Benthic biodiversity of seamounts on the northwest Chatham Rise

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EXECUTIVE SUMMARY

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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 New Zealand Foundation for Research, Science and Technology (FRST). Additional funding from MFish enabled a survey of seamounts of the northwest Chatham Rise to be extended, and further research on biodiversity to be undertaken.

2) The study site encompassed a group of seamounts known as the Graveyard complex within an area of 140 km^2 of seabed. The biodiversity of eight seamounts (Graveyard, Morgue, Pyre, Gothic, Zombie, Scroll, Ghoul, and Diabolical) with different physical characteristics were sampled using an 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 414 macro-invertebrate species were recorded from 42 epibenthic sled stations. At least 15% of the species are considered to be undescribed for the New Zealand region. Species were distributed among 14 phyla, with 6 of the phyla containing over 90% of the total number of taxa found. Taxonomic diversity varied considerably 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) There were no evident differences between seamounts in the mean number of species recorded for each feature.

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.

7) Results indicate high faunal diversity and endemism for these seamounts. However, further sampling of other seamounts and adjacent areas of hard substrate is required to substantiate this. Such studies should be conducted using a combination of sampling methods, including photographic techniques and direct sampling using epibenthic sleds.

1. INTRODUCTION

1.1 Overview

Seamounts are prominent and widely distributed features of the New Zealand marine environment (Wright 1999), and also the focus of important commercial fisheries (Clark 1999). However, very little is known about seamount ecology (Clark et al. 1999a) or the effects that human activities have on their physical and biological integrity (Probert et al. 1997). They are of considerable scientific interest, hosting unusual or unique fauna, and their importance for biodiversity is often disproportionate to their size or area (Probert 1999). Seamounts are widely recognised as areas of high productivity, but are also regarded as fragile habitat (Rogers 1994, Koslow et al. 2001). A research programme entitled "Seamounts: their importance to fisheries and marine ecosystems", currently being carried out by NIWA with funding from the New Zealand Foundation for Research, Science and Technology (FRST), aims to describe and build an understanding of the role and dynamics of seamounts (Clark et al. 1999b). As part of this research several seamounts on the northwest Chatham Rise were surveyed to investigate the effects of bottom trawling.

The Graveyard complex on the northwest Chatham Rise has been heavily trawled for orange roughy since the early 1990s. However, the effort has concentrated on three or four main commercial features. Work by NIWA and The Orange Roughy Management Company in a fisheries survey in 1999 revealed a number of seamounts nearby that had not been trawled. Two of these (Pyre, Gothic), and one fished seamount (Morgue), have since received protection by the closure to bottom trawling announced by the Minister of Fisheries in 2001 (Anon. 2001). The area therefore presented a number of seamount features close to one another, with various levels of trawling intensity, which could provide data on the natural variation and "patchiness" of fauna on the seamount, and also enable quantification of any differences between fished and unfished areas.

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 general results from this additional work describing the benthic macro-invertebrate assemblage on these seamounts, and quantify and compare biodiversity between the seamounts surveyed.

1.2 Objectives

There were four objectives in the MFish contract (project code ZBD2000/04):

- undertake more extensive sampling of the fauna on seamounts, and sample additional seamounts in the study area
- identify a complete range of benthic invertebrates in taxonomic detail
- quantify and analyse biodiversity of the seamounts, and compare between them
- quantify and compare biodiversity of seamounts and low-relief slope in vicinity of seamounts.

The results of the survey that relate to the first three objectives are the subject of this report. The fourth objective was unable to be addressed owing to the lack of suitable rocky seabed on the slope adjacent to the Graveyard seamounts.

2. METHODS

2.1 Study site

The study site, an area that encompasses a group of seamounts known as the ‘Graveyard complex’, was located on the northern flank of the Chatham Rise. The Chatham Rise is the ridge-like eastern part of the New Zealand Plateau that extends 100 km from Banks Peninsula eastwards for 1400 km. West of the Chatham Islands, the Rise is generally flat topped at 200–400 m, whilst east, north, and south of the feature the water depths increase to over 2000 m (Figure 1). The seamounts studied are known as Graveyard, Morgue, Pyre, Gothic, Zombie, Scroll, Ghoul, and Diabolical. These seamounts (over 100 m vertical elevation) were distributed over 140 km^2 of seafloor between water depths (at feature base) of 1050–1200 m (Figure 2), and had 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 four random replicate epibenthic sled samples was desired for each of the eight seamounts studied. Sample stations were selected at random by a combination of random direction from the seamount peak and random depth down the slope.

2.2.2 Photographic images

All the study seamounts could not be surveyed using images captured by a digital camera in the time available, so certain seamounts received priority treatment. For any sampled seamount, eight photographic transects were arranged in a starburst pattern centred on the seamount peak. Transects were aligned N–S, E–W, NE–SW, NW–SE, and extended 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 at the study site between 15^{th} and 21^{st} April 2001. Macrofauna 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, which 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 3) up the slope at 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 further analysis in the laboratory.

2.3.2 Photographic image sampling

A still camera was mounted on the sled frame of the CREST acoustic system. The digital camera, a Minolta Dimage with wide-angle lens and zenon flash, was fitted 25 cm from and perpendicular to the base of the frame. Such a camera frame had not previously been used for image sampling of New Zealand seamounts and therefore several trial tows were made to find the optimal deployment conditions. Towing up the slope of the seamount proved unsatisfactory, with the frame often hitting the seabed. Conversely, towing down slope appeared to work well. In order to achieve good quality pictures the camera frame had to be towed within 3–4 m of the seabed. Camera frame height above bottom could be monitored continuously using the CREST acoustic system, and supplied the information required to make the necessary adjustments to tow-wire length. Effective forward tow speed was about 1 knot. The camera was activated remotely at stations at approximately 1 minute intervals along the sample transects (Figure 3). The geographical location of the camera frame (and thereby the position of stills camera stations) was recorded by the attached CREST acoustic system. The camera had a limited number of shots, which necessitated retrieval of the camera frame after four transects for the images to be downloaded from the camera's disc on to a computer.

A low-light video camera was also mounted in the sled frame, and recorded continuously along each transect. This tape 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 with the aid of microscopy and taxonomic keys, and, when appropriate, species were also enumerated. After identification, samples were preserved in ethanol 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. Each 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', 'dim', 'blank', or 'cloud of mud'. Individual organisms or colonies visible in the images were enumerated (count or estimate of percentage cover) and assigned to one of the following taxonomic grouping: Porifera, Alcyonacea, Actinaria, *Madrepora oculata* (dead or alive), *Solenosmilia variabilis* (dead or alive), Decapoda, Gastropoda, Ophiuroidea, Asteroidea, Crinoidea, Echinoidea, 'other macro-invertebrates'. All data were transferred to computer spreadsheets for analysis.

2.5 Data analysis

2.5.1 Epibenthic sled samples

To test for statistically significant differences in the diversity of macro-invertebrate fauna between the seamounts sampled, an analysis of variance (ANOVA) test was performed using the number of species sampled as the response variable, and 'seamount' as the random factor (significance level was set at $\alpha = 0.05$). Data were tested for departures from homogeneous variance before ANOVA, in order to check that test assumptions were met. All analyses used the statistics software package NCSS.

2.5.2 Photographic images

Owing to the qualitative nature of the images, comparisons of taxonomic groupings between seamounts was simply made by examining differences in the number of groupings recorded, and by noting those groupings unrepresented on each seamount.

3. RESULTS

3.1 Sampling performance

3.1.1 Epibenthic sled samples

The epibenthic sled appeared to perform reasonably well for sampling the fauna of seamounts. The net sustained damage during the first seven deployments, because it was longer than the sled frame. Subsequently, the net was shortened to receive better protection. In order to effectively sample each of the eight seamounts at least four times, 47 epibenthic sled deployments were made: Graveyard (10), Morgue (6), Pyre (6), Gothic (6), Zombie (4), Scroll (5), Ghoul (5), and Diabolical (5). The plot of the species-accumulation curve for the 32 effective samples (Figure 4) reveals that the sampling effort was not sufficient to sample the whole of the macro-invertebrate assemblage of the seamounts. Thus, descriptions of the seamount assemblage of the northwestern Chatham Rise are incomplete. Whilst attempts were made to standardise the time and speed for each tow, occasional deviations 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 tow. Figure 5 shows the lack of relationship between the number of species sampled and the sample area (mean sample area per tow = 417 m^2 ± 24 1SE), hence comparisons of diversity between seamounts are valid.

3.1.2 Photographic images

In the time available, it was possible to sample 284 camera stations along 35 transects, distributed on four seamounts from close to the feature peaks to a maximum of 1106 m water depth. Sampling effort was unequal between seamounts: Graveyard was sampled with 94 stations on 13 transects (742–1009 m); Gothic 73 stations, 7 transects (984–1106 m); Diabolical 63 stations, 7 transects (888–1022 m) and Morgue 54 stations on 8 transects (903–1010 m). The quality of the photographic record varied. At times it proved difficult to maintain a steady flight of the camera frame at the desired height above the bottom. However, the quality of the still camera images was generally good, with data recovered from over 90% of the images. The remote firing proved a major advance over previously used bottom-contact triggers.

3.2 Biodiversity of seamount macro-invertebrate assemblage

3.2.1 Taxonomic diversity of assemblage

3.2.1.1 Epibenthic sled samples

There were 414 species in the 42 samples of macro-invertebrates from the study seamounts. Of the total number of species recorded, 286 are now identified to putative level only, of which 64 species (15% of total species sampled) probably represent previously undescribed taxa (including 14 probable undescribed genera). Species were distributed among 14 phyla, with 6 of the phyla containing over 90% of the total number of taxa found. Species were distributed fairly equally among these major phyla – the Porifera, Echinodermata, Crustacea, Cnidaria, Bryozoa, and Mollusca. The number and distribution of classes, orders, and species within the phyla, that is the taxonomic diversity, varied considerably (Table 2). The most species-rich group, the Porifera (70 species), was represented by 3 classes, one of which contained 70% of the total number of species recorded for this phyla. This class, Demospongiae, was taxonomically diverse containing 8 orders, of which 3 orders (Poecilosclerida, Hadromerida, Astrophorida) contained over half (39 species; 55%) of the Porifera recorded. The remaining dominant order in this group, the Hexactinosida, contained 13 species (class Hexactinellida). In the phylum Echinodermata (67 species), the distribution of species among taxonomic sub-groupings was somewhat different. Of the four classes that represented this phylum, two contained an almost equal proportion of the 80% of the species sampled for the group. The Asteroidea contained 7 orders, 3 of which contained fairly equal proportions of the 21 of the 26 species recorded for this class. The other dominant class, the Ophiuroidea, contained only two orders. One of these orders, the Ophiurida was relatively speciose with 25 species, that is nearly 90% of the taxa for this dominant echinoderm class. The Crustacea (65 species) were represented by 2 classes, one of which (Cirripedia) contained only 6 species. The other class, the Malacostraca, was by far the most dominant group within the phylum (90% of species) and was represented by four orders. Of these groups, the Decapoda was the second most speciose order (39 species) recorded for the sampled seamounts. Other dominant orders, Isopoda and Amphipoda, were represented by 10 and 9 species respectively. The Cnidaria (64 species) sampled were contained in the classes Hydrozoa and Anthozoa. The Hydrozoa was represented by three orders that made up just over a third of the species recorded for this class. The Leptothecata and Anthoathecata with 13 and 9 species respectively, were the most dominant orders of the class. The Anthozoa was more diverse in terms of number of orders (five), two of which contained more than 70% of the species. The Alcyonacea was represented by 20 species and the Scleractinia 11. Bryozoa (60 species) also comprised two classes, each represented by species within a single order. The order Cyclostomata (class Stenolaemata) contained 12 species, whilst the Cheilostomata (class Gymnolaemata) with 48 species was the most diverse order for the seamounts sampled. The Mollusca (46 species) sampled were represented by four classes, the equal maximum class-level taxonomic diversity (with Echinodermata) observed for the seamounts studied. Diversity of orders was high with species distributed among at least 12 orders (some undescribed taxa result in lack of certainty). The Neogastropoda (class Gastropoda) was the dominant order, containing over a third of the species (17) in this phylum. Figure 6 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 264 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 218 photographic records (Table 3). Members of the Echinodermata were the most frequently observed fauna (occurring on 144 images), with the class Crinoidea constituting the most numerous of all observations (80% of Echinodermata or 35% of total) (Figure 7). The Cnidaria were the next most frequently identifiable fauna, occurring in 97 images, of which the scleractinian corals *Madrepora oculata* and *Solenosmilia variabilis* constituted 14 and 35% (respectively) of the observations for this phylum (Figures 8 and 9). The phylum Porifera was not subdivided into any taxonomic sub-groupings and individual sponge colonies were seen in 59 of the image samples (Figure 10). For the phylum Mollusca and class Crustacea, records for only one subgrouping were noted. For the former, class Gastropoda occurred in 24% of the images (Figure 11), whilst for the latter, individuals of the order Decapoda were apparent in only 9% of the images (Figure 12).

3.2.2 Comparison of diversity between seamounts

3.2.2.1 Epibenthic sled samples

The mean diversity (expressed as number of species) for all seamounts sampled on the northwest Chatham Rise was 47.06 (± 3.32 1SE). Mean diversity per seamount was lowest on Diabolical (37.75 ± 11.6 1SE) and highest on Zombie (61.25 ± 9.61 1SE). Despite this range, however, mean diversity appears to be fairly uniform between seamounts (Figure 7). Indeed, a one-way analysis of variance (ANOVA) test revealed that there was no significant difference in the number of species sampled between the seamounts studied (Mean square = 233.20, F-Ratio = 0.60, P = 0.75).

3.2.2.2 Photographic images

The number of images in which macro-invertebrates could be identified differed between the four seamounts sampled by the camera: sample size was 63, 47, 49, and 59 for Graveyard, Morgue, Diabolical, and Gothic, respectively. Despite this, the number of taxa groupings observable in images was fairly consistent. Of the 12 faunal classifications used for the analysis, 10 were noted for Graveyard, 9 for Morgue, 11 for Diabolical, and all 12 for Gothic. No alcyonacean or *Madrepora oculata* coral colonies were observed on Graveyard. Sampling of Morgue, in addition to failing to recover image records for the Alcyonacea and the scleractinian *Solenosmilia variabilis*, resulted in no observations for the Ophiuroidea. Individuals of the latter faunal class were also not recorded on Diabolical. Observable images from transects sampled on Gothic revealed all of the taxonomic groupings into which identifiable fauna were classified were represented. The category ‘other macro-invertebrates’ was recorded for all seamounts sampled using the camera.

4. DISCUSSION

On the eight seamounts of the northwest Chatham Rise, sampled by 42 epibenthic sleds stations, 414 species of macro-invertebrate were recorded. At least 15% of the species recovered by the survey are considered to be undescribed for the New Zealand region. This estimate includes 14 genera new to science. However, because over half the taxa recorded have so far been identified to putative species only, the proportion of undescribed species/genera is probably much greater than this. Species were distributed among 14 phyla, with 6 of the phyla containing over 90% of the total number of taxa found. Taxonomic diversity varied considerably within these major phyla. Differences between seamounts were not 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.

A review of seamount studies by Rogers (1994) indicated that 597 invertebrate species had been recorded globally since directed sampling began at the end of the nineteenth century. However, the review also noted the relative lack of sampling effort for seamount environments. Indeed, few studies of seamounts are of a comparable nature to that reported here, but one study serves as a very useful comparison. The study by Richer de Forges et al. (2000) of seamounts in the Tasman Sea and southeast Coral Sea sampled more than 850 macrofauna species (*both* invertebrates and fish), of which 16–36% were deemed both new to science and potentially endemic to seamounts. The study involved sampling of a number of different groupings of seamounts. Sampling of 6 seamounts on the Norfolk Ridge recorded 516 species of macrofauna, 4 seamounts on Lord Howe Rise produced 108 species records, and 297 species were found on 14 seamounts southeast of Tasmania. Richer de Forges et al. (2000) also noted unequal sampling effort was probably, in part, responsible for differences in species number between seamount groupings, and that the number of species present on these seamounts is far greater than the number recorded.

The present evaluation of macro-invertebrate biodiversity for eight seamounts on the northwest Chatham Rise is broadly comparable with a similar study in a relatively nearby geographic location. However, although more species were recorded for seamounts of the Graveyard complex than those of the Lord Howe Rise and Tasmania, sampling effort was also marginally greater (42, 35, and 34 samples respectively). Seamounts of the Norfolk Ridge, which were found to have just over 100 more species recorded than seamounts in the present study, received over six times as much sampling effort. Estimates of seamount faunal endemism between the present study and that of Richer de Forges et al. (2000) appear to be similarly comparable. However, caution should be attached to any such comparison; any interpretation of the uniqueness of the seamount assemblages of the northwest Chatham Rise requires a study that compares species composition of seamounts and similar substrata of low-relief slope throughout the New Zealand region.

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 samples confirmed the dominance of certain taxa as revealed by direct sampling, but also indicated some additional useful methodological and biodiversity information. Notably, the high diversity of the Porifera cannot be effectively sampled by camera image, whilst members of the Crinoidea are a dominant component of the seamount assemblage that appears to be proportionally under-sampled by epibenthic sleds. In addition, comparison of results obtained by the epibenthic sled (large-integrated area sample) and the photographic images (small-point area sample) can reveal characteristics of faunal distribution. For example, on the Graveyard seamount, *Madrepora oculata* was sampled by the epibenthic sled (one sample out of four) but not by any of the camera images. Thus in all likelihood this coral species is sparsely and patchily distributed on this seamount. Digital images were also useful in illustrating the structure and arrangement of the scleractinian corals *Madrepora oculata* and *Solenosmilia variabilis*. Both these species, because they provide structural habitat for other organisms, are likely to influence the diversity of a seamount assemblage as a whole (Probert et al. 1997, Probert 1999). Clearly, the combination of sampling methods proved an advantage over the use of a single method. 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. Despite concerns about the destructive nature of sampling using an epibenthic sled, 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 sampling device used is relatively small. In addition, it is currently not possible to identify all components of a macro-invertebrate assemblage from a photographic image. When an assemblage is largely or partly undescribed, as for New Zealand seamounts, recovery of specimens by direct sampling is imperative for an assessment of biodiversity.

In summary, the present study of the Graveyard complex of seamounts on the northwest Chatham Rise revealed a diverse assemblage of macro-invertebrates, which is mainly composed of relatively few, taxonomically diverse, phyla. The extent of endemism within the seamount assemblage studied appears to be relatively high and, like the high diversity, 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 is 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 in press), 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 methodologies, including photographic techniques as well as direct sampling using epibenthic sleds.

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Table 1: Physical characteristics of the eight study seamounts of the Graveyard complex on the northwest Chatham Rise.

Seamount	Depth at peak (m)	Depth at base (m)	Elevation (m)	Area (km^2)
Graveyard	748	1 100	352	4.1
Morgue	890	1 200	310	3.1
Zombie	891	1 080	189	1.1
Scroll	888	1 080	192	0.9
Diabolical	894	1 050	156	0.9
Gothic	987	1 160	173	2.0
Pyre	1 004	1 200	196	1.5
Ghoul	935	1 050	115	0.6

Table 2: Taxonomic composition of the macro-invertebrate assemblage from eight seamounts of the Graveyard complex on the northwest Chatham Rise (total of 42 epibenthic sled samples).

Phylum	Class	Order	Number of species
Sarcomastigophora	Granuloreticulosa	Foraminiferida	1
Porifera	Demospongiae	Poecilosclerida	19
		Hadromerida	10
		Astrophorida	10
		Halichondrida	3
		Dictyoceratida	2
		Haplosclerida	2
		"Lithistida"	2
		Spirophorida	1
	Hexactinellida	Hexactinosida	13
		Lyssacinosida	3
		Amphidiscosida	1
		Lychniscosida	1
	Calcarea	Leucosoleniida	3
Cnidaria	Hydrozoa	Leptothecata	13
		Anthoathecata	9
	Anthozoa	Alcyonacea	20
		Scleractinia	11
		Actiniaria	7
		Antipatharia	2
		Zoanthiniaria	1
	Scyphozoa	Coronatae	1
Platyhelminthes	–	–	1
Nemertea	–	–	3
Annelida	Polychaeta	Phyllodocida	11
		Eunicida	9
		Sabellida	3
		Terebellida	3
		Scolecida	1
Sipuncula	–	–	2
Echiura	–	–	1
Crustacea	Cirripedia	–	6
	Malacostraca	Decapoda	39
		Isopoda	10
		Amphipoda	9
		Mysidacea	1
Pycnogonida	–	–	3
Mollusca	Polyplacophora	Lepidopleurina	1
		Ischnochitonina	1
	Scaphopoda	–	1
	Gastropoda	Neogastropoda	17
		Vetigastropoda	6
		Neotaenioglossa	3
		Heterostropha	1
		Nudibranchia	1
		–	7
	Bivalvia	Pterioida	4
		Arcoida	2
		Poromyoida	2
	Cephalopoda	Octopoda	1
Bryozoa	Gymnolaemata	Cheilostomata	48
	Stenolaemata	Cyclostomata	12
Brachiopoda	–	–	3
Echinodermata	Ophiuroidea	Ophiurida	25
		Euryalinida	3
	Asteroidea	Valvatida	9
		Forcipulatatida	6
		Brisingida	6
		Velatida	2
		Notomyotida	1
		Spinulosida	1
		Paxillosida	1
	Crinoidea	Comatulida	5
		Bourgueticrinida	3
	Echinoidea	Pellinoida	2
		Temnopleuroida	1
		Echinoida	1
		Spatangoida	1
Hemichordata	Pterobranchia	Rhabdopleurida	1

Table 3: Allocation of taxonomic groupings for photographic images recovered from four seamounts of the Graveyard complex on the northwest Chatham Rise.

Phylum	Class	Order	Species	Number of images
Porifera	–	–		59
Cnidaria	Anthozoa	Scleractinia	*Solenosmilia variabilis*	34
			Madrepora oculata	14
		Actinaria	–	14
		Alcyonacea	–	12
		–	–	24
Crustacea	Malacostraca	Decapoda	–	20
Mollusca	Gastropoda	–	–	54
Echinodermata	Crinoidea	–	–	115
	Asteroidea	–	–	17
	Echinoidea	–	–	9
	Ophiuroidea	–	–	3
'other invertebrates'	–	–	–	35

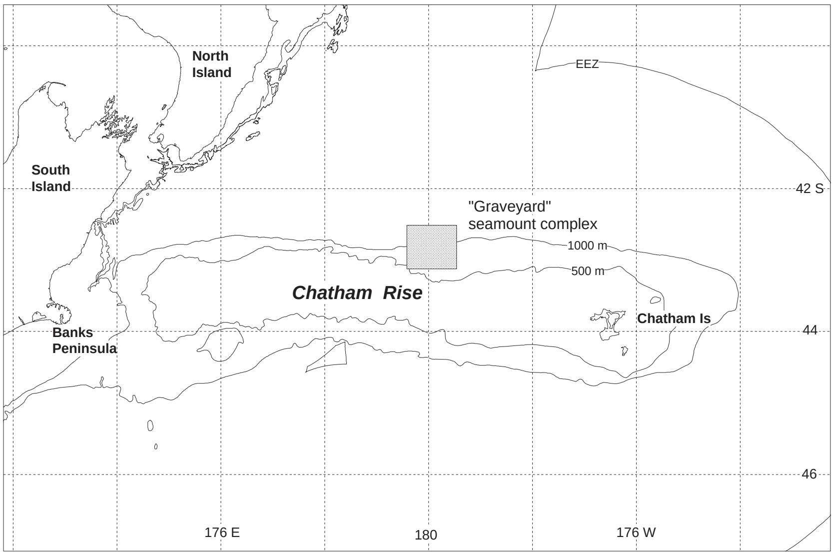

Figure 1: Location of the Graveyard complex study area on the northwest Chatham Rise.

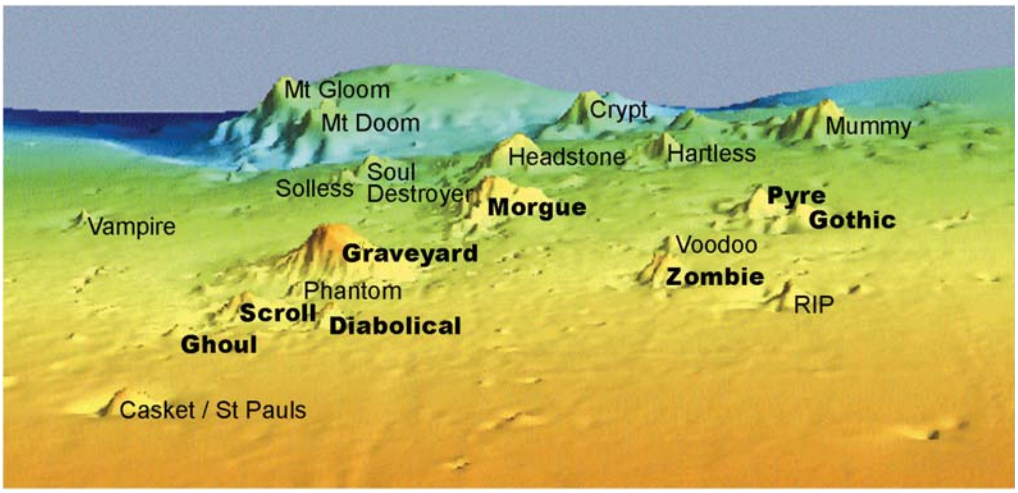

Figure 2: Identity and distribution of the seamounts (study seamounts in bold type) in the Graveyard complex study area on the northwest Chatham Rise (vertical exaggeration = x4)

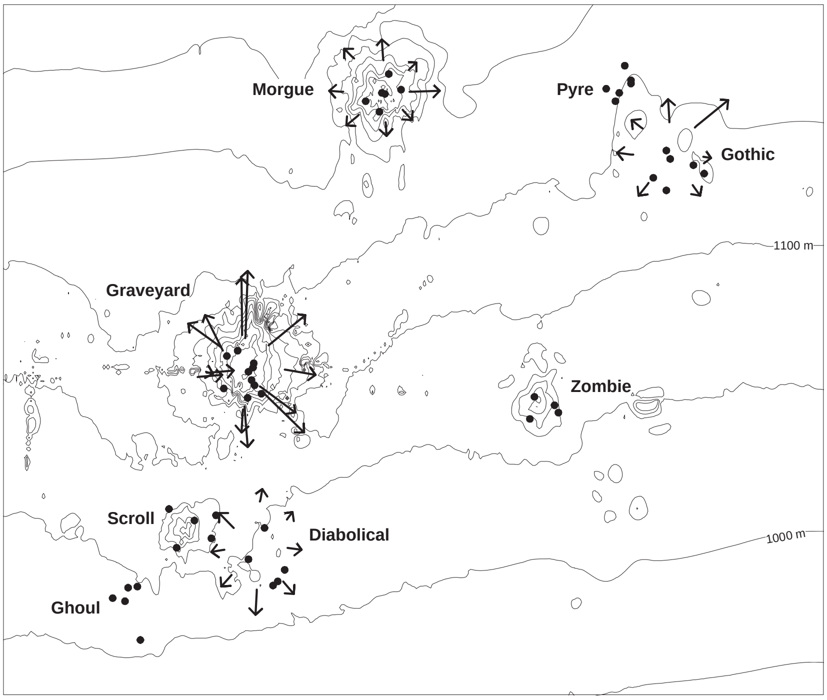

Figure 3: Distribution of epibenthic sled sample stations (filled circles) and camera frame transects (arrows) on the study seamounts of the Graveyard complex.

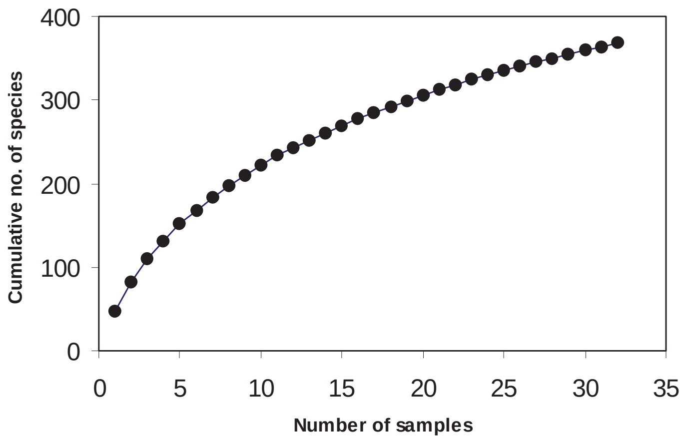

Figure 4: Species accumulation curve for the effective epibenthic sled samples from the study seamounts of the Graveyard complex.

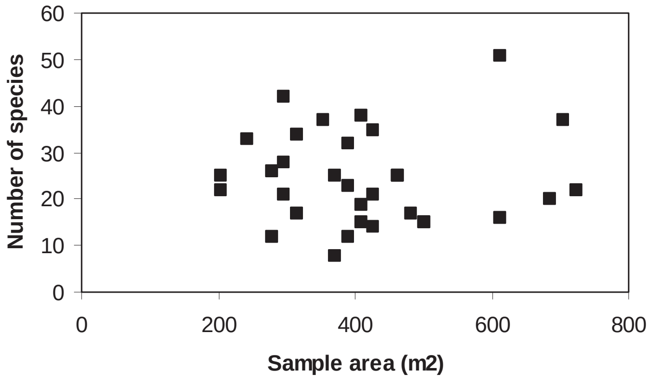

Figure 5: The relationship between the number of macro-invertebrate seamount species and the sample area of the epibenthic sled stations from the Graveyard complex.

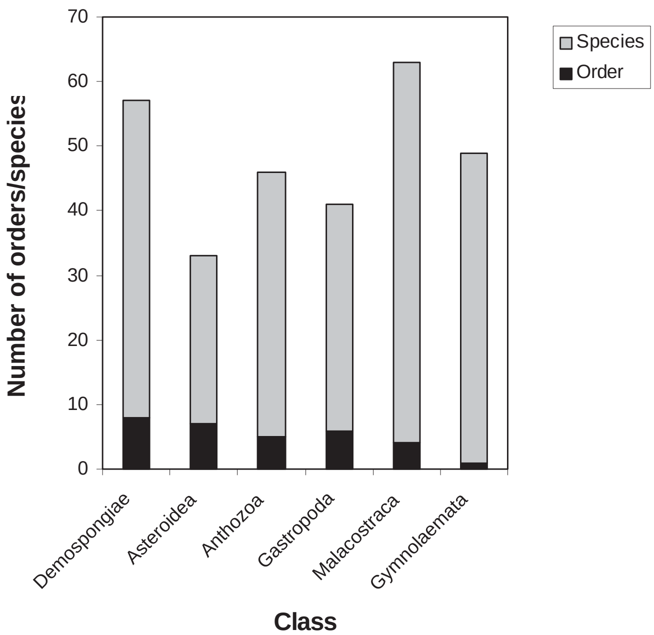

Figure 6: Taxonomic composition of the most order-diverse or dominant classes of the seamount macro-invertebrate assemblage sampled in the Graveyard complex.

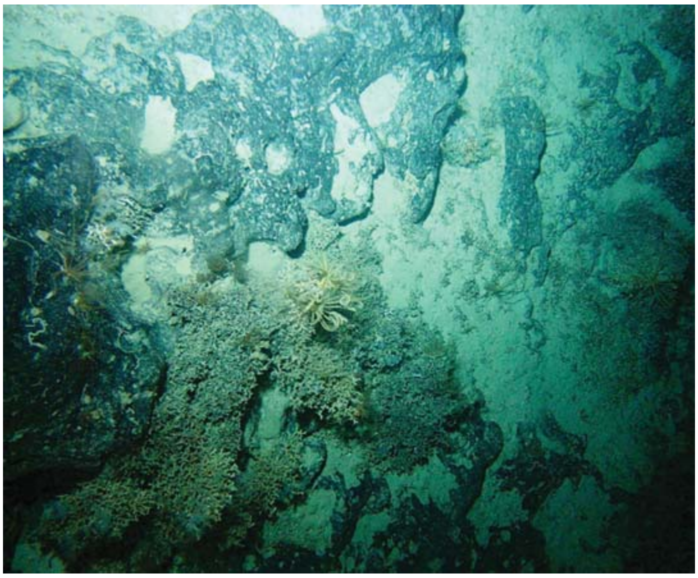

Figure 7: Photograph of seabed (Station 378) showing individuals of the class Crinoidea (e.g. organism at centre of image)

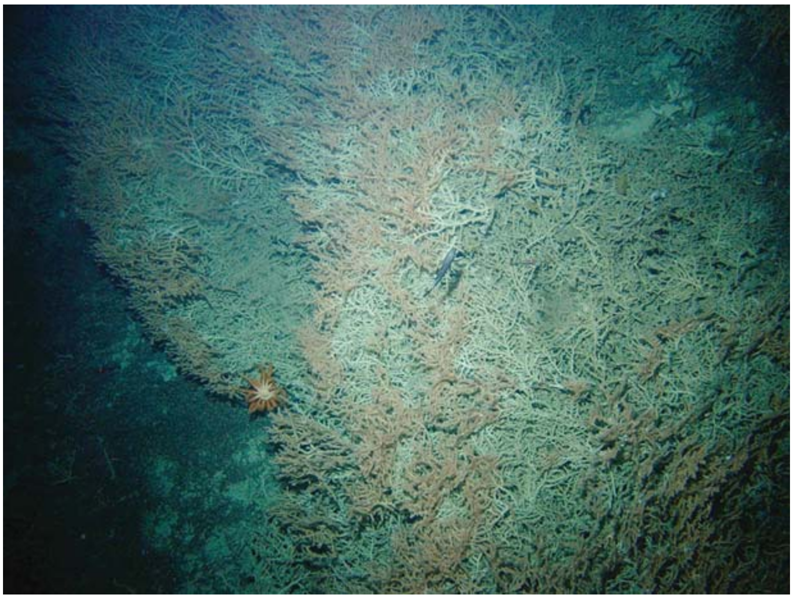

Figure 8: **Photograph of seabed (Station 213) showing colonies of *Madrepora oculata*.**

Figure 9: Photograph of the seabed (Station 360) showing colonies of *Solenosmelia variabilis*.

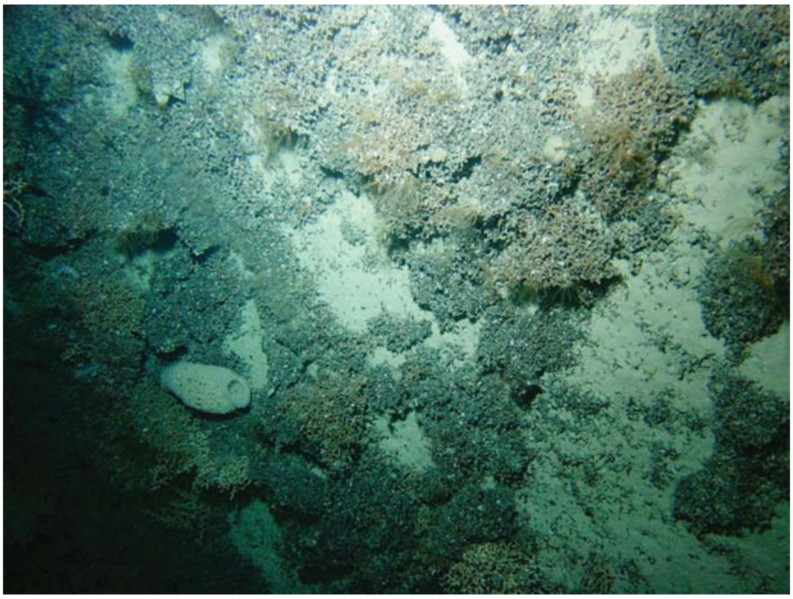

Figure 10: Photograph of the seabed (Station 351) showing organisms belonging to the phylum Porifera (e.g. centre-left).

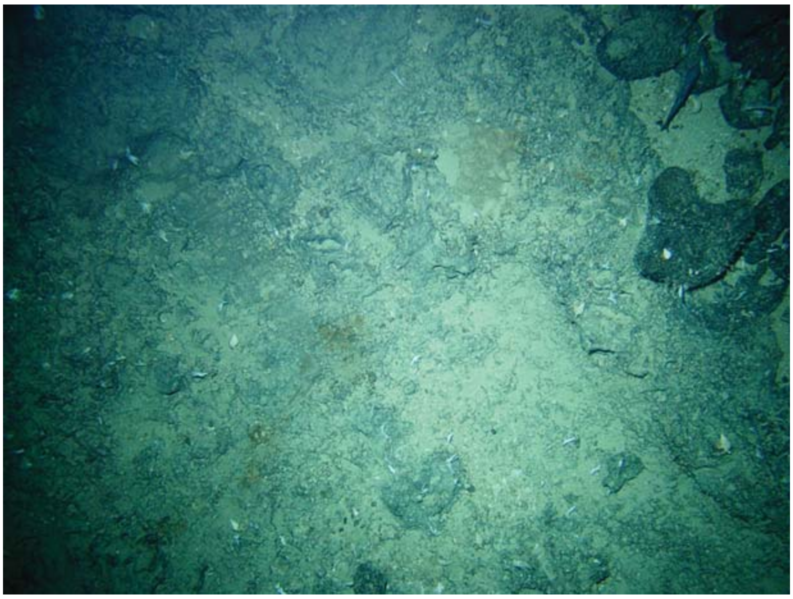

Figure 11: **Photograph of the seabed (Station 119) showing individuals belonging to the class Gastropoda (small white triangle shapes).**

Figure 12: **Photograph of the seabed (Station 250) showing individuals belonging to the class Decapoda (pink coloured organisms, top left and centre-right).**

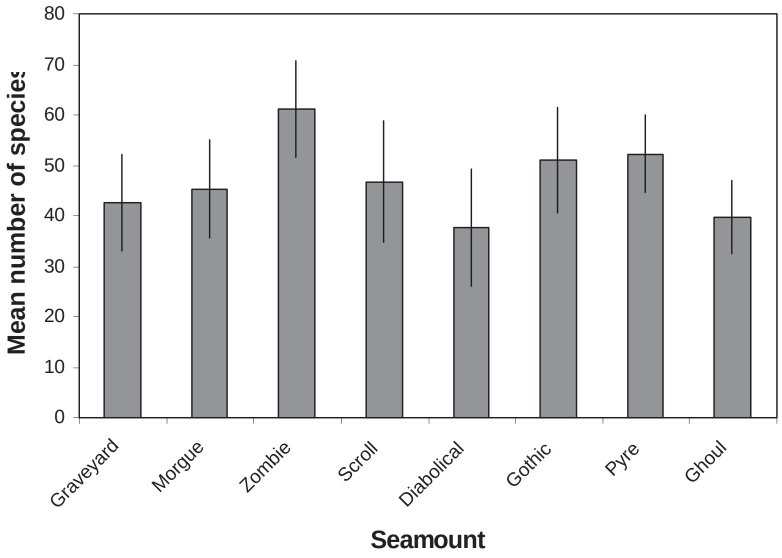

Figure 13: Mean number of macro-invertebrate species for each seamount sampled in the Graveyard complex (error bars = ± 1 SE).