of Molluscan Studies 70*: 283–294.

Grigg, R.W.; Malahoff, A.; Chave, E.H.; Landahl, J. (1987). Seamount benthic ecology and potential environmental impact from manganese crust mining in Hawaii. *In*: Keating, B.H.; Fryer, P.; Batiza, R.; Boehlert, G.W. (eds). Seamounts, Islands, and Atolls. *Geophysical Monograph 43:* 379–390.

Hubbs, C.L. (1959). Initial discoveries of fish faunas on seamounts and offshore banks in the mid-Pacific. *Pacific Science 13*: 311–316.

Jacobs, D.K.; Lindberg, D.R. (1998). Oxygen and evolutionary patterns in the sea: Onshore/offshore trends and recent recruitment of deep-sea faunas. *Proceedings of the National Academy of Sciences 95:* 9396–9401.

Kamenev, G.M.; Fadev, V.I.; Selin, N.I.; Tarasov, V.G.; Malakhov, V.V. (1993). Composition and distribution of macro- and meiobenthos around sublittoral hydrothermal vents in the Bay of Plenty, New Zealand. *New Zealand Journal of Marine and Freshwater Research 27*: 407–418.

Kaufmann, R.S.; Wakefield, W.W.; Genin, A. (1989). Distribution of epibenthic megafauna and lebensspuren on two central north Pacific seamounts. *Deep-Sea Research 36*: 1863–1896.

Lewis, M. (1999). CSIRO-SEBS (Seamount, Epibenthic Sampler), a new epibenthic sled for sampling seamounts and other rough terrain. *Deep-Sea Research I 46*: 1101–1107.

Little, C.T.S.; Vrijenhoek, R.C. (2003). Are hydrothermal vent animals living fossils? *Trends in Ecology and Evolution 18*: 582–588.

O'Driscoll, R.L.; Clark, M.R. (2005). Quantifying the relative intensity of fishing on New Zealand seamounts. *New Zealand Journal of Marine and Freshwater Research 39*: 839–850.

O'Hara, T.D. (2007) Seamounts: centres of endemism or species richness for ophiuroids. *Global Ecology and Biogeography 16*: 720–732.

Magurran, A.E. (2004). Measuring biological diversity. Blackwell Science Ltd.

Ministry of Fisheries (2004). Baseline Information on the diversity and function of marine ecosystems [BioInfo], Medium-term Research Plan 2004/05 to 2007/08, Draft May 2004. Ministry of Fisheries, Wellington, 21 p.

Probert, P.K. (1999). Seamounts, sanctuaries and sustainability: moving towards deep-sea conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems 9*: 601–605.

Raymore, P.A. (1982). Photographic investigations on three seamounts in the Gulf of Alaska. *Pacific Science 36*: 15–34.

Rogers, A.D. (1994). The biology of seamounts. *Advances in Marine Biology 30*: 305–350.

de Ronde, C.E.J.; Baker, E.T.; Massoth, G.J.; Lupton, J.E.; Wright, I.C.; Feely, R.A.; Greene, R.R. 2001. Intra-oceanic subduction-related hydrothermal venting, Kermadec volcanic arc, New Zealand. *Earth and Planetary Science Letters 193*: 359–369.

Richer de Forges, B.; Koslow, J.A.; Poore, G.C.B. (2000). Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature 405*: 944–947.

Rowden, A.A.; Clark, M.R.; O'Shea (2004) Benthic biodiversity of seamounts on the Northland Plateau. *Marine Biodiversity Biosecurity Report No. 5.* 21 p.

Rowden, A.A.; Clark, M.R.; O'Shea, S., McKnight, D.G. (2003) Benthic biodiversity of seamounts on the southern Kermadec volcanic arc. *Marine Biodiversity Biosecurity Report No. 3.* 23 p.

Rowden, A.A., Clark, M.R., Wright, I.C (2005) Physical characterisation and a biologically focused classification of 'seamounts' in the New Zealand region. *New Zealand Journal of Marine and Freshwater Research 39*: 1039–1059.

Rowden, A.A.; Oliver, M.; Clark, M.R.; MacKay, K. (2008). New Zealand's "SEAMOUNT" database: recent updates and its potential use for ecological risk assessment. *New Zealand Aquatic Environment and Biodiversity Report No. 27.* 49 p.

Rowden, A.A.; O'Shea, S.; Clark, M.R. (2002). Benthic biodiversity of seamounts on the northwest Chatham Rise. *Marine Biodiversity Biosecurity Report No. 2.* 21 p.

Samadi, S; Bottan, L.M; MacPherson, E.; Richer de Forges, B; Boisselier, M-C. (2006). Seamount endemism questioned by the geographic distribution and population genetic structure of marine invertebrates. *Marine Biolog, 149*: 1463–1475.

Smith, P.J.; McVeagh, S.M.; Won, Y.; Vrijenhoek, R.C. (2004). Genetic heterogeneity among New Zealand species of hydrothermal vent mussels (Mytildae: *Bathymodiolus*). *Marine Biology 144*: 537–545.

Webber, W.R. (2004). A new species of Alvinocaris (Crustacea: Decapoda: Alvinocarididae) and new records of alvinocaridids from hydrothermal vents north of New Zealand. *Zootaxa 444*: 1–26.

Wright, I.C. (1994). Nature and tectonic setting of the southern Kermadec submarine arc volcanoes: an overview. *Marine Geology 118*: 217–236.

Wright, I.C.; Stoffers, P.; Hannington, M.; Ronde, C.E.J. de; Herzig, P; Smith, I.E.,M.; Browne, P.R.L. (2002). Towed-camera investigations of shallow-intermediate water-depth submarine stratovolcanoes of the southern Kermadec arc, New Zealand. *Marine Geology 185*: 207–218

Table 1: Morphological and fishing information for the study seamounts on the southern end of the Kermadec volcanic arc. Source: NIWA SEAMOUNT v2 (4/7/06) database. See Clark & O'Driscoll (2003) and O'Driscoll & Clark (2005) for explanation of Fishing Importance Index (FII) and Fishing Effects Index (FEI).

Seamount	Area (km^2)	Water depth (m)	No. of tows (reported since 1989)	Years fished (since 1989)	FII	FEI
Whakatane	88.0	880–2196	37	2	96.77	0.36
Otara	22.6	1060–1900	0	0	0	0
Nukuhou	31.5	690–1000	488	5	135 033.86	31.39
Tuatoru	3.8	175–350	0	0	0	0
Rungapapa	7.6	134–166	0	0	0	0
Mahina	35.3	256–650	23	0?	0	0.34
Tumokemoke	12.2	213–600	20	0?	0	0.67

Table 2: Count of stations by gear type completed during TAN0413. The number of valid deployments are given, followed in parentheses by additional deployments where performance was regarded as unsatisfactory.

Seamount	Epibenthic sled	Grab	Beam trawl	Tow-camera
Whakatane	6 (1)	4 (3)	2 (2)	0 (2)
Otara	6 (4)	4 (4)	1 (1)	
Nukuhou	6 (0)	5 (0)	2 (0)	7 (0)
Tuatoru	8 (2)	5 (3)	2 (0)	8 (0)
Rungapapa	9 (1)	6 (0)	1 (0)	8 (0)
Mahina	18 (0)	5 (0)		6 (2)
Tumokemoke	16 (4)	4 (0)		4 (0)

Table 3: Taxonomic composition of the macro-invertebrate assemblage sampled by different gear types from the study seamounts on the southern end of the Kermadec volcanic arc. (Note the beam trawl sampled only five of the seven study seamounts).

Taxonomic level			Number of species			
Phylum	Class	Order	All gears (n=110)	Epibenthic sled (n=69)	Grab (n=33)	Beam trawl (n=8)
Porifera	Demospongiae	Astrophorida	24	24	0	0
		Dictyoceratida	9	9	0	0
		Hadromerida	2	2	0	0
		Halichondrida	8	8	0	0
		Haplosclerida	13	12	1	0
		Lithistida	7	7	0	3
		Poecilosclerida	12	11	1	1
	Hexactinellida	Hyalonematidae	1	0	0	1
		Hexactinosida	3	3	0	0
		Lyssacinosida	6	5	0	4
Cnidaria	Hydrozoa	Anthoathecata	6	6	1	0
		Leptothecatae	26	24	0	3
	Anthozoa	Alcyonacea	2	1	0	2
		Antipatharia	1	0	0	1
		Gorgonacea	24	20	1	6
		Pennatulacea	5	4	1	3
		Scleractinia	16	14	2	4
		Actinaria	>1	>1	>1	>1
Annelida	Polychaeta	Amphinomida	2	1	1	1
		Eunicida	16	14	6	1
		Phyllodocida	13	8	6	0
		Sabellida	6	6	0	0
		Scolecida	6	4	4	0
		Spionida	4	1	4	0
		Terebellida	1	1	0	0
Priapulida	-	-	1	1	0	0
Nermertea	-	-	1	1	0	0
Sipuncula	-	-	1	1	0	0
Arthropoda	Malacostraca	Amphipoda	7	1	7	1
		Isopoda	4	3	1	1
		Decapoda	77	68	2	15
	Maxillopoda	Pedunculata	1	1	0	1
Mollusca	Polyplacophora	Ischnochitonida	1	1	0	0
	Scaphopoda	Dentaliida	2	2	0	0
	Gastropoda	Heterostropha	1	0	1	0
		Neogastropoda	23	17	3	4
		Neotaenioglossa	3	1	1	1
		Vetigastropoda	5	2	3	0

	Bivalvia	Arcoida	2	1	1	0
		Myoida	2	1	1	0
		Nuculoidea	1	0	1	0
		Ostreoida	1	1	0	0
		Pholadomyoida	1	1	0	0
		Pterioida	2	2	0	0
		Veneroida	2	1	1	0
	Cephalopoda	Octopoda	1	1	0	0
		Teuthida	1	1	0	0
Echinodermata	Ophiuroidea	Ophiurida	24	20	3	10
		Euryalinida	1	1	0	1
	Echinoidea	Cidaroida	4	4	0	1
		Clypeasteroida	1	1	1	0
		Diadematoida	1	1	0	1
		Echinoida	1	1	0	1
		Echinothurioida	5	5	0	4
		Pedinoida	2	2	0	0
		Spatangoida	1	1	0	0
		unknown	1	1	0	0
	Asteroidea	Paxillosida	6	5	0	2
		Notomyotida	3	3	0	2
		Valvatida	9	7	0	3
		Velatida	2	1	0	1
		Spinulosida	3	2	1	1
		Forcepulatida	6	6	0	1
		Brisingida	4	4	0	0
	Crinoidea	Comatulida	5	5	1	1
	Holothuroidea	Aspidochirotida	4	4	0	1
		Elasipodida	4	3	0	3
		Molpadida	1	1	0	0
Bryozoa	Gymnolaemata	Cheilostomata	93	93	0	1
	Stenolaemata	Cyclostomata	17	17	0	0
Brachiopoda	-	-	1	0	0	1
Chordata	Ascidiacea	-	>1	>1	0	>1

Table 4: Allocation of taxonomic groupings for the still-camera images recovered from five of the study seamounts on the southern end of the Kermadec volcanic arc.

Taxonomic level			Number of images					
Phylum	Class	Order	All seamounts (n=1479)	Nukuhou (n=379)	Tuatoru (n=305)	Rungapapa (n=358)	Mahina (n=291)	Tumokemoke (n=147)
Porifera	-	-	180	9	19	72	62	18
Cnidaria	Anthozoa	Scleractinia	39	1	4	1	25	8
		Gorgonacea	68	9	20	6	25	8
		Actinaria	18	6	3	2	4	3
		Pennatulacea	44	13	8	4	5	14
		Antipatharia	50	1	7	2	33	7
	Hydrozoa	Stylastrida	17	5	2	6	3	1
		Anthothecata	10	0	1	3	5	1
Annelida	Polychaeta	-	62	1	4	1	49	7
Arthropoda	Malacostraca	Decapoda	39	19	6	3	6	5
	Maxillopoda	Pedunculata	2	2	0	0	0	0
Mollusca	Gastropoda	-	35	17	1	9	3	5
Echinodermata	Echinoidea	-	138	6	22	51	45	14
	Holothuroidea	-	18	3	7	1	7	0
	Asteroidea	-	13	4	1	0	8	0
	Ophiuroidea	-	10	7	0	0	3	0
	Crinoidea	-	7	2	0	1	4	0

Table 5: Allocation of taxonomic groupings for the video-grab images recovered from six of the study seamounts on the southern end of the Kermadec volcanic arc.

Taxonomic level			Number of images						
Phylum	Class	Order	All seamounts (n=174)	Mahina (n= 37)	Nukuhou (n=11)	Rungapapa (n=42)	Tuatoru (n=38)	Tumok (n=22)	Whakatane (n=24)
Porifera	-	-	7	0	1	4	2	0	0
Cnidaria	Anthozoa	Scleractinia	4	0	0	4	0	0	0
		Gorgonacea	1	0	0	0	0	0	1
		Actinaria	1	1	0	0	0	0	0
Arthropoda	Malacostraca	Decapoda	1	0	0	0	0	0	1
	Indet. crustacean	-	2	0	1	0	1	0	0
Mollusca	Gastropoda	-	2	0	0	0	2	0	0
Echinodermata	Echinoidea	-	2	0	0	0	2	0	0
	Holothuroidea	-	2	0	0	0	2	0	0
Chordata	Thaliacea	-	13	10	2	0	0	0	1
Lebenspurren	Craters (ragged edges)		7	0	0	4	1	1	1
	Depressions (smooth edges)		8	6	0	0	0	2	0
	Burrows		57	26	1	8	15	7	0
	Small mounds		1	0	0	1	0	0	0
	Small paired indentations		3	0	0	0	3	0	0

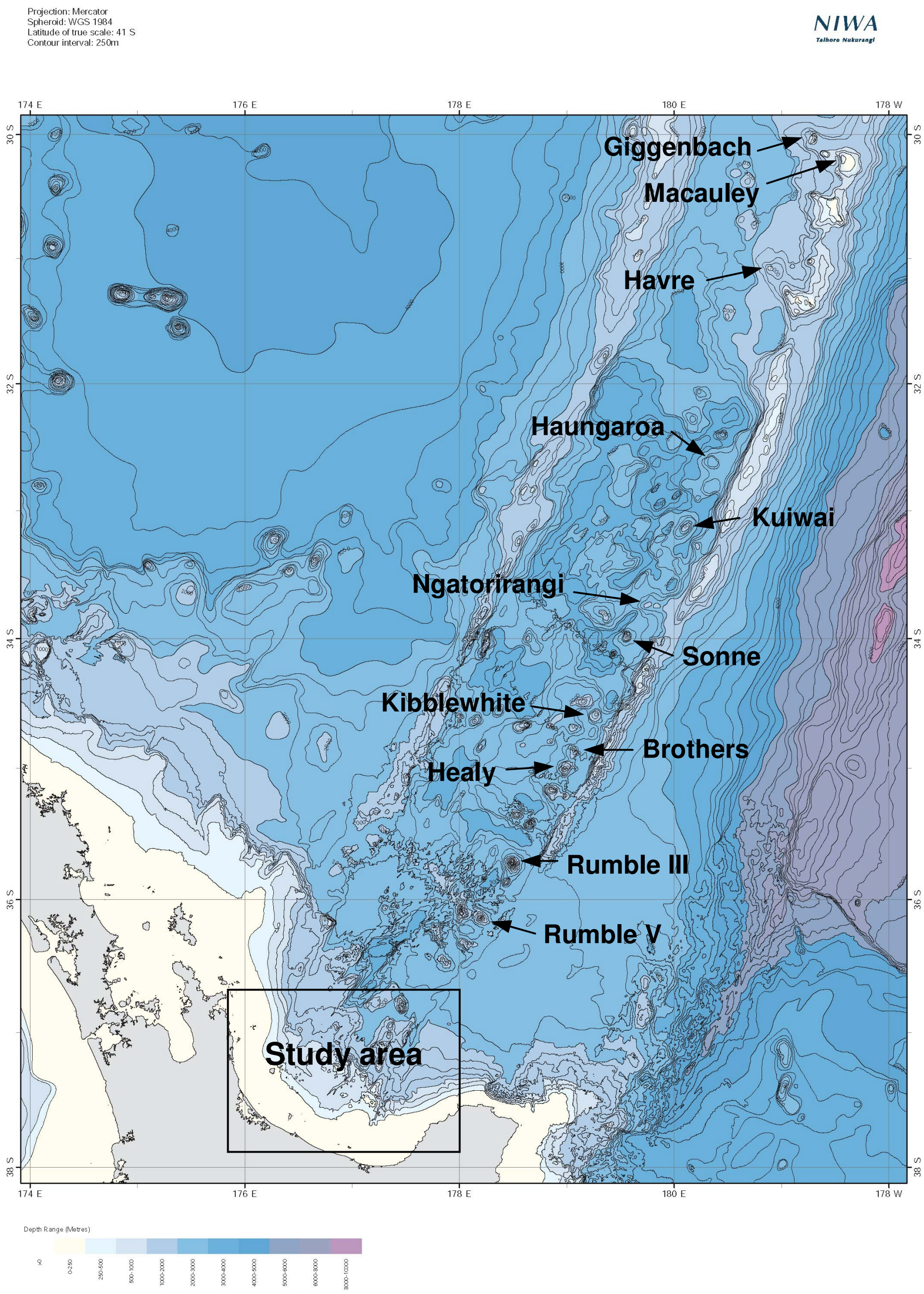


Figure 1: Map showing the study area in the Bay of Plenty at the southern end of the Kermadec volcanic arc, and those seamounts to the north that have already been sampled by NIWA.

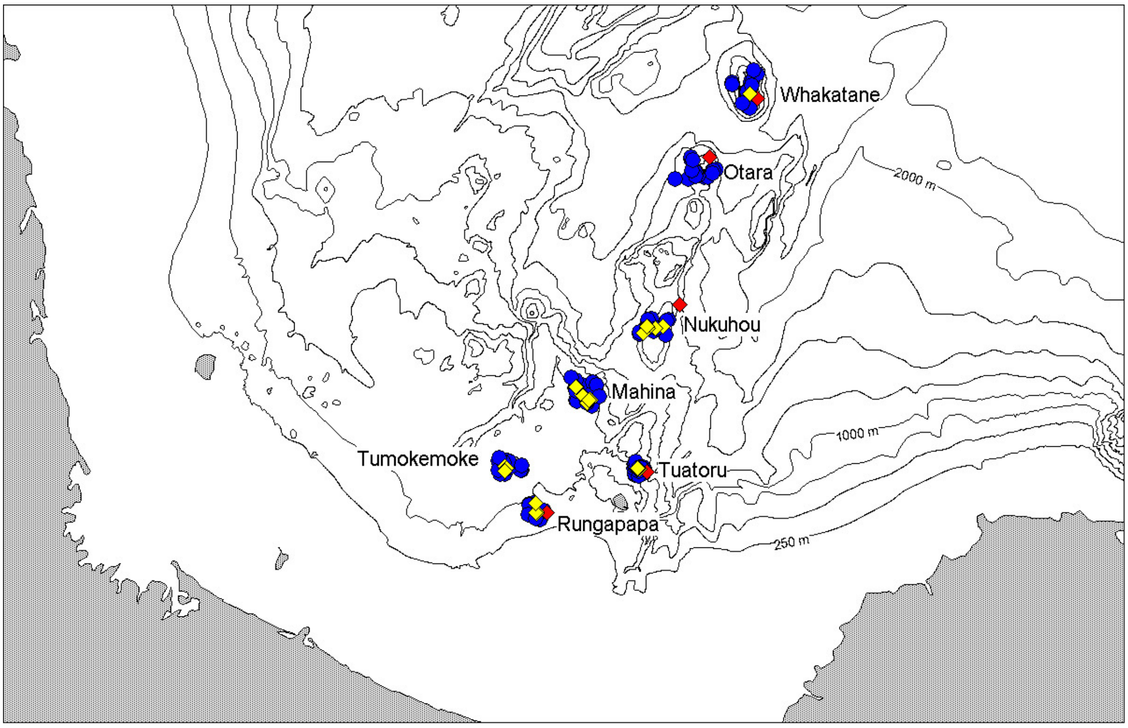


Figure 2: Location of stations sampled on the study seamounts. CTD, red diamond; Camera, yellow diamond; Grab, sled, beam (biological sample), blue circle.

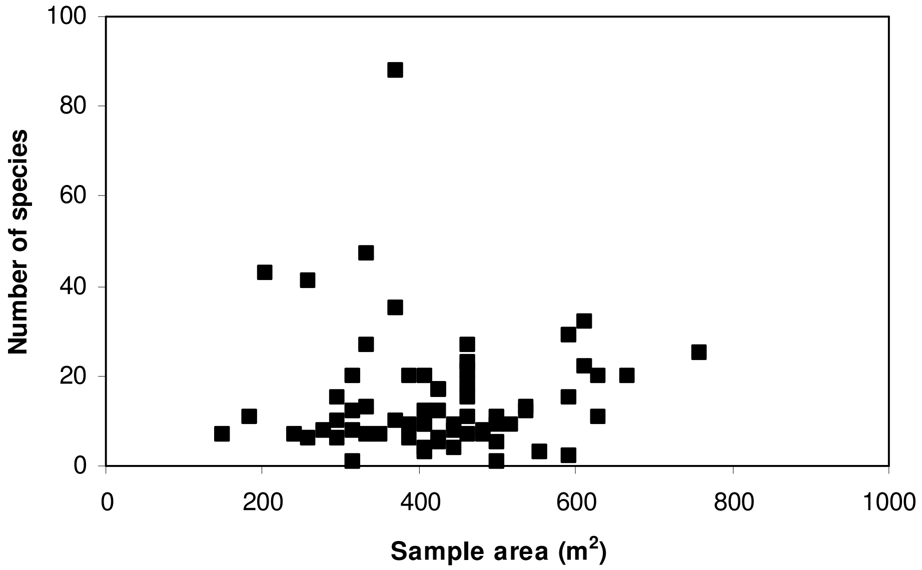


Figure 3: The relationship between the number of macro-invertebrate seamount species and the sample area of the epibenthic sled stations from the study seamounts.

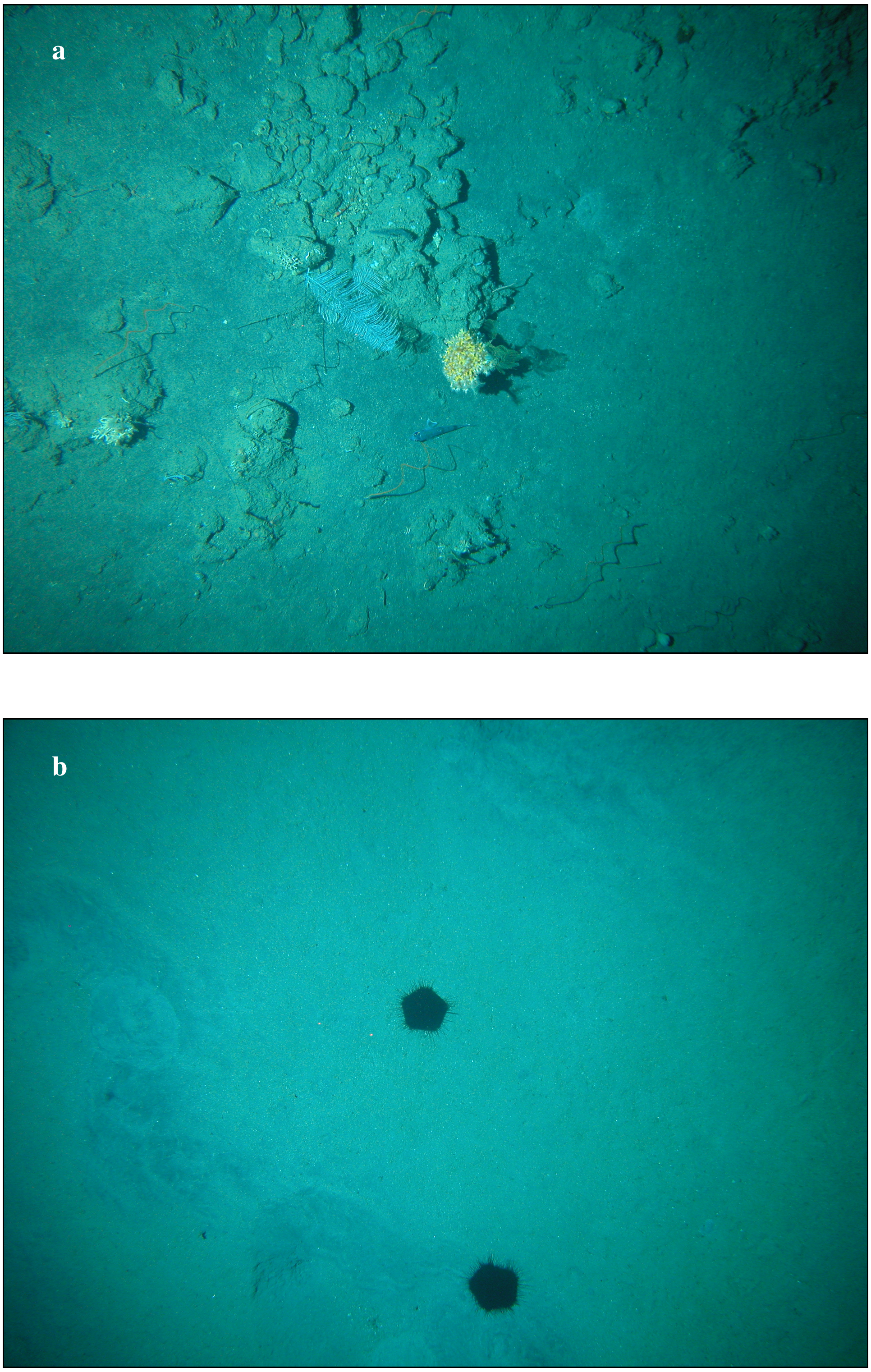
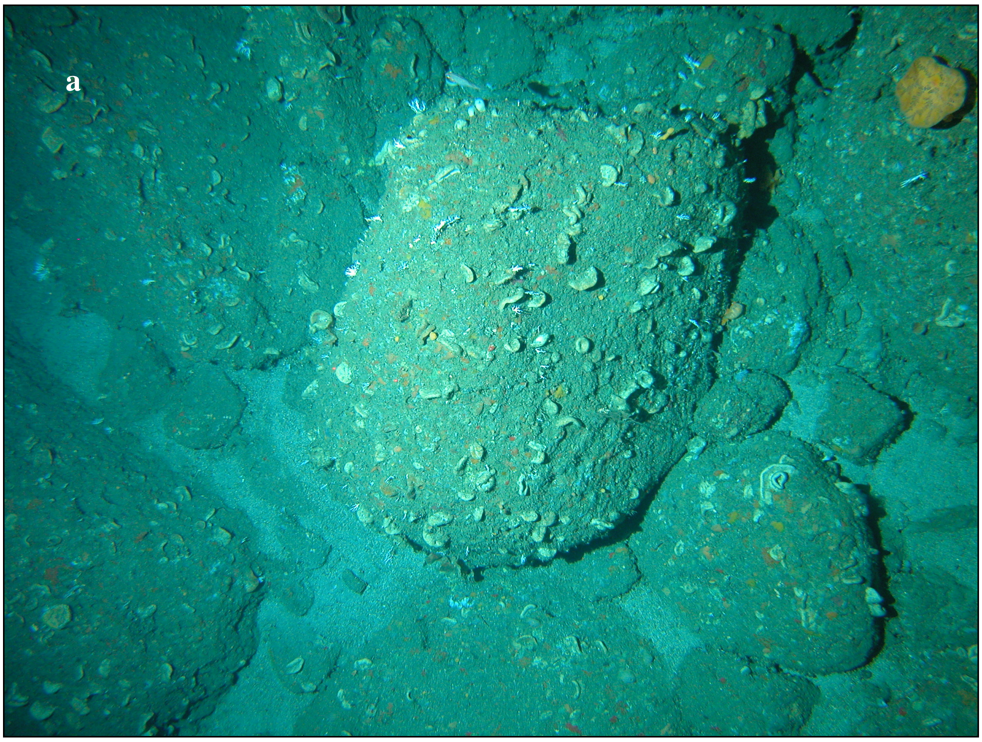


Figure 4: Photographs of the seabed showing representatives of (a) Phylum Cnidaria (Tuatoru, station 87) and (b) Phylum Echinodermata (Tumokemoke, station 158).



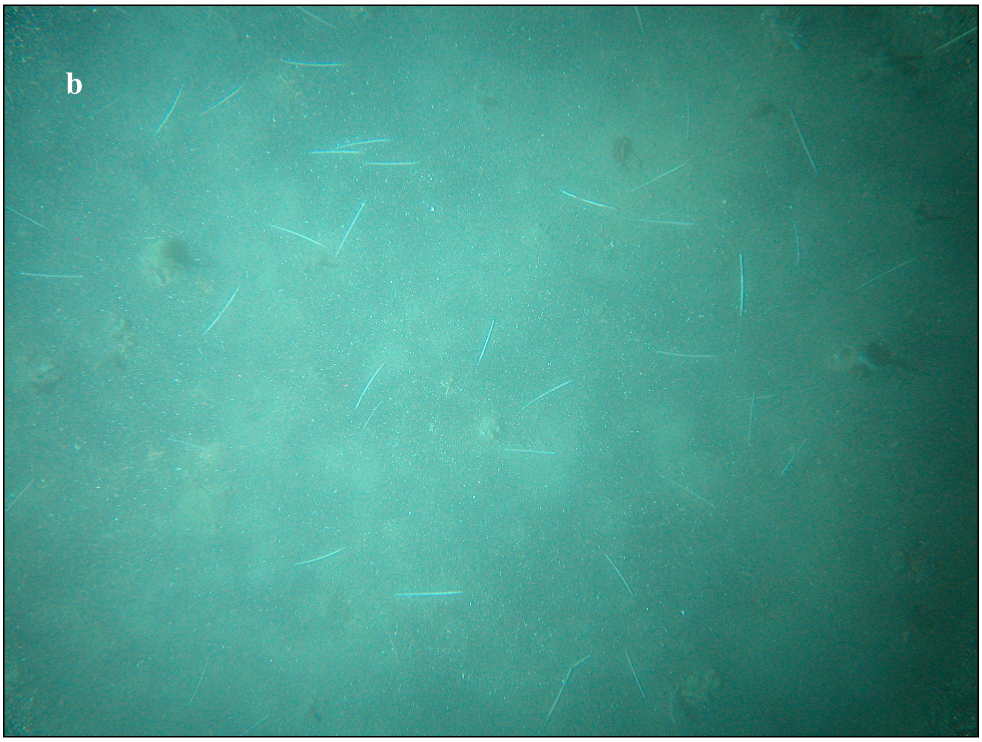


Figure 5: Photographs of the seabed showing representatives of (a) the phylum Porifera (Rungapapa, station 115) and (b) the class Polychaeta (Mahina, station 142).

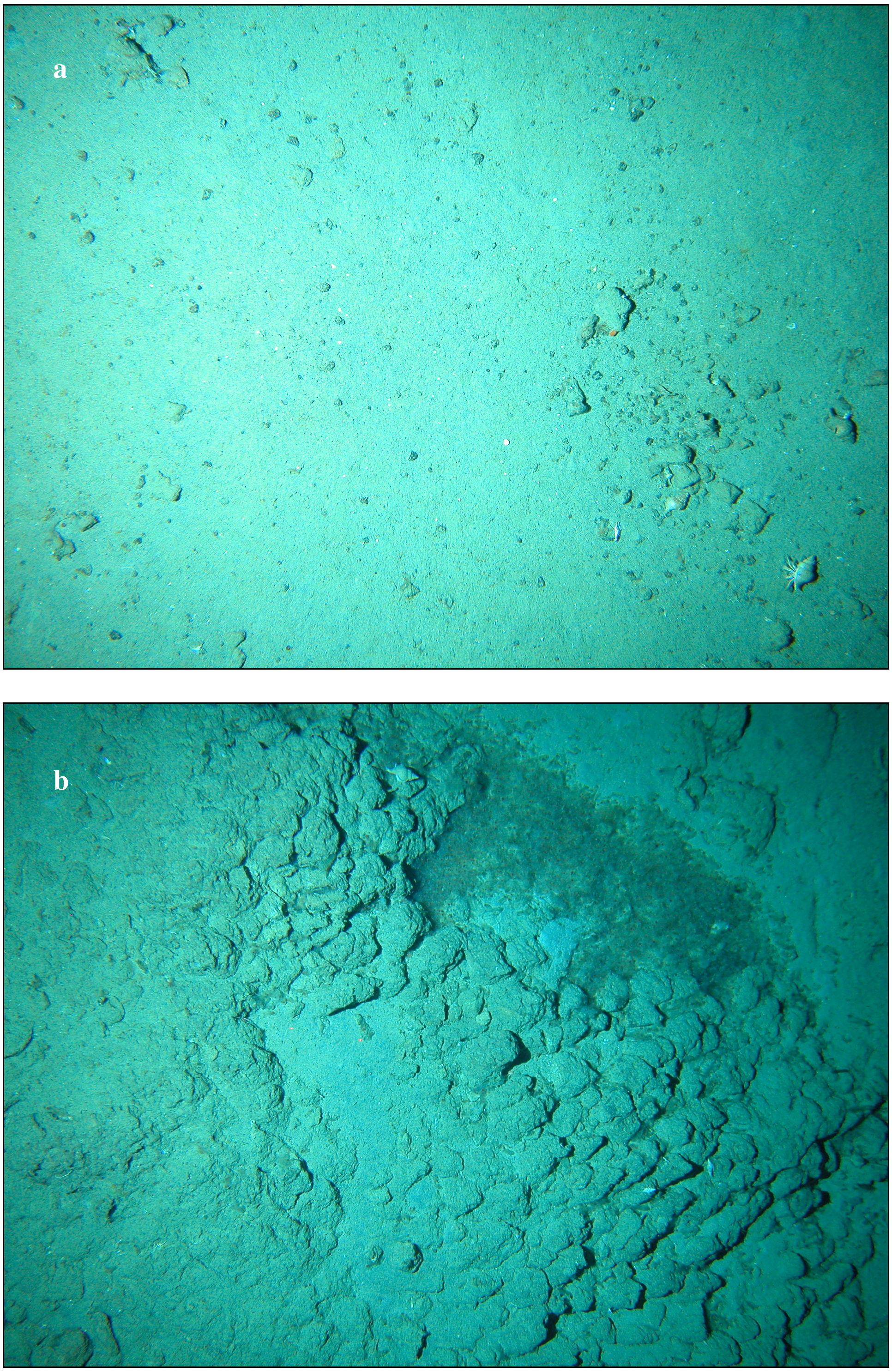


Figure 6: Photographs of the seabed showing representatives of (a) the order Decapoda (Nukuhou, station 61) and (b) the class Gastropoda (Nukuhou, station 51).

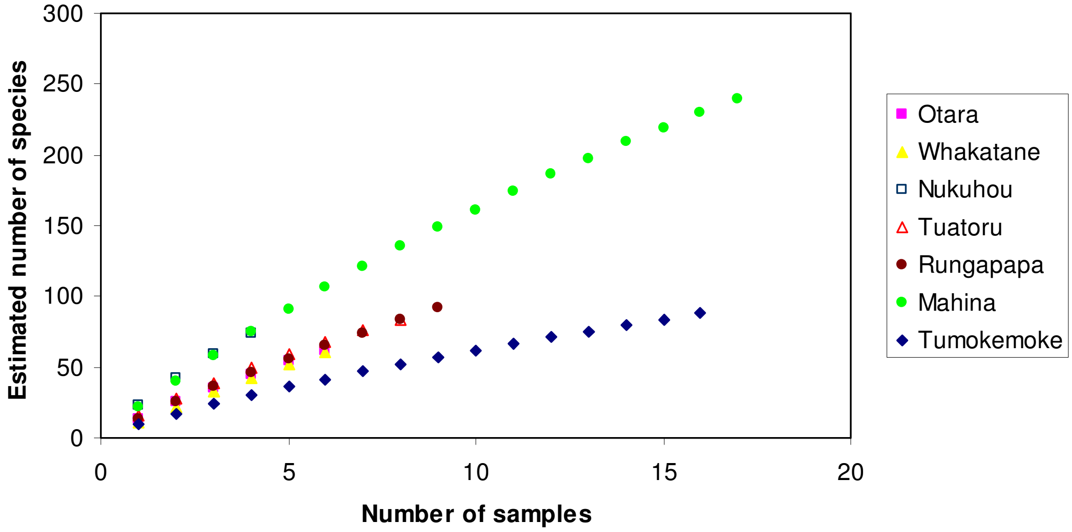


Figure 7: Estimates of species richness (estimator of Ugland et al. 2003) for epibenthic sled data from the study seamounts.