



Biodiversity of macroinvertebrate and fish assemblages of the Balleny Islands seamounts.

New Zealand Aquatic Environment and Biodiversity Report No. 115.

A.A. Rowden
K. Kröger
M.R. Clark

ISSN 1179-6480 (online)
ISBN 978-0-478-41493-6 (online)

August 2013



Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:
<http://www.mpi.govt.nz/news-resources/publications.aspx>
<http://fs.fish.govt.nz> go to Document library/Research reports

© Crown Copyright - Ministry for Primary Industries

EXECUTIVE SUMMARY

Rowden, A.A.; Kröger, K.; Clark, M.R. (2013). Biodiversity of macroinvertebrate and fish assemblages of the Balleny Islands seamounts.

New Zealand Aquatic Environment and Biodiversity Report No. 115. 76 p.

In March 2004, RV *Tangaroa* completed “BioRoss”, New Zealand’s first comprehensive survey of the northwest Ross Sea shelf. The survey included an assessment of the biodiversity of the sub-aerial seamounts that form the Balleny Islands and two nearby seamounts.

Four seamounts (Balleny, Sturge, Young-Buckle, S-100) were sampled during the study, making it possible to describe the assemblage composition and biodiversity of this relatively understudied Antarctic region, and to examine multiple diversity hypotheses. The hypotheses examined were the energy-diversity hypothesis, habitat heterogeneity-diversity hypothesis, seamounts as islands hypothesis, and seamount stepping-stone hypothesis.

Some 331 putative macroinvertebrate species and 23 fish species were recorded from the four Balleny Islands seamounts. Environmental variables assessed at the time of the survey included sediment grain size parameters, sediment particulate organic carbon and nitrogen, sediment surface chlorophyll *a*, and sediment sponge spicule content. Sea surface chlorophyll *a* and sea ice cover were determined by remote sensing.

Average and Variation in Taxonomic Distinctness values for macroinvertebrate assemblages and proxy measures of productivity among the seamounts, conformed to the pattern predicted by the energy-diversity hypothesis. However, analysis of fish data did not support this hypothesis. Values of the same diversity metrics compared to average metric values for the region did not provide general support for the seamounts as islands hypothesis, for either macroinvertebrate or fish assemblages

Overall differences in assemblage composition (macroinvertebrates and fish) among the seamounts were relatively small. However, large differences in assemblage composition were evident between certain pairs of seamounts for all components of the macroinvertebrate fauna (infauna, epifauna, mega-epifauna). The differences, between seamounts with contrasting regimes of chlorophyll *a* and ice cover, provide some support for the hypothesis that surface water productivity influences the composition of macroinvertebrate assemblages on seamounts. Most of the difference between infaunal assemblages was explained by local sediment characteristics. Depth-related variables seemed to be the most influential environmental factors for the fish assemblages of the Balleny Islands seamounts. It is speculated that habitat heterogeneity, which varied among seamounts, and to some extent with depth, may also explain some of the observed patterns of assemblage composition. Analysis of both macroinvertebrate and fish data provided no support for the seamount stepping-stone hypothesis, at least over the geographic distance examined.

Future data analysis and the further processing of samples recovered during the study voyage will continue to improve biological knowledge of the region, including the biogeographical affinities of subantarctic seamount fauna with the fauna of the Antarctic and New Zealand regions, and will provide useful biodiversity information for conservation and environmental management purposes.

1. INTRODUCTION

1.1. Overview

Seamounts are distinct, elevated topographic features of the ocean seafloor; globally there are estimated to be more than 200 000 seamounts greater than one kilometre in elevation (Hillier & Watts 2007) and many more smaller seamount features such as hills and knolls. Seamounts are generally volcanic in origin and can occur in chains and clusters, sometimes associated with island archipelagos (Wessel et al. 2007). In the deep sea, seamounts provide a relatively shallow and predominantly hard substratum habitat for benthic fauna (Samadi et al. 2007). Thus the composition of benthic assemblages on seamounts is generally distinct compared to those of the deeper, generally soft sediment, surrounding seafloor (Rogers 1994). However, aspects of benthic assemblage composition on seamounts are not always different from similar habitat (e.g. substratum type) at comparable depths (e.g. slopes, O'Hara 2007). While seamounts are generally considered to be submarine (Pitcher et al. 2007), some studies that have included sub-aerial or island seamounts have also found that the biota is not distinct from those found on slopes (O'Hara 2007; but see Hall-Spencer et al. 2007).

Several benthic studies of Southern Ocean islands and archipelagos have recently been published (e.g., Crozet Islands: Sicinski & Gillett 2002, Bouvet Island: Artz et al. 2005, South Georgia: Barnes et al. 2006, South Shetland Islands: San Vicente et al. 2007, South Sandwich Arc: Kaiser et al. 2008, Scotia Arc: Griffiths et al. 2008). Most of the islands studied, however, are sub-Antarctic and often the studies are limited to certain faunal groups. The majority of these studies are descriptive with a biogeographical focus, and little has been revealed about the environmental variables shaping the faunal patterns observed. The Balleny Islands are one of the few Antarctic island groups for which published information on deepwater benthic invertebrates exists.

Benthic macrofaunal assemblages of isolated islands and seamounts can be modified by human activities (e.g. Koslow et al. 2001), and threats exist for the future in Antarctica as a consequence of increased tourist boat traffic and the opening of the region to bottom long-line fishing (e.g. Lewis et al. 2004), increased temperatures from global warming and acidification from CO₂ uptake (Clarke & Harris 2003). Calls have been made for some time to set aside marine protected areas of sufficient size to fulfill conservation objectives in the region (Gallardo 1987). Appropriate selection of these areas requires that both descriptive and experimental research will have to improve methodologically, and such research be extended around the Antarctic continent (Gallardo 1987). Within New Zealand's Ross Dependency, there are areas including the Balleny Islands (Bradford-Grieve & Fenwick 2002) where relatively little is known about the benthic macrofauna, which may require the establishment of protected areas because they face current and potential threats (e.g., toothfish fishery and tourism - see Waterhouse 2001).

1.2 The study area, survey and hypotheses

1.2.1 Balleny Islands and adjacent seamounts

The Balleny Islands, which are situated in the Southern Ocean some 700 km northwest of the Ross Sea yet south of the Polar Front/Antarctic Convergence (Figure 1), consist of three large islands (Young, Buckle, Sturge) and several smaller ones (e.g., Borradaile, Sabrina) of volcanic origin. They form a chain running northwest-southeast for about 200 km. The islands are in effect two sub-aerial seamounts, part of a chain of seamounts that continue to the northwest for 150 km (the Balleny Seamounts, e.g., Ellsworth, Soucek and Slava 'Banks') and southeast for 400 km (Glacier Bank and the Adare Seamounts) to the Ross Sea (Johnson et al. 1982). This chain of seamounts is part of the Macquarie-Balleny Ridge (Summerhayes 1974) which provides an opportunity for macroinvertebrates with restricted larval life and specific habitat requirements to disperse between New Zealand waters

and the Ross Sea (Brodie & Dawson 1965). In 1964 and 1965, New Zealand Oceanographic Institute scientists undertook sampling of benthic macrofauna around the Balleny Islands, to determine whether the fauna was entirely Antarctic in composition (as was then presumed) or, as a consequence of ridge connections, possessing elements of sub-Antarctic and New Zealand fauna (Hatherton et al. 1965; Forbes 1966).

The analysis of the results of these earlier studies was primarily focused on echinoderm fauna (McKnight 1976a,b). Dawson (1970) summarized this and other research on echinoderm distribution, in an attempt to evaluate the faunal similarities between the New Zealand plateau and the Ross Sea. Dawson (1970) concluded that there were "...close links between the Balleny Islands and Ross Sea areas and somewhat looser links between the New Zealand Plateau and Macquarie Island areas." That is, ridges did not appear to provide a particularly effective migration route for echinoderms northwards from the Balleny Islands (Dawson 1970). However, he acknowledged that planned sampling of ridges north of the Balleny Islands were "thwarted by topography and weather", and thus much of the macroinvertebrate biodiversity and assemblage composition of the islands remained unexplored. Sampling the macroinvertebrates on the slopes of Balleny Islands and adjacent seamounts will enable detailed description of high latitude seamount fauna from an environment undisturbed by human activities and provide useful synergies with extant seamount studies in New Zealand waters, that are examining differences in assemblage composition within and between seamounts.

The fish fauna of the Balleny Islands is relatively unsampled and poorly known. Only 21 species of fish have been recorded in the scientific literature, in contrast to about 94 in the adjacent Ross Sea (Gon & Heemstra 1990, Eastman & Hubold 1999). Thus, sampling of the fish and macroinvertebrate assemblages of the Balleny Islands, and other seamounts associated with the same ridge system, allows the community composition and biodiversity of a relatively understudied Antarctic area to be described, and a more complete assessment of the biogeographical affinities of the regions' fauna to be made.

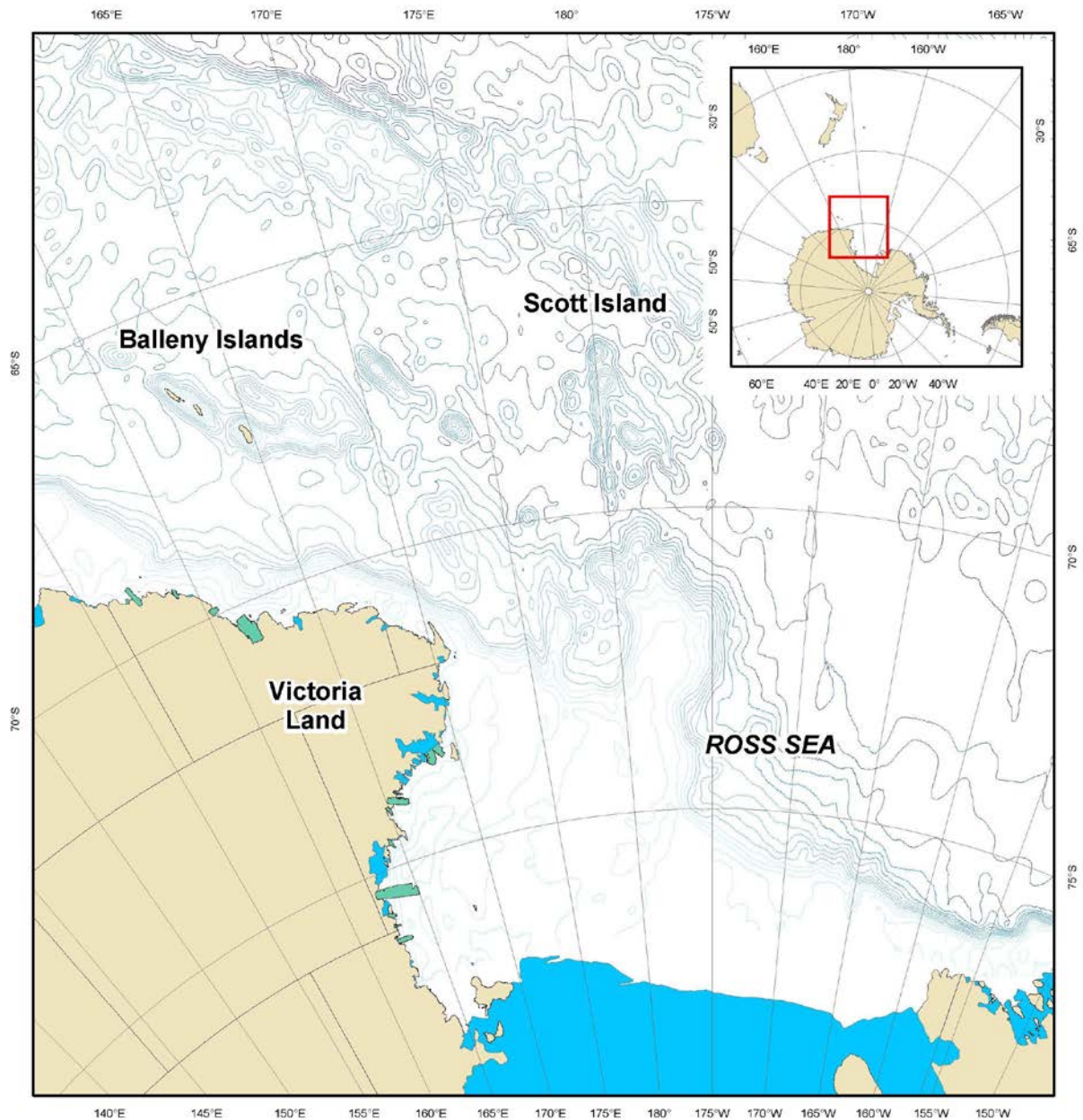


Figure 1: Map showing the Balleny Islands and their position relative to the Ross Sea, Antarctic continent and New Zealand. Blue areas indicate sea ice shelves (the largest of which is the Ross Sea Ice Shelf), green areas land ice tongues.

1.2.2 The BioRoss Survey

With the publication of reviews by Bradford-Grieve & Fenwick (2001, 2002) it was apparent that relatively little was known about the benthic macroinvertebrate and fish biodiversity of the Ross Sea and the Balleny Islands. Whilst a number of explanations of the distribution of macroinvertebrate (Bullivant 1967) and fish assemblages (Eastman & Hubold 1999) on the Ross Sea shelf and at the Balleny Islands have been put forward (Dawson 1970), no formal testing of any hypothesis to account for the region's benthic biodiversity has been forthcoming. The New Zealand Biodiversity Strategy

(Anon. 2000) indicates that this deficit of knowledge and understanding should be addressed. After preliminary biodiversity assessments (Stewart & Roberts 2001; Page et al. 2002), a quantitative survey of the biodiversity of selected marine communities of the Ross Sea region and Balleny Islands was launched under the banner of the New Zealand Biodiversity Strategy. The “BioRoss Survey”, New Zealand’s first comprehensive biodiversity survey in Antarctic seas since the surveys by the HMNZS *Endeavour* in late 1950s, took place in March 2004 using RV *Tangaroa*.

1.2.3 Study hypotheses

Answering the question as to why assemblages and biodiversity are distributed heterogeneously is a prerequisite to making recommendations about vulnerability, and areas or communities that may require protection (Currie et al. 1999). A plethora of general hypotheses have been proposed to explain the types of patterns observed, a number of which appear to be particularly applicable to the macrofauna assemblages of the Balleny Islands seamounts. The following hypotheses were chosen for testing during the BioRoss study.

1.2.3.1 The energy-diversity hypothesis

The relationship between a measure of diversity and a measure of the productivity of a system, the ‘energy-diversity hypothesis’, has long been observed in terrestrial habitats (see Rosenzweig 1995). However, the nature of the relationship is inconsistent across habitats and taxa, and further empirical data (particularly for aquatic species) are required before the mechanisms that explain the relationship can be understood (Mittelbach et al. 2001).

The waters above seamounts display spatial and temporal variations in primary productivity (Dower et al. 1992) that may influence macrofauna community composition and diversity on the seabed (Piepenburg & Müller 2004). In Antarctica, however, it is likely that the extent and duration of ice cover, and bottom currents will further influence the arrival and distribution of organic phytodetritus derived from surface primary production (Barry & Dayton 1988, Smith & Dunbar 1998, Cattaneo-Vietti et al. 1999), and thereby moderate the expected pelagic-benthic coupling relationship. Thus, any examination of the energy-diversity hypothesis for the benthic fauna of the Balleny Islands and adjacent seamounts would need to take into account the interaction of these variables (e.g., Gutt et al. 1998, Gutt 2000).

1.2.3.2 The habitat heterogeneity-diversity hypothesis

The relationship between habitat heterogeneity and diversity has been observed in both terrestrial and aquatic habitats, and incorporated into a number of ecological hypotheses (Rosenzweig 1995). Seamounts can have macrofauna communities dominated by relatively large habitat-forming epifauna such as stony corals and sponges (Samadi et al. 2007). Studies have shown that habitat patches formed by stony corals can be particularly species rich (Henry & Roberts 2007), and can contribute to larger scale differences in community composition among seamounts (O’Hara et al. 2008). In the Antarctic region, significant positive relationships between the number of macrofauna species and the abundance of two “types” of sponges have been shown (Gutt & Starmanns 1998). Other organisms such as bryozoans and gorgonians are also thought to play an important role in providing suitable habitat for a considerable number of macrofauna, explaining in part the local community composition and high species diversity observed in Antarctic waters (Gutt & Schickan 1998, Gutt 2000).

1.2.3.3 Seamounts as islands hypothesis

Hubbs (1959) first speculated that seamounts may be like islands, with the presumed spatial and temporal isolation affecting species composition and promoting the development of unique communities. Interactions between currents and topography can sometimes result in relatively closed recirculating currents and tidal rectification around seamount summits. These oceanographic features can retain larvae over seamounts (Mullineaux & Mills 1997, Dower & Perry 2001). The degree of entrainment and retention of fauna on a particular seamount depends on whether species have larval dispersal mechanisms that can overcome this cause of isolation. Population genetic studies of benthic invertebrates have provided some evidence for limited dispersal among seamounts within a region for some taxa (Samadi et al. 2006), but not for others (Smith et al. 2004). Studies suggest that fish populations on seamounts have genetically homogeneous populations, even across ocean basins (Martin et al. 1992). Comparisons of taxonomic distinctness (average or variation) of biotic assemblages on seamounts compared to values from other habitats, or a theoretical regional species pool, can provide an indication of relative insularity (or 'islandness') (Clarke & Warwick 2001a). Hall-Spencer et al. (2007) assessed taxonomic distinctness of coral assemblages on five seamounts in the Northeast Atlantic and found that two of them had island characteristics (i.e. average taxonomic distinctness was lower than the value for the regional species pool).

1.2.3.4 The stepping-stone hypothesis

Hubb's (1959) question "Do seamounts provide stepping-stones for dispersal of biota?", otherwise known as the 'stepping-stone hypothesis', remains untested for the seamounts of Antarctica. Elsewhere in the world this hypothesis has been examined (e.g., Wilson & Kaufman 1987, Leal & Bouchet 1991, Parin et al. 1997) and continues to be tested by scientists examining the reasons for the macrofauna assemblage composition of seamounts. A study in the southwest Pacific revealed that seamounts along ridges functioned as separate 'island groups' or 'chains' (Richer de Forges et al. 2000). Their study not only provides some evidence for the theory that seamounts can act as 'stepping-stones' for faunal dispersal, but it demonstrated that adjacent seamount chains even in the same region have highly distinct faunas. That many seamount benthic assemblages have localised distributions has implications for their conservation (Richer de Forges et al. 2000).

1.2.3.5 Examining multiple hypotheses

Since it is probable that environmental factors will co-vary with the spatial pattern of macrofauna diversity and assemblage composition, it is necessary (and efficient) to simultaneously test multiple hypotheses and ensure that the analyses are appropriate to the spatial scale of the variation (Currie et al. 1999). To date, no concurrent examination of the above hypotheses as they relate to the macrofauna communities of the Balleny Islands seamounts has been reported.

1.3 OBJECTIVES

The overall objective of the project was to carry out a quantitative study of the biodiversity of selected marine communities in the Ross Sea region. The specific objective was: to describe, and quantify the diversity of, the benthic macroinvertebrates and fish assemblages of the Balleny Islands and adjacent seamounts, and to determine the importance of certain environmental variables influencing assemblage composition.

2. METHODS

2.1 Study area

The study area in the vicinity of the Balleny Islands included two sub-aerial seamounts Young-Buckle and Sturge Islands, and two submarine seamounts Balleny and S-100 (Figure 2). The four seamounts have similar depth ranges but are quite different in size and physical characteristics. S-100, the smallest, has a depth range of 97–2000 m and an area of 115 km²; Balleny extends between 68 and 2750 m with an area of 2500 km²; Sturge seamount descends from the tideline of the island to 2250 m and has an area of 3500 km²; Young-Buckle seamount descends to 2500 m water depth and is the largest of the features sampled with an area of 7500 km² (including islands).

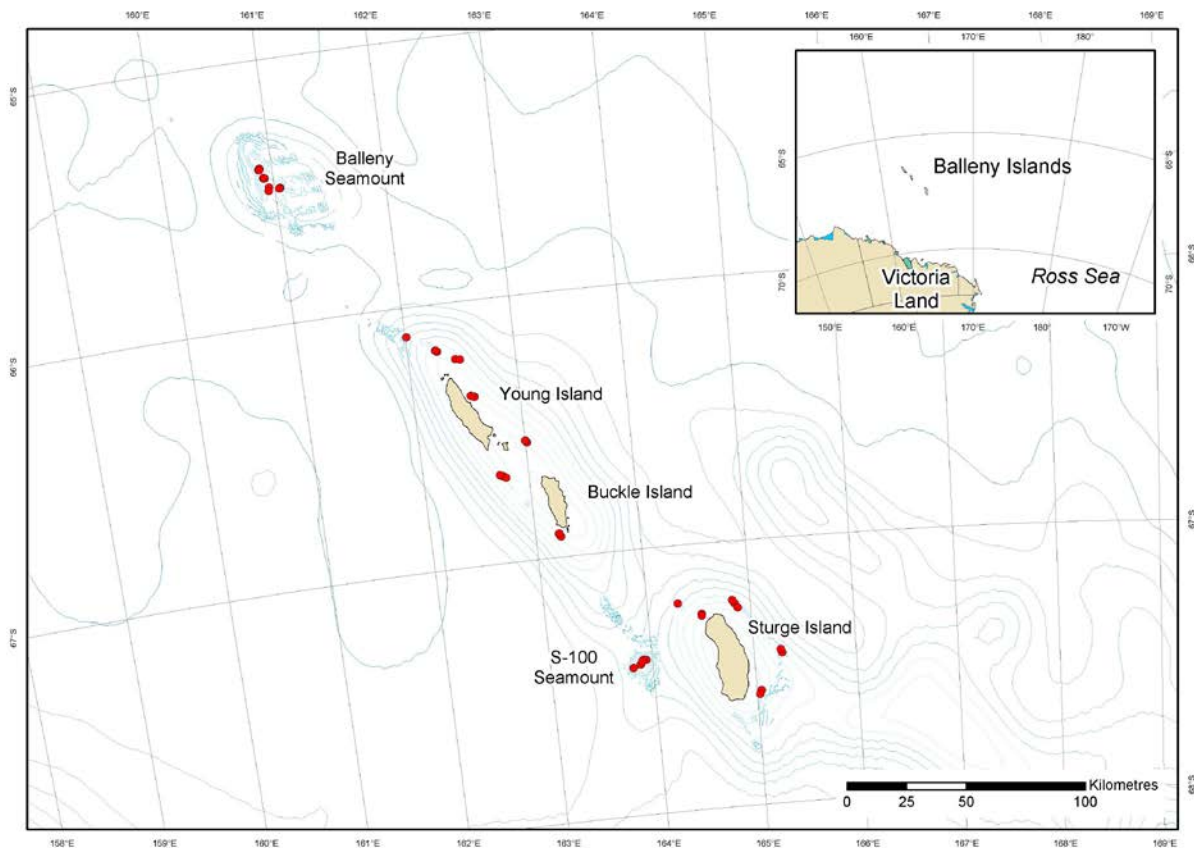


Figure 2: Map of the Balleny Islands and adjacent seamounts. Sampling stations are marked as red circles.

2.2 Sampling Design

Random replicate sampling (minimum target of four samples per seamount) was carried out on each of the seamounts studied. The position of sampling stations (Figure 2) was chosen based on a combination of random depth and direction from the peak utilising information from bathymetry already produced for the region (Mitchell 2001) and additional bathymetric data gathered during the study by multibeam swath mapping.

2.3.1 Direct biological sampling

Macroinvertebrates and fish were sampled using a bottom trawl, an epibenthic sled and a van Veen grab (a video camera was mounted on the latter two gear types) in order to sample three major components of the benthos: the mega-epifaunal component with a wider distribution (trawl), the epifauna (sled) and the infauna (grab) (see Appendix 1 for photographs of gear used). Following the successful retrieval of the sampling gear, the sample volume was recorded and digital images of macrofauna sampled were taken to provide a visual record to aid identification of specimens. Whenever time restraints prohibited the processing of the total sample, sub-sampling was undertaken (see Appendix 2 for station and sample details).

2.3.1.1 Bottom trawl

An orange roughy wing trawl (mouth opening 40 by 40 m, 40 mm stretched mesh diameter in cod end) was used to sample the mega-epifaunal invertebrate and the demersal and pelago-benthic fish fauna. Tow length was approximately one nautical mile. A cone net (mesh diameter 2 mm) was attached to the trawl to sample plankton. Analysis of plankton samples was beyond the scope of the project, but samples have been retained for future study.

2.3.1.2 Epibenthic sled

An epibenthic sled (mouth opening 1.4 by 0.5 m, 2 m long, 25 mm stretched mesh diameter) was deployed to sample the epifaunal and uppermost infaunal components of the benthic communities. On the slopes of the islands the epibenthic sled was towed parallel to the depth contour and downslope on submarine seamounts at a standard target speed of 1.5–2.0 knots (actual speed, 1.0–2.7 knots) and 15 minute duration (actual tow length, 0.12–0.70 n.mile).

2.3.1.3 van Veen grab

A van Veen grab (surface area 0.2 m², volume 90 l) was deployed to sample the infaunal macroinvertebrate component of the benthos. After retrieving the grab, sub-samples (approximately 30 ml) for sediment characteristics (see below) were taken through ports on the top of the grab, using either a cut-off 60 ml syringe or a small scoop, before the sample volume was established (by emptying contents into a pre-calibrated bin). The contents of the grab were then removed from the bin and gently washed through a sieve with 1 mm screen size.

2.3.1.4 Beam trawl

A beam trawl (4 m opening, stretched mesh diameter 30 mm) was deployed when conditions allowed (relatively flat and soft substratum seabed) in order to sample benthic invertebrates and fishes. Although the beam trawl is a useful method for obtaining qualitative data, it was not used as a standard sampling tool because of the limited range of bottom types that it could be deployed on. Thus, data derived from beam trawl deployments were excluded from quantitative analyses.

2.3.2 Video sampling

Video cameras were mounted onto the frames of the sled and the grab (see Rowden et al. 2002 and Blackwood & Parolski 2001 for details of camera set-up) in order to provide additional information about abundance, cover and morphology of structural species such as sponges and corals. The combination of grab and camera allowed for quantitative assessments of the faunal assemblages present on and in the seabed, and measurement of some key environmental variables (i.e., sediment characteristics) at the same spatial scale. Two parallel lasers 20 cm apart were used as part of the

camera set-up for scaling organisms in video images. Video records from the epibenthic sled were used to confirm the identity of some species caught by the sled and to assist provide information on the spatial distribution and structure of particular fauna and their habitat.

2.3.3 Environmental sampling

In order to determine the influence of environmental variables operating at small to intermediate spatial scales on the composition of benthic macrofauna assemblages, four separate sediment sub-samples (approximately 200 g) were taken from the undisturbed surface of each grab sample. The sub-samples were analysed for sediment grain size distribution and sediment sponge spicule content (per 1 g sediment); sediment particulate organic carbon content (% POC) and particulate nitrogen content (% PN); sediment surface phytodetritus (chlorophyll *a*) content (ng/mg). Samples were also taken for meiofauna, although these samples were not analysed as part of this study.

2.4 Sample Processing

2.4.1 Biological

2.4.1.1 Taxonomic identification

Macrofauna recovered by the direct sampling methods were identified at sea to the lowest possible taxonomic level (in the time available), counted and their weight estimated (to plus or minus 0.01 kg). Length measurements of fish were also taken (to plus or minus 1 mm). Guidance from taxonomists was sought for confirmation of on-board identifications of the benthic macroinvertebrate taxa sampled (see Appendix 3 for the list of all taxonomists or parataxonomists who contributed their skill and time to this project).

2.4.1.2 Sample treatment

Biological samples were fixed, preserved and stored for future sample identification and management, following best practices used by NIWA's National Invertebrate Collection and the National Museum of New Zealand Te Papa Tongarewa fish collection. The majority of biological samples were preserved in 80% ethanol. Where required, samples were fixed in 5% buffered formalin (e.g., medusae). All sponge samples and some bulk samples of other taxa were frozen at -20°C (e.g., ascidians, holothurians). Sub-samples of unsorted material from trawl, sled and grab sampling were also frozen for potential later analysis. The sieved unsorted grab samples were fixed in 5% buffered formalin prior to sorting in the laboratory at NIWA. After sorting, samples were transferred to 80% ethanol for storage. Sediment sub-samples taken for environmental determinations were transferred to labelled plastic bags and frozen at -20°C for later analysis at NIWA. Meiofauna subsamples were transferred to labelled containers and fixed with 10% buffered formalin. Samples are currently stored in the NIWA Invertebrate Collection facilities and the National Museum of New Zealand Te Papa Tongarewa (fishes). Collection databases have recorded the location and MPI ownership of specimens recovered by the sampling.

2.4.1.3 Image analysis

Sub-samples of the video images from grab deployments were used to identify the visible macrofauna (typically of size greater than 0.5 cm, Gutt & Starman 1998) to the lowest possible taxonomic level, and to determine their abundance. Sub-portions (50 by 50 cm), which were non-overlapping, of good quality (in focus and sufficiently illuminated) and included the presence of both the scaling laser marks, were selected in Ulead Video Studio 5 software before being imported into ImageJ (a Java

image processing software) for image analysis. Sedentary macrofauna (structural species) taxa were manually outlined with the freehand drawing tool, and area covered was calculated by the software as a proportion (expressed as a percentage) of the sub-portion image. Motile macrofauna taxa were counted and their size (to within plus or minus 0.01 cm) determined using the measuring tool in ImageJ. Sediment characteristics were also determined from the same images. That is, the percentage cover (of area not covered by macrofauna) of boulders (greater than 25 cm), cobbles (6.5–25 cm), pebbles (0.4–6.4 cm), gravel (up to 0.4 cm; ‘black’ and ‘pale’ components determined separately), sand (sediment with a ‘coarse’ appearance; ‘pale’ and ‘dark’ components determined separately), and mud (sediment with a ‘fine and silty’ appearance) was also determined and recorded. The percentage cover of biogenic elements of the substrate (‘broken barnacle shell’, ‘dead scleractinian coral’, ‘mixed broken shell/dead coral fragments’, and ‘mud burrows’ – which were also counted) were similarly determined. As many 50 by 50 cm non-overlapping images as possible were analysed from each deployment of the grab-camera. The number of suitable images obtained from the video records of grabs deployed at sampling stations ranged from one to six.

An index of biological habitat complexity (BHC) was developed for each image using the following formula:

$$\frac{N \times CN_{ST}}{NP} + CS_B$$

where N = the mean number of ‘patches’ of structural taxa per image, CN_{ST} = the total area (%) covered by N per image, NP = the total number of different patches per image and CS_B = the mean area (%) covered by biogenic substrate per image.

Images obtained by a video camera mounted on epibenthic sleds were used only in a qualitative manner (e.g., to obtain a general understanding of the extent of some fauna) or to assist in the identification of preserved material.

2.4.2 Environmental measures

2.4.2.1 Grain size analysis

Aliquots of sediment from the sub-samples were initially wet weighed and dry weights were obtained after oven drying at 60 °C for approximately 12 hrs. The dried samples were soaked in a washing solution made of NaH_2CO_3 and NaHCO_3 to disperse the particles and then washed over a 63 μm sieve using a fine spray of washing solution. The sediment fine fraction (less than 63 μm) was allowed to settle and excess washing solution was siphoned off. This fraction was then run through the Micromeritics Sedigraph 5100 when sufficient material for this process was available. The coarse fraction (greater than 63 μm) was oven dried and sieved into seven size fractions from 63–125 μm to greater than 4 mm, with each size fraction being weighed separately. Mean and median grain size and sorting coefficients were calculated using the indices of Folk & Ward (1957).

2.4.2.2 Sediment sponge spicule content

Sponge spicule estimates were obtained by counting the number of spicules in a 1 g sediment aliquot under a dissecting microscope using a 16-fold magnification.

2.4.2.3 Sediment particulate organic carbon and particulate nitrogen

Sub-samples for particulate organic Carbon (POC) and particulate Nitrogen (PN) analyses were treated with sulphuric acid to remove inorganic carbon before combustion in a pure oxygen

environment at 900°C. Catalysts were used to ensure complete combustion of C and N to CO₂ and N₂. Any carbon monoxide was oxidised further to CO₂ by passing the gases through a column of copper. The gases were separated using a chromatographic column and measured as a function of thermal conductivity (Manual of Analytical Methods Vol 1. The National Laboratory for Environmental Testing, Burlington, Ontario, Canada. Method 01-1090). Almost all PN values were less than 0.02% and thus were excluded from further analysis.

2.4.2.4 Sediment surface chlorophyll *a* content

The method of Humphreys & Jeffrey (1997) was followed to extract chlorophyll *a* from sediment sub-samples. Samples were extracted with the addition of 40 ml of cold acetone into a 100 ml container which was then sonicated for 20 pulses. After being left for 4 hrs at 4 °C to extract, samples were agitated, allowed to settle and 10 ml of the sample was removed and centrifuged for 10 min. In order to detect the total absorption in a visible spectrum, the extract was scanned (340–750 nm) in a spectrometer before being transferred to a fluorometer where sample readings were taken before and after acidification (excitation 431, emission 670, band width 5nm).

Calibrations were performed at a 5 nm bandwidth from a freshly made stock sample. The chlorophyll *a* (ng/g) and phaeopigment *a* (ng/g) contents of the sediment samples were then calculated using the following equations:

$$\begin{aligned} \text{chlorophyll } a \text{ (ng/g)} &= K \times Fm \times v(Fo - Fa) / [W(Fm - 1)] \\ \text{phaeophytin } a \text{ (ng/g)} &= K \times Fm \times v(Fm \times Fo) / [W(Fm - 1)] \end{aligned}$$

where

K = fluorescence sensitivity coefficient in extraction solvent (ng Chl *a*/ml)/instrument flow unit

Fm = maximum ratio *Fo*/*Fa* in the absence of phaeopigments and Chl *b*

Fo = fluorescence before acidification

Fa = fluorescence after acidification.

v = volume of acetone used for extraction (ml)

W = total weight of sample extracted (mg).

Environmental variables that might influence the compositional patterns of macrofauna assemblages at intermediate to large spatial scales in the study area were also examined. These included chlorophyll *a* content of the surface water and ice cover from satellite image data, iceberg scour from acoustic bottom topography data of the northwest Ross Sea shelf, and bottom water currents from mathematical models of the Ross Sea.

2.4.2.5 Sea surface chlorophyll *a* content

Sea Viewing Wide Field-of-view Sensor (SeaWiFS: Hooker et al. 1992) surface chlorophyll concentration data (mg/m³) were obtained from the ocean colour ftp archive at <http://oceancolor.gsfc.nasa.gov/ftp.html> in Standard Mapped Image format (SMI: Campbell et al. 1995) with a spatial resolution of approximately 9 km. The chlorophyll data were generated from whole-of-mission atmospherically corrected satellite radiances using the OC4v4 algorithm (O'Reilly et al. 1998, 2000), and composited into climatological means for each month (Jan-Dec) using an arithmetic average. The means for the spring (Sep-Nov) and summer (Dec-Feb) period were calculated from the monthly values. Because the OC4v4 algorithm was developed for open ocean systems, it uses ocean colour to generate chlorophyll data. Thus when used for coastal areas, the

algorithm cannot distinguish between surface water coloration due to primary production or due to terrigenous sediment run-off.

2.4.2.6 Ice cover

Sea-ice distributions (percentage cover of 25 by 25 km pixel) were obtained from the National Snow and Ice Data Centre (NSIDC), University of Colorado, Boulder, CO, USA (<http://nsidc.org>). Special Sensor Microwave/Imager (SSM/I) and Scanning Multichannel Microwave Radiometer (SMMR) brightness temperatures were used as input to the bootstrap algorithm (Comiso et al. 1997) to derive climatological monthly sea ice concentrations. These data represent mean ice concentration (percentage of grid cell covered by ice) for each month averaged over the entire time period of the data set (November 1978 to December 2003) at a spatial resolution of about 25 km. The annual and seasonal means were calculated for spring (Sep-Nov), summer (Dec-Feb), autumn (Mar-May) and winter (Jun-Aug) from monthly values. However, only mean values for spring, summer and annual ice cover were included for analysis due to their perceived stronger influence on the biological communities. Due to the relatively large size of the pixels used for ice cover data, land contamination can introduce some error. That is, the pixels closest to the coast are likely to overlap sea and land ice and thus might slightly distort the sea ice cover values. The algorithm used distinguishes the different light refractions of water and ice and thus a melt water pool on the ice would be interpreted as open water.

2.5 Data Analysis

All biological and environmental data generated directly by the survey were added to the BioRoss database, and data from bottom trawl samples were also added to the MPI Trawl database (both maintained by NIWA). All macroinvertebrate and fish data were also incorporated into the South Western Pacific Regional OBIS portal (<http://www.nzbois.niwa.co.nz>) and summarised in the main Ocean Biogeographic Information System (OBIS) node (<http://www.iobis.org/>).

The survey was not designed to sample taxa such as algae, planktonic medusa and copepoda, foraminiferans, nemertines and nematodes. Consequently these taxa were excluded from analyses.

2.5.1 Univariate analysis

2.5.1.1 Choice of biodiversity metric

A prerequisite for the description of biodiversity is the need to define it in ecologically meaningful ways that are practical to measure. The most widely used measures of biodiversity are those based on the number of species present, sometimes adjusted for the number of individuals sampled, or indices that describe the evenness of the distribution of the numbers of individuals among species, or that combine both richness and evenness properties (see review by Magurran 2004). Changes in such measures are not explicitly linked to changes in functional diversity, and so their ecological significance is difficult to establish. Traditional diversity measures have disadvantages in assessing biodiversity change on wide spatial scales because they are often sample method-, size- or habitat-specific. In response to these limitations, alternative measures have been devised to overcome these problems. Such a measure is average taxonomic distinctness (AvTD), which is based on the degree of relatedness of species, and is independent of sample size (Warwick & Clarke 1995). Clarke & Warwick (1998) have also devised a randomisation test to detect a difference in the average taxonomic distinctness, for any observed set of species, from the 'expected' value derived from a 'master species list' for the relevant group of organisms (Clarke & Warwick 1999). Taxonomic distinctness also appears to be explicitly related to trophic diversity (i.e., one aspect of 'functional'

diversity) (Warwick & Clarke 1998). This diversity measure is beginning to find application in broad scale geographical comparisons of biodiversity (Piepenburg et al. 1997, Price et al. 1999) and in environmental impact assessment (Hall & Greenstreet 1998, Rogers et al. 1999) in the marine environment. Most recently, Clarke & Warwick (2001a) have presented another measure, variation in taxonomic distinctness (VarTD), which reflects the unevenness of the taxonomic tree. This measure is particularly relevant for comparing biodiversity at larger spatial scales where, in addition to anthropogenic environmental degradation, habitat heterogeneity is likely to influence patterns of diversity. Therefore, the present assessment of biodiversity patterns in the Ross Sea study area adopted the use of these two biodiversity indices.

The presence-absence forms of the biodiversity indices used were derived from quantitative data of the three main gear types from stations associated with the *a priori* sampling design and number of species greater than one. The taxonomic categories used in the analysis were: species, genus, family, order, class and phylum (phylum only for macroinvertebrate biodiversity). The weight of the path lengths between hierarchical taxonomic levels were standardised to be 100 for two species connected at the highest (taxonomically coarsest) possible level. Steps between each level were set as being equal. It has been found that for some taxa, an inherent correlation (either positive or negative) between AvTD and VarTD can exist (Warwick & Clarke 2001). If a correlation between the two indices is inherent, then the indices cannot be interpreted separately because one is a surrogate of the other. The macroinvertebrate and the fish data were examined for the existence of a linear correlation, but no such correlations were found, so values for both indices are reported upon here.

See Appendix 4 for additional information on the use of taxonomic distinctness metrics.

2.5.1.2 Predictions and tests

Studies have shown that species richness and taxonomic distinctness are not generally related in their response to environmental variables (e.g., Heino et al. 2005) and thus it is not possible to simply replace predictions based on diversity hypotheses for species richness with those for taxonomic distinctness. Hence, it is necessary to make specific predictions based upon a qualitative understanding on how the taxonomic composition of an assemblage may be expected to react to various forcing factors (Bates et al. 2005). Below, the hypotheses being tested in the present study are examined with respect to how measures of taxonomic distinctness may respond, before the applicable test is described.

2.5.1.2.1 Energy-diversity hypothesis

It has been argued that a continuous low or high supply of energy-limiting parameters (e.g., light, nutrients, primary productivity) results in steady-state assemblages, where some species able to compete for the energy resource develop in high abundances, while weaker competitors are scarce or completely excluded (Sommer 1985, Capblancq 1995). On the other hand, a discontinuous or moderate supply of an energy resource would encourage the coexistence of species and thus would support high species richness (Mittelbach et al. 2001), with species being distributed relatively evenly among a large range of taxonomic groups. The results of a study examining the influence of nutrient supply on phytoplankton assemblages in lakes have demonstrated that high and low nutrient inputs were associated with assemblages dominated by relatively few closely related taxa (low measures of AvTD and high VarTD) whilst moderate nutrient inputs stimulated the growth of different taxonomic groups (high AvTD) and increased the evenness of assemblages (low VarTD) (Spatharis et al. 2007). In the present study, surface water primary productivity (which peaks or is highest primarily in spring and summer months) was used as a proxy measure of the potential supply of energy to benthic macrofauna. It is reasonable to expect that where productivity is low (or extremely high – if such a

situation should exist above the Balleny Islands seamounts) assemblages will be dominated by a few species within a limited number of taxonomic groups, hence AvTD would be low and VarTD high. Where productivity is relatively high (moderate/intermediate levels in a wider context), samples from assemblages in such areas would be expected to have relatively high values of AvTD and low VarTD. It is possible that because the proxy measures of productivity are better suited for examining relationships with macroinvertebrate assemblages than fish assemblages, such a prediction may not necessarily apply to the latter taxonomic group.

In order to test the energy hypothesis thought likely to explain the patterns of macrofauna biodiversity composition among the Balleny Islands seamounts, means of AvTD and VarTD for each seamount were computed (using the Taxdisc sub-routine of the DIVERSE routine in the statistical software package PRIMER v 6.15; Clarke & Gorley 2001, Clarke & Warwick 2001b) and tested using one-way ANOVA models (STATISTICA 7.1, StatSoft, Inc.). The Shapiro Wilk W test and Cochran's test were used to assess data assumptions of normal distribution and homoscedasticity, respectively. In most cases such assumptions were violated and thus the one-way ANOVA was conducted using ranked data. For multiple post-hoc comparisons, Tukey's Honestly Significant difference (HSD) test for unequal n was used.

2.5.1.2.2 Habitat heterogeneity-diversity hypothesis

Heterogeneous environmental conditions allow for a range of species that are adapted to distinct conditions to coexist. Such taxa with contrasting ecological requirements are often distantly related. That is, high habitat heterogeneity leads to high biodiversity, both in terms of species richness and taxonomic distinctness (high AvTD) (Warwick & Clarke 1998). Conversely, when habitat heterogeneity is low, the number of species supported is also low and these species are likely to be more closely related (low AvTD). Because some higher taxa are associated with specific habitats (e.g., most species of the phylum Porifera (sponges) live attached to hard substrate), if such habitats are absent then the assemblage may contain taxa that are more unevenly distributed across the taxonomic spectrum (high VarTD) (Clarke & Warwick 2001a). With an increase in habitat heterogeneity, the increase in species richness could be represented by congeneric species which are either able to avoid direct competition or are adapted to slightly different niches – which would result in a decrease in VarTD. However because such taxonomic structure patterns do not always follow, taxonomic distinctness may not be a particularly useful metric for habitat heterogeneity-diversity studies, something which Warwick & Clarke (1998) already noted when they examined the influence of habitat heterogeneity on average taxonomic distinctness of free-living nematode communities. These authors concluded that measures of species richness are more strongly affected by relative levels of habitat heterogeneity than measures of taxonomic distinctness.

Thus for the BioRoss study, no attempt was made to relate values of AvTD and VarTD for macroinvertebrate assemblages to values of the habitat heterogeneity variables measured (measures of habitat heterogeneity relevant to fish assemblages were also not obtained).

2.5.1.2.3 Seamounts as islands hypothesis

Isolated or insular environments such as oceanic islands are often centres of speciation and typically their faunal assemblages have fewer representatives at higher taxonomic levels but more species within those higher taxonomic levels present. For example, if speciation has largely occurred within a limited number of families then path lengths between all pairs of species in the assemblage will be short and uneven, and samples from an island will have a relatively low AvTD and high VarTD. Supporting evidence for this generalisation from studies that have used measures of TD is limited. Nonetheless, a study of marine nematodes did find that VarTD for the assemblages of the islands that comprise the Isles of Scilly was higher than the mean value of this biodiversity metric for the theoretical regional pool that included the mainland (Clarke & Warwick 2001b). Measures of AvTD

for the coral assemblages of oceanic islands (and some seamounts) were found to be lower than the mean value for the regional pool of coral species collated for the North-East Atlantic (Hall-Spencer et al. 2007). Thus, if a seamount in the present study is an isolated habitat then it can be predicted to have lower measures of AvTD and higher values for VarTD compared to the wider regional fauna from which the assemblage is theoretically drawn (including less isolated seamounts). Conversely, if the seamount is not particularly isolated (in comparison to other seamount habitats and/or the wider region) and the species in the assemblage come equally from a range of genera, families, orders, etc. then path lengths between all pairs of species in an assemblage are long and even, and AvTD and VarTD will be relatively high and low, respectively (and not significantly different from one another or the regional mean).

In order to test the seamounts as islands hypothesis, i.e. whether the observed species assemblages of the seamounts were distinct from a random selection from the regional species pool, a permutation test was constructed for AvTD and VarTD (TAXDTEST, Clarke & Warwick 1998, 2001b). In the absence of our ability to create a realistic species list for the region, a master species list consisting of all species occurring at the stations sampled during the BioRoss study was used as a pragmatic alternative (see Appendices 7 and 13 in the companion report (Rowden et al. 2012) for macroinvertebrate and fish data from the northwestern Ross Sea shelf, and Appendices 7 and 9 of this report for data from the Balleny Islands seamounts). For the observed number of species in a group, m , the computed values of AvTD and VarTD were compared with the range of values of 1000 random selections of m species from the master list. If the measured value was outside the 95 % probability limits of the simulated values, the computed value was considered to have departed significantly from the random expectation. The measured values were plotted as points on a 'probability funnel' (Clarke & Warwick 2001b), which was constructed by plotting the mean and the 95% probability intervals for 1000 simulations from the master list.

2.5.1.2.4 The stepping-stone hypothesis

Measures of TD are not suited to examining the Stepping-stone hypothesis; rather measures of β -diversity (species turnover), similarity indices, are used (see multivariate analysis section).

2.5.2 Multivariate analysis

2.5.2.1 Choice of statistical methods

Multivariate statistical techniques that utilise similarity measures have long been employed in benthic ecology (e.g., Stephenson et al. 1970) to describe assemblages, and have been successfully used to nominate Antarctic assemblages (e.g., Gerdes et al. 1992). Numerous similarity measures and associated multivariate techniques have been applied but the rationale for the choice of particular methods used is rarely given. The rationale for adopting the suite of multivariate statistical procedures contained within the PRIMER software package (Clarke & Gorley 2001) used in the present study relate to convincing arguments made in the book that supports the package (Clarke & Warwick 2001a). Peer-reviewed arguments have also been made by these and other authors in the primary literature concerning the comparative usefulness of the PRIMER procedures (e.g. Warwick & Clarke 1991, Clarke 1993). A recent textbook on ecological statistics supports the contentions by Clarke & Warwick (2001a) regarding applicability of non-metric multidimensional scaling (NMDS) ordination (the technique promoted by PRIMER) to the type of study undertaken (Gotelli & Ellison 2004, see Chapter 12).

For all multivariate analyses of invertebrate and fish assemblage compositional patterns, only data derived from the three main gear types from stations associated with the *a priori* sampling design and more than one macroinvertebrate or fish species were included in the analysis. For initial visual comparisons of data from different gear types and for analyses of the macroinvertebrate assemblage

compositions, data were presence-absence transformed. Fish abundance data were standardised and square-root transformed to down-weight the influence of dominant taxa and increase the weight of rare taxa. Similarity matrices were constructed for these data using the Bray-Curtis Index (Bray & Curtis 1957). Non-metric multidimensional-scaling ordination (NMDS) plots were produced to visualise the (dis)similarity of macroinvertebrate assemblages. The different gear types were used in order to sample different components of the macroinvertebrate assemblages (mega-epifauna, epifauna and infauna) and thus it can be expected that an analysis of assemblage composition may reveal gear type to be a significant factor which could override differences caused by latitude and/or depth. Thus it was seen as prudent to test for gear differences (one-way ANOSIM) and to subsequently analyse the different faunal components separately.

2.5.2.2 Predictions and tests

According to the hypotheses examined by the study, and the findings of previous studies in the region (see Introduction), the composition of the benthic assemblages is predicted to be different among seamounts that represent different productivity regimes, and sites with different levels of habitat heterogeneity (variously quantified). The influence of other potential drivers of assemblage composition (some of which are likely to interact with the main variables e.g. ice cover) were also predicted to exhibit some influence on the compositional patterns observed.

In order to test and examine the hypotheses thought likely to explain the patterns of macrofauna assemblage composition among the Balleny Islands seamounts, the following analyses were undertaken.

A one-way crossed ANOSIM (Analysis of Similarities) (Warwick et al. 1990) was performed to test for significant differences in assemblage composition among seamounts. Pairwise differences in assemblage composition between individual seamounts were also determined.

A one-way SIMPER analysis (similarity percent analysis, Clarke 1993) was employed to calculate the assemblage similarities and dissimilarities among the *a priori* sample groupings, and to identify those species contributing most to the average similarity for each grouping (typifying species) and dissimilarities between such groups (discriminatory species; only for groups being significantly different). Relatively high ratios (greater than 1.3) of the average (dis)similarity to standard deviation of the (dis)similarity were used to identify typifying and discriminatory species.

Relationships between the patterns of macroinvertebrate and fish assemblage composition and measured environmental variables were examined using the statistical correlation technique BVSTEP (e.g., Clarke & Ainsworth 1993). All pairwise combinations of environmental variables were visually examined (using draftsman plots) to assess the possible need for transformation and for co-correlation prior to conducting the BVSTEP analysis. For pairs of variables with a correlation factor of at least 0.9, one variable was excluded from the analysis. Variables excluded from analyses and variables requiring log-transformations are listed in the respective results sections. All variables were normalised prior to the BVSTEP analysis.

In order to examine the stepping-stone hypothesis, linear regression analysis was used to assess the correlation between levels of assemblage dissimilarity and geographic distance among seamounts.

3. RESULTS

3.1 Environment

Maximum water depth, surface chlorophyll *a* data averaged for spring and summer seasons and mean seasonal and annual ice cover (%) are listed for 73 stations from four Balleny Islands seamounts in Appendix 5. Sediment characteristics and the Biological Habitat Complexity Index (BHC), which were derived from image analysis data from grab deployments, are listed in Appendix 6.

No prior assumptions or predictions were made with regard to particular patterns for any of the environmental data collected at the Balleny Islands seamount study area. Some of the patterns that did exist are described here (see also Table 1 for summary). There was a large range in the values for surface chl *a* and sediment chl *a* content (proxies for productivity) recorded at the four seamounts, and the pattern among seamounts for these two variables was largely similar (Figure 3a and b). Highest mean levels of surface chl *a* and sediment chl *a* occurred at Young-Buckle seamount (0.96 mg m⁻³, 4.34 µg g⁻¹, respectively) and the lowest at Balleny seamount (0.31 mg m⁻³, 0.81 µg g⁻¹, respectively). Mean values for both these measures at Sturge seamount were in between the two aforementioned extremes. The mean measures of surface chl *a* and sediment chl *a* were relatively high (0.78 mg m⁻³) and low (1.24 µg g⁻¹) for S-100 seamount, respectively. Differences in mean annual ice cover among the seamounts were relatively small with 66.0 % cover at S-100 and 56.8 % at Young. The extent of the mean summer ice cover was more variable with the cover being highest at S-100 seamount (42.8%) and lowest at Balleny seamount (25.8%). The sediment at the four seamounts was poorly to very poorly sorted and consisted of coarse and very fine sand at Balleny and Sturge, and of coarse silt at Young-Buckle. At S-100, where only one sediment sample was taken, the sediment consisted of poorly sorted medium sand with relatively high pebble content (approximately 22 %).

Table 1: Mean values for environmental variables for the Balleny Islands seamounts.

Environmental Variable (mean)	Sturge	S-100	Young-Buckle	Balleny
annual ice cover (%)	63.52	65.99	56.83	61.41
summer ice cover (%)	38.70	42.77	29.35	25.82
particle size (phi)	3.75	0.00	4.40	0.75
sorting coefficient	3.11	2.00	2.42	1.64
POC content (%)	0.20	0.03	0.15	0.10
% fine	60.03	3.78	55.73	6.44
% pebbles	27.38	22.27	3.04	18.85

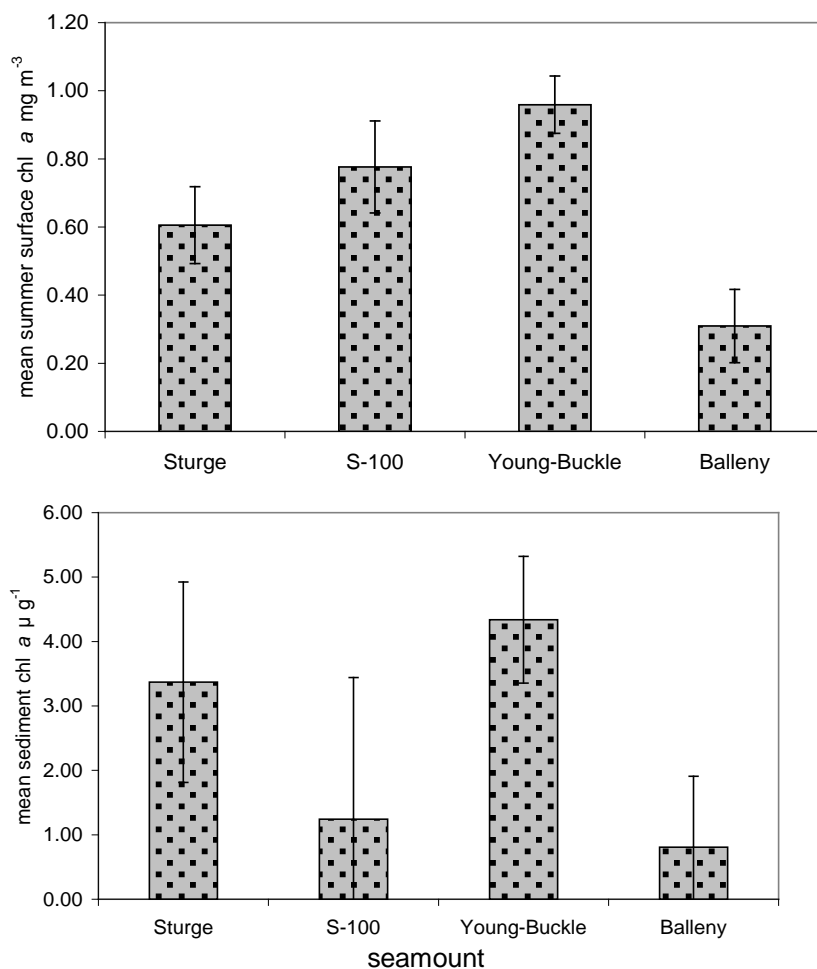


Figure 3: Mean surface water chl *a* concentration (mg g^{-1}) for austral summer (December-February 2004–2005; SeaWiFS) (a), and mean sediment chl *a* content ($\mu\text{g g}^{-1}$) (b) for the Balleny Islands seamounts. Error bars indicate plus or minus one Standard Error.

3.1 Macroinvertebrate assemblages

A total of 331 putative macroinvertebrate species were identified from 18 infaunal, 12 epifaunal and 16 mega-epifaunal samples taken on four Balleny Islands seamounts, Sturge, S-100, Young-Buckle and Balleny. See Appendix 7 for a list of macroinvertebrate species incorporated in quantitative analyses. The majority of species were solitary (226 species) and 105 species were colonial. The most speciose groups were the Polychaeta with 67 species and the Echinodermata with 61 species. For number of species (solitary and colonial species separately) and number of individuals (solitary species only) per station see Appendix 8.

Overall mean species richness was relatively similar among the seamounts, with the largest number of species recorded for Young-Buckle (144 species) and fewest for Sturge (120 species; Table 2). However, these values cannot be used for any statistically meaningful comparison because of the differences in the number of samples (and gear types used to obtain these samples) among seamounts. Thus, as noted earlier, measures of taxonomic distinctness were used to allow for a robust diversity analysis (see below).

Table 2: Number of samples, mean number of species *S* for colonial and solitary taxa and mean number of individuals *N* for macroinvertebrate assemblages from the seamounts of the Balleny Islands.

Seamount	Number of samples	Mean <i>S</i> colonial taxa	Mean <i>S</i> solitary taxa	Mean <i>S</i> total	Mean <i>N</i> solitary taxa
Sturge	10	26	94	120	56
S-100	7	53	81	134	112
Young- Buckle	18	31	113	144	68
Balleny	11	39	83	122	101

3.2.1 Univariate analysis

No significant differences were detected by the ANOVA test when comparing the mean AvTD and VarTD values among the seamounts (Table 3).

Table 3: ANOVA results for comparisons of biodiversity indices Average taxonomic distinctness (AvTD) and Variation in taxonomic distinctness (VarTD) of macroinvertebrate assemblages from the Balleny Island seamounts Sturge, S-100, Balleny and Young-Buckle. Where ANOVA data assumptions were violated, ranked data were used.

Factor	Data	MS	dF	F	<i>p</i> -value
AvTD	Ranked	61.62	3	0.3267	0.8060
VarTD	Unranked	12 509.95	3	0.9660	0.4177

Mean measures of AvTD were similar among seamounts, with only Balleny seamount having a slighter lower value (Figure 4). Mean values of VarTD were highest for S-100 and lowest for Young-Buckles seamounts, respectively. Surge and Balleny seamounts had similar mean values of VarTD (Figure 4).

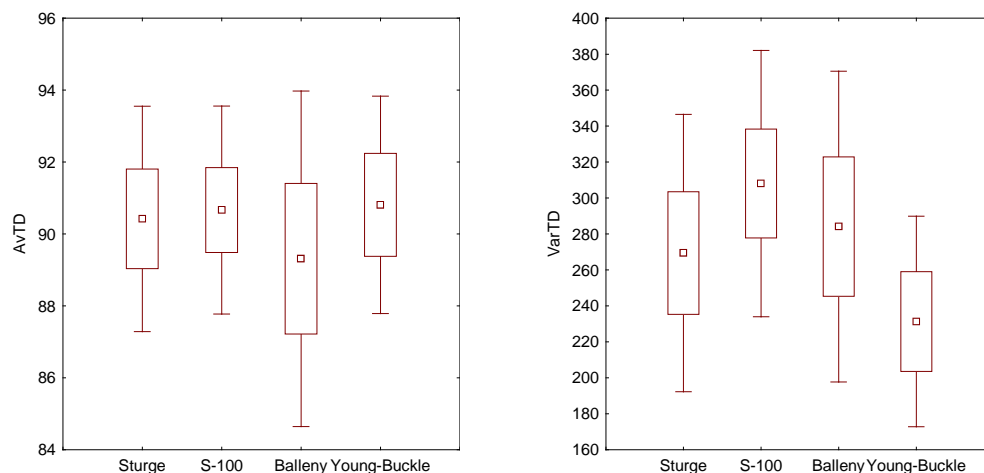


Figure 4: Mean (small square), standard error (box) and 95% confidence interval (bar) values for Average taxonomic distinctness (AvTD) and Variation in taxonomic distinctness (VarTD) of macroinvertebrate assemblages from the Balleny Island seamounts Sturge, S-100, Balleny and Young-Buckle.

The TAXDTEST revealed that the macroinvertebrate assemblages of Sturge, Young-Buckle and Balleny seamounts had values of average taxonomic distinctness (AvTD) well within the 95% confidence funnel, with AvTD ranging between 94.7 for Sturge and 95.5 for Balleny. The assemblage of S-100 showed an AvTD value below the confidence funnel with AvTD= 93.6 (Figure 5, top). The value for variation in taxonomic distinctness (VarTD) for S-100 was above the confidence funnel (238.5, Figure 5, bottom). The remaining three seamounts showed VarTD values within the funnel, with macroinvertebrate assemblages from Balleny having lowest and Sturge highest VarTD values (153.9 and 173.0, respectively).

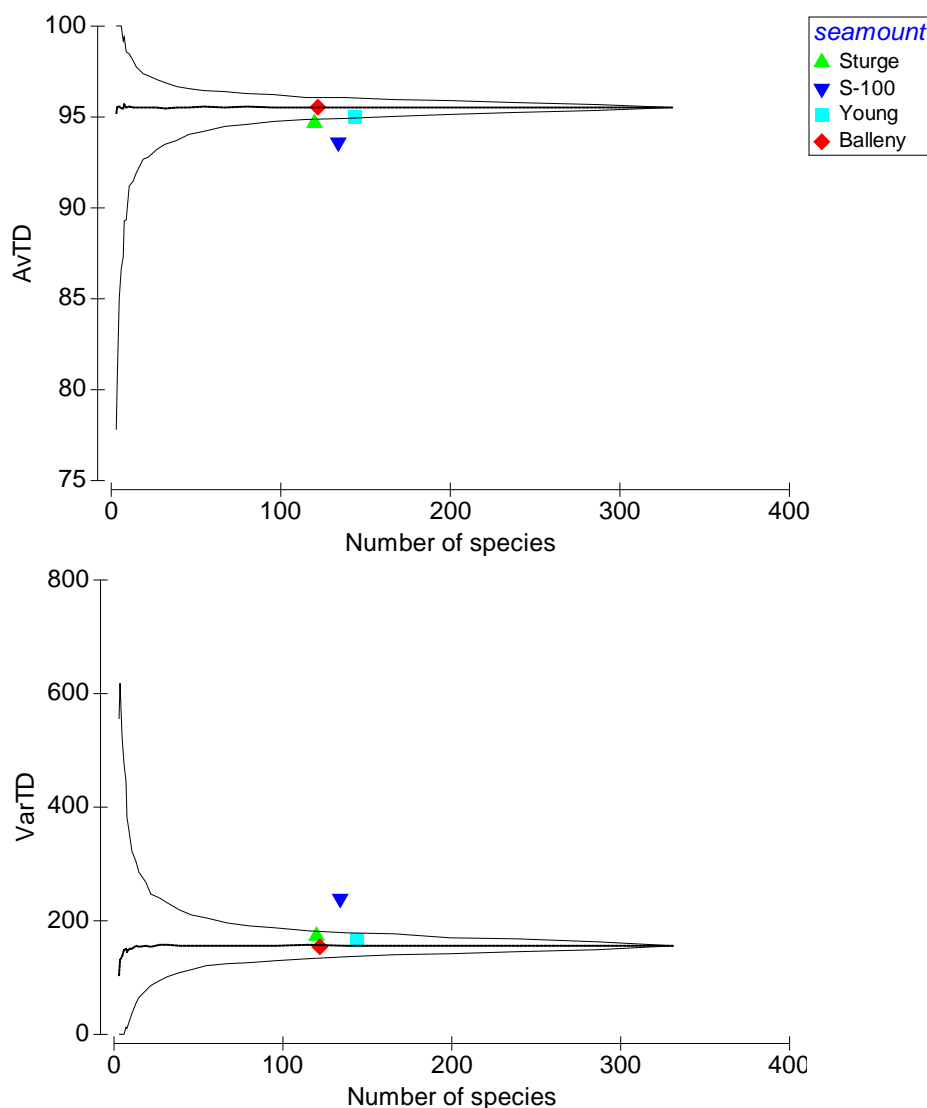


Figure 5: Departure from theoretical mean average taxonomic distinctness (AvTD; top) and variation in taxonomic distinctness (VarTD; bottom) and 95% confidence funnel, for macroinvertebrate assemblages from seamounts of the Balleny Islands.

3.2.2. Multivariate analysis

Different gear types were used in order to sample the different components of the benthic macroinvertebrate fauna of the Balleny Islands seamounts. The grab was used to sample the infauna; the epifauna was sampled by sled and the widely dispersed mega-epifauna by trawl deployments. Macroinvertebrate samples used for the assemblage analysis were recovered from a different range of overlapping water depths on the the four study seamounts: 111–526 m (S-100 seamount), 218–1444 m (Sturge seamount), 78–1570 m (Young-Buckle seamount), and 68–764 m (Balleny seamount). A visual analysis of the MDS plot for the presence-absence transformed abundance data (Figure 6) showed that samples generally clustered according to gear type although samples of all gear types showed relatively high variability. This visual observation was confirmed by an ANOSIM analysis (Global $R=0.433$ with $p\leq 0.001$) and further analyses were conducted for each gear type, i.e., assemblage type separately, in order to avoid possible confoundment.

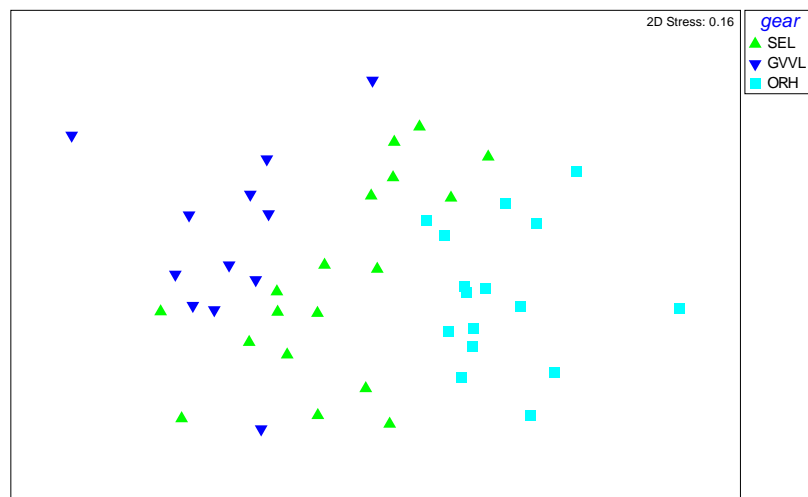


Figure 6: MDS ordination plot of Bray-Curtis similarity for presence-absence transformed macroinvertebrate abundance data for three assemblage types; infauna (grab, GVVL), epifauna (sled, SEL) and mega-epifauna (trawl, ORH) sampled at four Balleny Island seamounts. Stress value = 0.16.

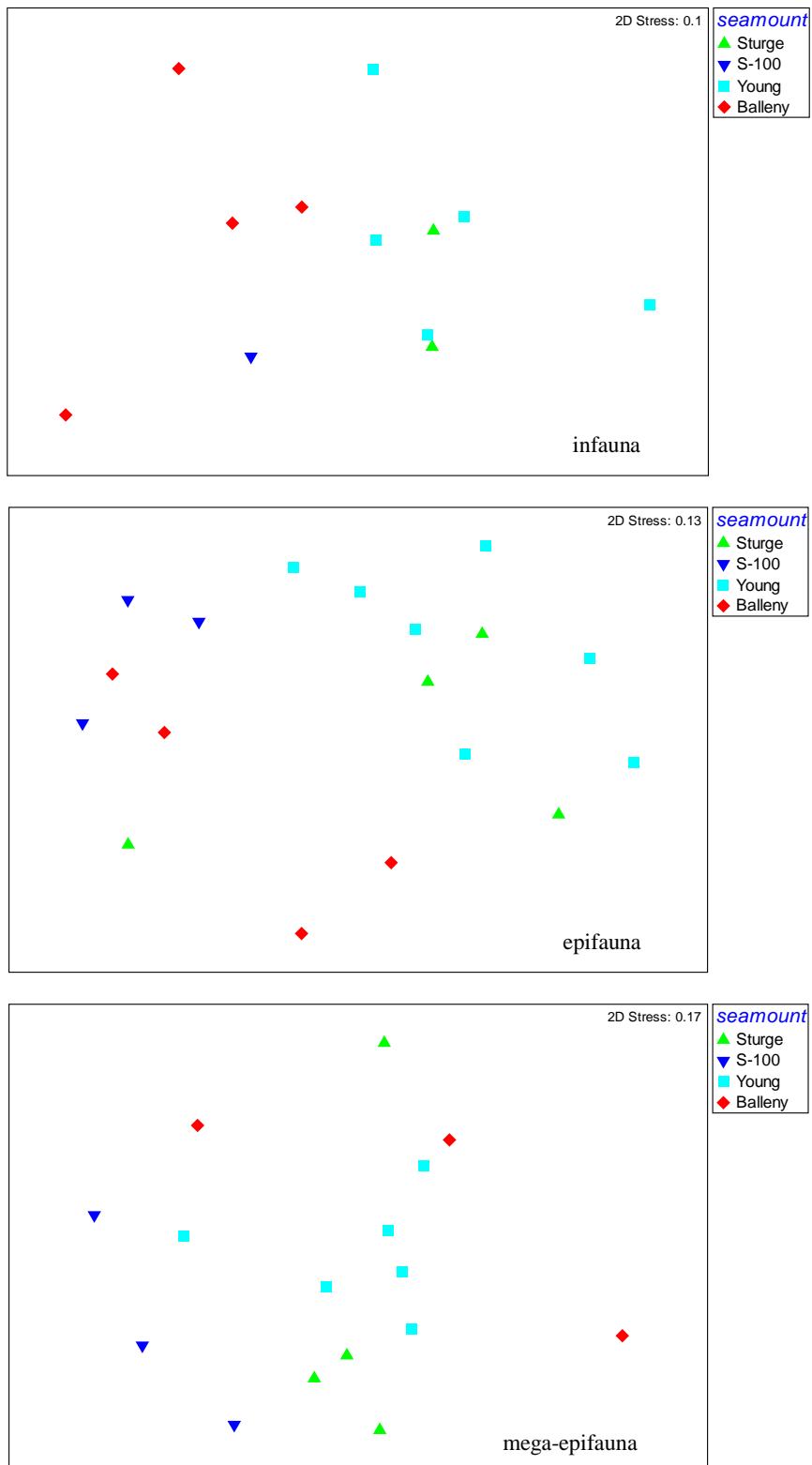


Figure 7: MDS ordination plot of Bray-Curtis similarity for presence-absence transformed infauna (top), epifauna (middle) and mega-epifauna (bottom) abundance data sampled at the Balleny Island seamounts. Stress values = 0.1, 0.13, 0.17, respectively.

The MDS ordination plots for the macroinvertebrate assemblage data of the Balleny Islands seamounts (Figure 7) illustrate a degree of sample clustering by seamount for all assemblage types. However, variability among samples appears to be high and some overlap between samples is apparent among seamounts. The formal ANOSIM tests revealed that only the epifauna and the mega-epifauna showed significant differences in assemblage composition among seamounts, with differences being more pronounced among epifauna (Global $R=0.45$, $p=0.002$) than mega-epifauna (Global $R=0.33$, $p=0.003$; Table 4). Pairwise tests indicated that the macroinvertebrate assemblages of S-100 and Young-Buckle were significantly different for both these assemblage types (epifauna: $R=0.69$, $p=0.008$; mega-epifauna: $R=0.61$, $p=0.012$), and Young-Buckle was also different from Balleny with respect to the mega-epifaunal assemblage composition.

Table 4: Pairwise comparison of differences in macroinvertebrate assemblage composition between the Balleny Islands seamounts (abundance data presence-absence transformed) for three assemblage types. Bold p -values indicate significance at a level of $p \leq 0.05$.

Assemblage type	Groups compared	R -value	Significance level p
Infauna	All seamounts	0.186	0.152
Epifauna	All seamounts	0.45	0.002
	Sturge/S-100	0.648	0.057
	Sturge/Young-Buckle	0.216	0.094
	Sturge/Balleny	0.354	0.114
	S-100/Young-Buckle	0.688	0.008
	S-100/Balleny	0.13	0.257
	Young-Buckle/Balleny	0.582	0.003
Mega-epifauna	All seamounts	0.331	0.009
	Sturge/S-100	0.148	0.229
	Sturge/Young-Buckle	0.171	0.133
	Sturge/Balleny	0.148	0.229
	S-100/Young-Buckle	0.614	0.012
	S-100/Balleny	0.5	0.10
	Young-Buckle/Balleny	0.423	0.048

Assemblage similarities varied relatively strongly among not only the seamounts but also among the assemblage types (Table 5). The Balleny seamount macroinvertebrate assemblage showed lowest similarities for all three assemblage types (infauna=14.8%, epifauna and mega-epifauna=10.2%). For Sturge seamount the infaunal assemblage was most similar (33.3 %) whereas for the epifaunal assemblage similarities were highest (25.0%) for S-100 seamount. At Young-Buckle seamount the mega-epifauna assemblage showed the highest measure of assemblage similarity (27.7%). Because only one infaunal sample from S-100 seamount was recovered no similarity values could be calculated.

Table 5: Group-average similarity (%) of macroinvertebrate abundance data from the Balleny Islands seamounts for each of three assemblage types (data presence-absence-transformed). No similarity value available for Sturge because only one infaunal sample was taken.

Seamount	Similarity (%)		
	Infauna	Epifauna	Mega-epifauna
Sturge	33.33	13.80	19.54
S-100	-	25.01	17.76
Young-Buckle	19.05	18.13	27.70
Balleny	14.84	10.22	10.23

The infauna of the Balleny Islands seamounts was dominated by polychaete species with only five species being responsible for up to 83% of cumulative similarity (Table 6). For Young-Buckle seamount, the lumbrinerid polychaete *Augeneria tentaculata* dominated the assemblage and contributed more than 30% to the cumulative similarity. However, none of the infaunal species occurred frequently enough to qualify as a typifying or characteristic species for any of the seamounts. The epifaunal assemblages were also dominated by relatively few species which were responsible for high cumulative similarities (between 61% for S-100 and 78% for Balleny seamounts). The epifauna of Young-Buckle seamount was strongly dominated by the capitellid polychaete *Notomastus latericeus*. Nonetheless, *N. latericeus* did not occur consistently enough to be a typifying species. The epifaunal assemblages of the seamount S-100 were characterised by three ophiuroid species, *Ophiocantha pentactis*, *Ophioceres incipiens* and *Ophionotus victoriae*, each with a ratio of Similarity/SD of 5.6. *Ophionotus victoriae* also characterised the epifaunal assemblage of Balleny seamount where the species contributed strongly and consistently (Av. Sim/SD=2.4). The picture is similar for the mega-epifaunal assemblages with only few species contributing strongly to cumulative similarities of each seamount. At Balleny seamount only two mega-epifaunal species occurred, the gorgonian coral *Acanthogorgia* sp. and the soft coral *Gersemia* sp. 1 with individual contributions of 60% and 40%, respectively. The asteroid *Porania antarctica* dominated the mega-epifaunal assemblage of S-100 and was a good typifying species for this seamount with Av Sim./SD=3.7. No other megafaunal species qualified as a typifying species for any of the macroinvertebrate assemblages of the other seamounts.

Table 6: Typifying macroinvertebrate species and their average contribution to cumulative similarity S for each of three assemblage types of the Balleny Islands seamounts. The five species contributing most are listed. Av. Abund=average abundance per seamount – for presence/absence data equates to frequency of occurrence, Av. Sim.=average similarity, SD=standard deviation, Contrib %=% contribution to similarity, Cum %=% cumulative similarity. Abundance data presence-absence transformed. ANT=Actinaria, ASC=Ascidia, ASR=Asteroidea, BIV=Bivalvia, COR=Stylasteridae, COZ=Bryozoa, CRI=Crinoidea, ECN=Echinoidea, GOC=Gorgonacea, HTH=Holothuroidea, POL=Polychaeta, PYC=Pycnogonida, OCT=Octopoda, ONG=Porifera, OPH=Ophiuroidea, SPH=Scaphopoda, SOC=Alcyonacea. Infauna: Sturge: no ratio of Av.Sim/SD could be calculated; S-100: fewer than two samples available in group.

Seamount	Species	Group	Av. Abund.	Av. Sim.	Av.Sim/SD	Contrib %	Cum %
Infauna							
Sturge	<i>Augeneria tentaculata</i>	POL	1.00	5.56	-	16.67	16.67
	<i>Notomastus latericeus</i>	POL	1.00	5.56	-	16.67	33.33
	<i>Pseudoscalibregma bransfieldium</i>	POL	1.00	5.56	-	16.67	50.00
	<i>Laonice weddellia</i>	POL	1.00	5.56	-	16.67	66.67
	<i>Tharyx cincinnatus</i>	POL	1.00	5.56	-	16.67	83.33
S-100	<2 samples available in group						
Young-Buckle	<i>Augeneria tentaculata</i>	POL	0.80	6.53	1.08	34.26	34.26
	<i>Notomastus latericeus</i>	POL	0.60	2.60	0.62	13.66	47.93
	<i>Tharyx cincinnatus</i>	POL	0.60	1.80	0.54	9.45	57.38
	<i>Ampharete kerguelensis</i>	POL	0.60	1.61	0.56	8.43	65.80
	<i>Aglaophamus trissophyllus</i>	POL	0.60	1.53	0.57	8.01	73.81
Balleny	<i>Glycera kerguelensis</i>	POL	0.75	3.57	0.86	24.06	24.06
	<i>Scoloplos marginatus mcleani</i>	POL	0.75	3.57	0.86	24.06	48.12
	<i>Amphicteis gunneri antarctica</i>	POL	0.50	1.15	0.41	7.75	55.87
	<i>Myriochele</i> sp. 1	POL	0.50	0.83	0.41	5.62	61.49
	<i>Notomastus latericeus</i>	POL	0.50	0.83	0.41	5.62	67.10
Epifauna							
Sturge	<i>Notomastus latericeus</i>	POL	0.75	3.67	0.89	26.64	26.64
	<i>Maldane sarsi antarctica</i>	POL	0.75	3.67	0.89	26.64	53.27
	<i>Phyllochaetopterus ?socialis</i>	POL	0.50	1.33	0.41	9.66	62.94
	<i>Augeneria tentaculata</i>	POL	0.50	0.95	0.41	6.90	69.84
	<i>Aglaophamus trissophyllus</i>	POL	0.50	0.95	0.41	6.90	76.74
S-100	<i>Ophiacantha pentactis</i>	OPH	1.00	4.14	5.57	16.57	16.57
	<i>Ophioceres incipiens</i>	OPH	1.00	4.14	5.57	16.57	33.15
	<i>Ophionotus victoriae</i>	OPH	1.00	4.14	5.57	16.57	49.72
	<i>Polynoe laevis</i>	POL	0.67	1.63	0.58	6.50	56.23
	<i>Thouarella</i> sp. 4	GOC	0.67	1.39	0.58	5.55	61.78
Young-Buckle	<i>Notomastus latericeus</i>	POL	0.86	7.89	1.13	43.54	43.54
	<i>Ophionotus victoriae</i>	OPH	0.57	1.78	0.55	9.81	53.34
	<i>Augeneria tentaculata</i>	POL	0.43	1.65	0.39	9.13	62.47
	<i>Nymphon australe</i> sp.	PYC	0.57	1.54	0.58	8.49	70.96
	<i>Dentalium majorinum</i>	SPH	0.43	0.91	0.37	5.04	76.00
Balleny	<i>Ophionotus victoriae</i>	OPH	1.00	5.57	2.43	54.53	54.53
	<i>Nymphon longicoxa</i>	PYC	0.50	0.76	0.41	7.41	61.94
	<i>Thouarella</i> sp. 4	GOC	0.50	0.56	0.41	5.44	67.38
	<i>Errina laterorifa</i>	COR	0.50	0.56	0.41	5.44	72.82
	<i>Limopsis marionensis</i>	BIV	0.50	0.56	0.41	5.44	78.25

Seamount	Species	Group	Av. Abund.	Av. Sim.	Av.Sim/SD	Contrib %	Cum %
Mega-Epifauna							
Sturge	<i>Thouarella</i> sp. 1	GOC	0.75	2.28	0.88	11.64	11.64
	<i>Laetmonice producta</i>	POL	0.75	2.28	0.88	11.64	23.29
	<i>Astrotoma agassizii</i>	OPH	0.75	2.28	0.88	11.64	34.93
	<i>Ophionotus victoriae</i>	OPH	0.75	2.28	0.88	11.64	46.58
	<i>Ascidia challengerii</i>	ASC	0.75	2.28	0.88	11.64	58.22
S-100	<i>Porania antarctica</i>	ASR	1.00	5.33	3.71	29.99	29.99
	<i>Tedania (Tedaniopsis) triraphis</i>	ONG	0.67	2.30	0.58	12.94	42.93
	<i>Sterechinus neumayeri</i>	ECN	0.67	1.67	0.58	9.38	52.31
	<i>Reteporella erugata</i>	COZ	0.67	1.67	0.58	9.38	61.70
	<i>Gersemia</i> sp. 1	SOC	0.67	1.36	0.58	7.66	69.36
Young-Buckle	<i>Psychoroteuthis glacialis</i>	OCT	0.67	3.52	0.78	12.70	12.70
	<i>Ophionotus victoriae</i>	OPH	0.67	3.09	0.76	11.16	23.86
	<i>Laetmogone</i> sp.	HTH	0.67	3.02	0.78	10.90	34.76
	<i>Acanthogorgia</i> sp.	GOC	0.67	2.95	0.78	10.66	45.42
	<i>Bathyblaster loripes obesus</i>	ASR	0.67	2.65	0.77	9.57	54.99
Balleny	<i>Acanthogorgia</i> sp.	GOC	0.67	6.06	0.58	59.26	59.26
	<i>Gersemia</i> sp. 1	SOC	0.67	4.17	0.58	40.74	100.0

Dissimilarity measures for seamounts significantly different in their macro-invertebrate assemblage composition (2-way crossed ANSOSIM, Table 7) are given in Table 8. Dissimilarities were high and ranged between 84.6% for the mega-epifaunal assemblages of Young-Buckle and Balleny, and 93.9% for the epifaunal assemblages of the same seamounts.

Table 7: Average Dissimilarity (%) for group-wise comparisons of macroinvertebrate assemblages from the Balleny Island seamounts analysed for each of three assemblage types. Data presence-absence transformed. Only significantly different comparisons are listed (ANOSIM).

Assemblage Type	Seamounts	Av. Diss. %
Infauna	Young-Buckle, Balleny	88.73
Epifauna	S-100, Young-Buckle	93.46
	Young-Buckle, Balleny	93.90
Mega-epifauna	S-100, Young-Buckle	86.53
	Young-Buckle, Balleny	84.60

Contributions of individual species to measures of assemblage dissimilarity between seamounts were small for all assemblage types (Table 8). Many species occurred at one but not the other seamount in the pairwise comparisons. The five species contributing most to the dissimilarities between the infaunal assemblages of Young-Buckle and Balleny seamounts were polychaetes but none of them was a good discriminatory species. Highest contributions to dissimilarity were made by the lumbrinerid *Augeneria tentaculata* which occurred at Young-Buckle but not at Balleny. The frequent occurrence of the capitellid *N. latericeus* in the epifaunal assemblage of Young-Buckle seamount made this species a good discriminator between the assemblages of Young-Buckle and S-100 (Av.Sim/SD=1.8) and Young-Buckle and Balleny (Av.Sim/SD=1.5). The ophiuroids *Ophiacantha pentactis* and *Ophioceres incipiens* were even better discriminators between the epifaunal assemblages of Young-Buckle and S-100 seamounts, with ratios of Av.Sim/SD of 2.7 for each species. Both species occurred on S-100 but not at the Young-Buckle seamount. None of the mega-epifaunal species qualified as discriminatory species. The demosponge *Tedania (Tedaniopsis)*

triraphis contributed most to dissimilarities between the mega-epifaunal assemblages of Young-Buckle and S-100 seamounts because this species occurred only at S-100. The asteroids *Bathyblaster loripes obesus* and *Labidiaster annulatus* contributed most to the dissimilarities in mega-epifaunal assemblages between Young-Buckle and Balleny seamount. Both asteroid species occurred only on the latter seamount.

Table 8: Breakdown of average dissimilarity between assemblages of the Balleny Islands seamounts into contributions from each species for each of three macroinvertebrate assemblage types. Only the five species contributing the most to the measure of dissimilarity or species with AvDis/SD ≥ 1.3 are listed. Av. Abund=average abundance per seamount – for presence/absence data equates to frequency of occurrence, Av. Diss.=average dissimilarity (%), SD=standard deviation of average dissimilarity, Contrib %=contribution to dissimilarity, Cum %=cumulative dissimilarity. Abundance data presence-absence transformed. Abbreviation for taxa as in Table 6

Groups compared	Species	Taxa	Group 1	Group 2	Av. Diss.	Av. Diss./SD	Contrib. %	Cum. %
			Av. Abund.	Av. Abund.				
Infauna								
Young-Buckle, Balleny	<i>Augeneria tentaculata</i>	POL	0.80	0.00	3.44	1.28	3.88	3.88
	<i>Scoloplos marginatus mcleani</i>	POL	0.20	0.75	2.95	0.99	3.32	7.20
	<i>Glycera kerguelensis</i>	POL	0.40	0.75	2.53	0.83	2.85	10.05
	<i>Amphicteis gunneri antarctica</i>	POL	0.00	0.50	2.27	0.74	2.55	12.61
	<i>Tharyx cincinnatus</i>	POL	0.60	0.25	1.92	0.87	2.16	14.76
Epifauna								
S-100, Young-Buckle	<i>Ophiacantha pentactis</i>	OPH	1.00	0.00	2.92	2.73	3.12	3.12
	<i>Ophioceres incipiens</i>	OPH	1.00	0.00	2.92	2.73	3.12	6.25
	<i>Notomastus latericeus</i>	POL	0.00	0.86	2.63	1.78	2.81	9.06
	<i>Polynoe laevis</i>	POL	0.67	0.00	2.18	1.20	2.33	11.39
	<i>Thouarella</i> sp. 4	GOC	0.67	0.00	2.03	1.14	2.17	13.56
Young-Buckle, Balleny	<i>Notomastus latericeus</i>	POL	0.86	0.00	3.36	1.46	3.58	3.58
	<i>Ophionotus victoriae</i>	OPH	0.57	1.00	1.86	0.74	1.98	5.57
	<i>Augeneria tentaculata</i>	POL	0.43	0.00	1.75	0.73	1.86	7.43
	<i>Nymphon longicoxa</i>	PYC	0.00	0.50	1.68	0.83	1.79	9.22
	<i>Nymphon australe</i> sp.	PYC	0.57	0.00	1.64	0.96	1.74	10.96
Mega-epifauna								
S-100, Young-Buckle	<i>Tedania (Tedaniopsis) triraphis</i>	ONG	0.67	0.00	2.44	1.28	2.82	2.82
	<i>Psychoroteuthis glacialis</i>	OCT	0.00	0.67	2.31	1.23	2.67	5.49
	<i>Porania antarctica</i>	ASR	1.00	0.33	2.31	1.23	2.67	8.17
	<i>Ophionotus victoriae</i>	OPH	0.00	0.67	2.19	1.21	2.54	10.70
	<i>Sterechinus neumayeri</i>	ECN	0.67	0.00	2.18	1.18	2.52	13.22
Young-Buckle, Balleny	<i>Bathyblaster loripes obesus</i>	ASR	0.67	0.00	3.23	1.26	3.84	3.84
	<i>Labidiaster annulatus</i>	ASR	0.67	0.00	3.23	1.26	3.84	7.68
	<i>Psychoroteuthis glacialis</i>	OCT	0.67	0.33	3.12	1.01	3.72	11.40
	<i>Ophionotus victoriae</i>	OPH	0.67	0.33	3.01	1.00	3.58	14.98
	<i>Laetmogone</i> sp.	HTH	0.67	0.33	2.96	1.02	3.52	18.50

A BVSTEP analysis matched the macroinvertebrate assemblage patterns observed with the environmental variables measured in order to elucidate which of the environmental variables were the likely ‘drivers’ of assemblage composition for the Balleny Islands seamounts. The environmental variables excluded from the analysis due to a correlation value of at least 0.9 were mean spring ice cover (%) (correlated to mean annual ice cover) and mean grain size (correlated to median grain size and to % fines). Sediment characteristics and the biological habitat complexity were available only for grab samples and thus were included only in analysis of the infaunal assemblages (Table 9).

Table 9: List of environmental variables included in BVSTEP analysis.

Environmental variables included in BVSTEP analysis
Actual depth (m)
Mean surface chl <i>a</i> content spring (mg/m ³)
Mean surface chl <i>a</i> content summer (mg/m ³)
Mean annual ice cover (%)
Mean summer ice cover (%)
Biological habitat complexity (BHC) *
Sorting coefficient*
Median grain size (phi) *
Sediment chl <i>a</i> content (ng/g) *
% particulate organic carbon (POC) *
% fines (>63 µm) *
% pebbles (>4 mm) *
Sponge spicule content *

* Variables only available for grab samples, i.e., only for correlation between infaunal assemblages and environmental variables.

Water depth was an important factor in all the best combinations of environmental variables that explained the assemblage patterns of infauna, epifauna and mega-epifaunal assemblages of the Balleny Islands seamounts (Table 10). For the infaunal assemblage patterns a combination of seven environmental variables with a Spearman rank correlation of $\rho=0.62$ ($p=0.01$) had the best explanatory power. In addition to water depth, this combination consisted of satellite derived variables such as the surface chlorophyll *a* content in spring and the mean ice cover in summer, but also of sediment characteristics such as the particulate organic carbon content (POC), the sorting coefficient, % fines and % pebbles. The single variable with the highest correlation was % fines (\equiv mean grain size) of the sediment ($\rho=0.44$) followed by the surface chl *a* content in summer ($\rho=0.28$). The epifaunal assemblage patterns were best matched by a combination of water depth, the surface chl *a* content in spring and the mean annual ice cover (\equiv mean spring ice cover), but the correlation had far less explanatory power ($\rho=0.25$, $p=0.04$) than the combination of variables for the infaunal assemblages of the Balleny Islands seamounts. Water depth proved to be the variable with the single most explanatory environmental power and had only a slightly weaker correlation factor ($\rho=0.23$) than the combination of the three variables together. For the mega-epifaunal assemblages depth and the mean ice cover in summer were the best explanatory combination of environmental variables ($\rho=0.36$; $p=0.02$). The mean ice cover in summer on its own had an explanatory power of nearly 30% ($\rho=0.29$) and the water depth explained nearly 15% ($\rho=0.14$).

Table 10: Environmental variables (best combination and best single variable) explaining macroinvertebrate assemblage composition patterns for infaunal, epifaunal and mega-epifaunal assemblages of the Balleny Islands seamounts. Significance level p given in brackets.

Assemblage type	Best combination	Spearman rank correlation ρ	Best single variable	Spearman rank correlation ρ
Infauna	Water depth	0.616 ($p=0.01$)	% fines	0.442
	Surface chl a spring		Surface chl a summer	0.280
	Mean ice cover summer		Median grain size (ϕ)	0.249
	POC			
	Sorting coefficient			
Epifauna	% fines	0.253 ($p=0.04$)	Water depth	0.228
	% pebbles		Surface chl a spring	0.093
	Water depth		Mean ice cover summer	0.093
	Surface chl a spring			
Mega-epifauna	Mean annual ice cover	0.359 ($p=0.02$)	Mean ice cover summer	0.289
	Water depth		Water depth	0.143
	Mean ice cover summer			

3.3 Fish assemblages

A total of 876 fishes belonging to 23 putative species in 9 families were sampled by 5 sled and 15 trawl deployments on the four Balleny Islands seamounts Sturge, S-100, Young-Buckle and Balleny (for species list see Appendix 7).

The greatest number of species ($S=18$) and also highest mean abundance were recorded from Young-Buckle seamount ($N=66$) where the number of valid samples included in the analysis was also highest (six trawls and one sled sample; Table 11). Only five species were caught on S-100 seamount with mean abundance also being low ($N=21$). However, these values cannot be used for any statistically meaningful comparison because of the differences in the number of samples (and gears used to obtain these samples) between seamounts. Thus, as noted earlier, measures of taxonomic distinctness were employed to allow for a robust diversity analysis.

Table 11: Number of fish samples (trawl and sled), mean number of species (S) and mean number of individual fish (N) per sample from the Balleny Islands seamounts.

Seamount	Number of samples	Mean S	Mean N
Sturge	5	16	42
S-100	5	5	21
Young-Buckle	7	18	66
Balleny	5	8	30

3.3.1 Univariate analysis

No significant differences were detected by the ANOVA test when comparing the mean AvTD and VarTD values for fish assemblages among the seamounts (Table 12).

Table 12: ANOVA results for comparisons of biodiversity indices Average taxonomic distinctness (AvTD) and Variation in taxonomic distinctness (VarTD) of fish assemblages from the Balleny Island seamounts Sturge, S-100, Balleny and Young-Buckle. Where ANOVA data assumptions were violated, ranked data were used. Significant results in red (significance level set at $p \leq 0.05$)

Factor	Data	MS	dF	F	p -value
AvTD	Unranked	127.73	3	0.2832	0.8368
VarTD	Ranked	72.76	3	2.7163	0.0793

Mean measures of AvTD were similar among seamounts, with only Young-Buckle seamount having a slighter higher value (Figure 8). Mean values of VarTD were, respectively, highest for Sturge and Young-Buckles seamounts, and lowest for S-100 and Balleny seamounts (Figure 8).

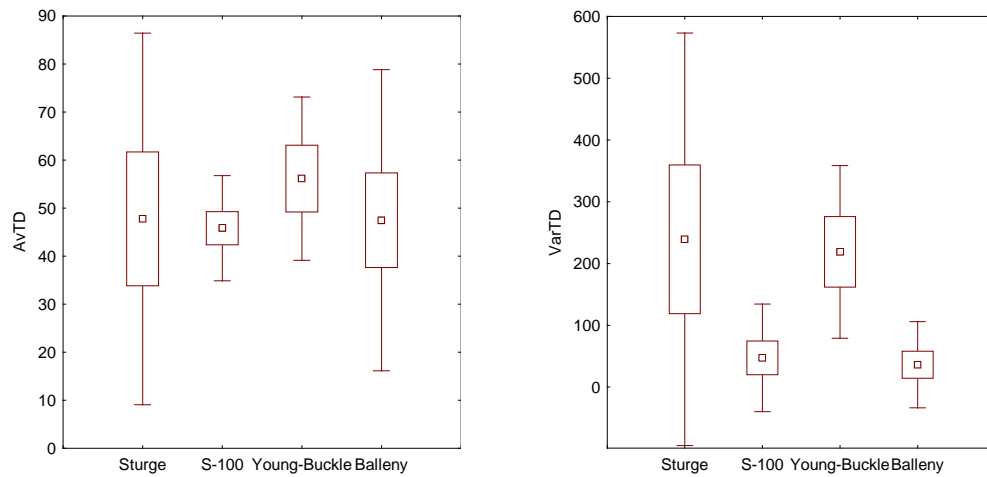


Figure 8: Mean (small square), standard error (box) and 95 confidence intervals (bar) values for Average taxonomic distinctness (AvTD) and Variation in taxonomic distinctness (VarTD) of fish assemblages from the Balleny Island seamounts Sturge, S-100, Balleny and Young-Buckle.

The TAXDTEST revealed that fish assemblages from all seamounts were not significantly different from the theoretical mean of the regional species pool, i.e. all values were well within the 95% confidence funnel (Figure 9). 1. Lowest values for the average taxonomic distinctness (AvTD) and also for variation in taxonomic distinctness (VarTD) were calculated for the fish assemblage of S-100 seamount (AvTD=48; VarTD=96), whereas the values for AvTD were very similar for the assemblages of the remaining three seamounts (AvTD≈63). Variation of taxonomic distinctness showed a wider range, with VarTD=320.4 for the Balleny seamount fish assemblage and VarTD=597.8 for the assemblage of Sturge seamount.

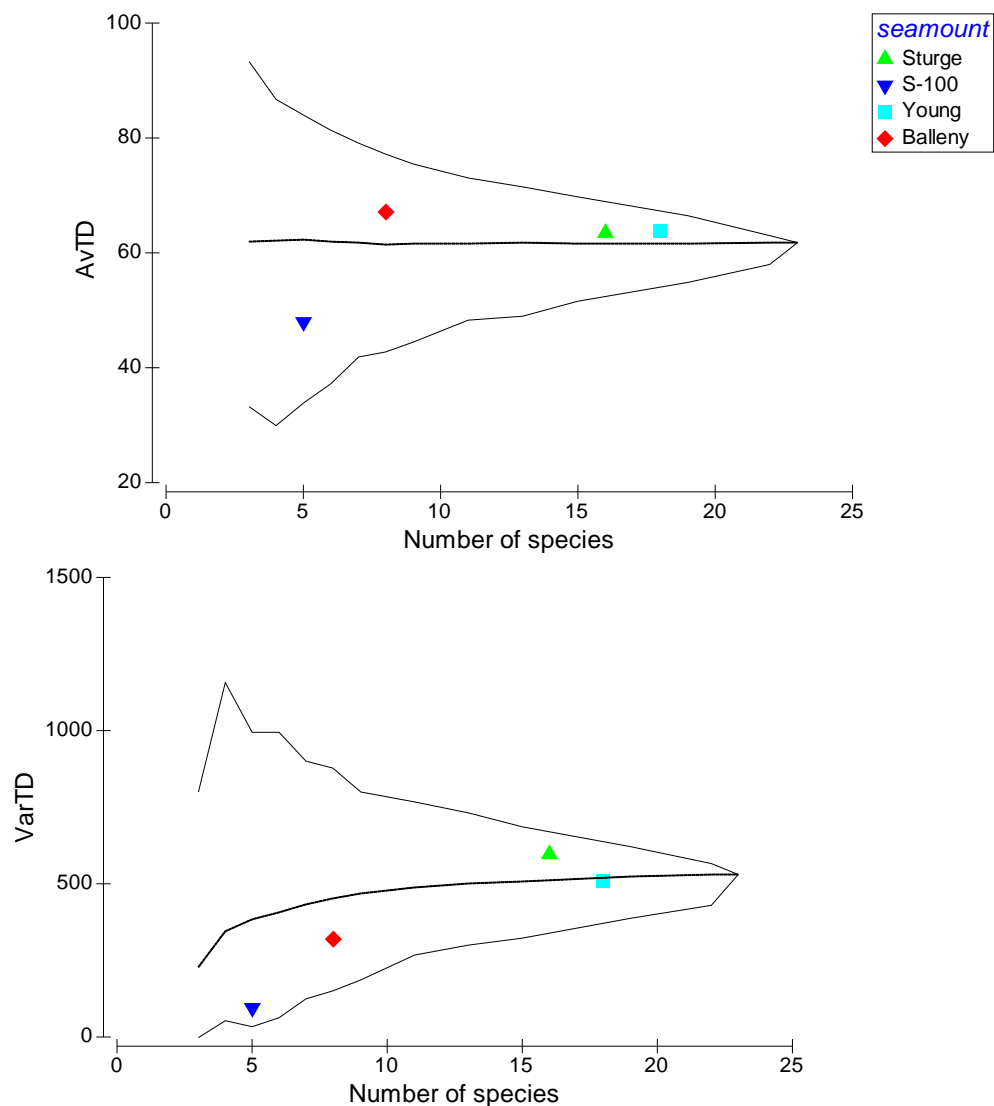


Figure 9: Average taxonomic distinctness (AvTD; top) and variation in taxonomic distinctness (Var TD, bottom) for fish assemblages from the Balleny Islands seamounts.

3.3.2 Multivariate analysis

Multivariate analyses were based on quantitative data only (20 stations: 876 individuals belonging to 23 putative species). Samples were recovered from a different range of water depths (but overlapping) on the the four study seamounts: 117–526 m (S-100 seamount), 218–1444 m (Sturge seamount), 78–1570 m (Young-Buckle seamount), 96–764 m (Balleny seamount). Initial visual comparisons in the form of an MDS ordination of data from sled and trawl deployments (data presence-absence transformed) revealed no clear clustering between the gear types used (Figure 10 top). Statistical analysis confirmed that there was no significant difference between assemblages sampled by sleds and trawls (ANOSIM: Global $R=0.087$ with $p=0.23$) and because one sled sample was taken on each seamount all further analyses were conducted using sled and trawl data combined.

The MDS ordination plot for fish assemblage data exhibited no clear clustering by sample grouping seamount (Figure 10, bottom). In two instances samples were so similar in their assemblage composition that they were overlying each other in the ordination: in both instances one sample was

from the Balleny and the other from the S-100 seamount. With the exception of S-100, variability in assemblage composition was high for all seamounts sampled.

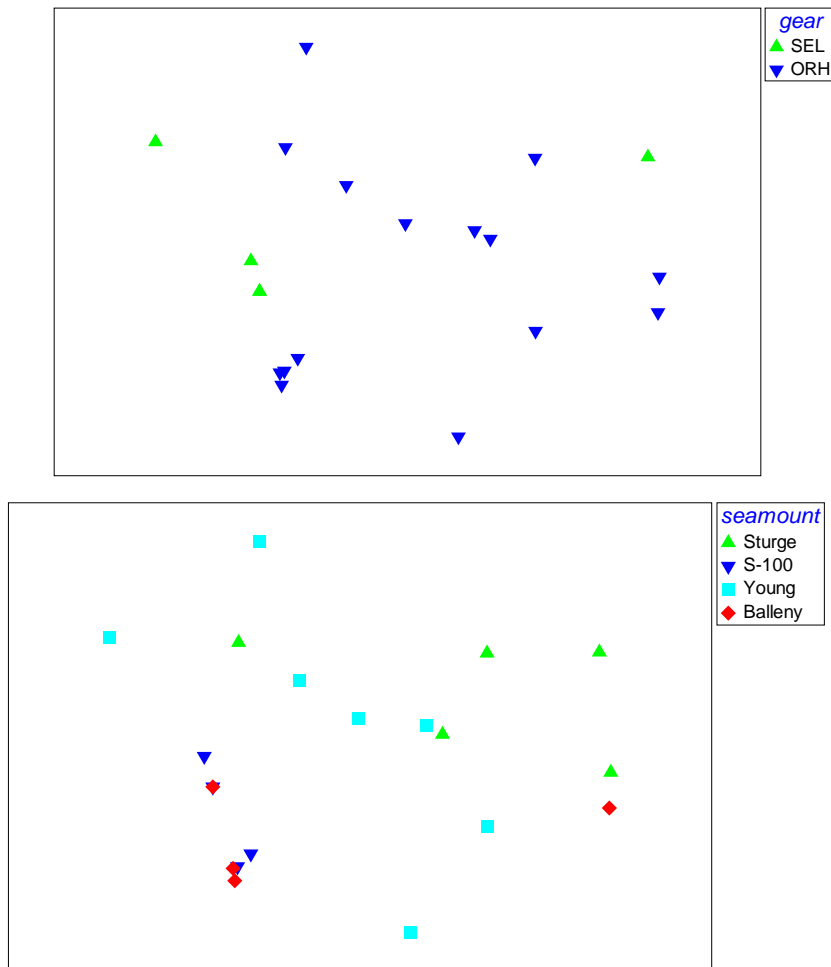


Figure 10: MDS ordination using Bray-Curtis similarities for absence-presence transformed fish abundance data obtained from 15 trawl and 5 sled deployments on the Balleny Islands seamounts. Top: factor gear; bottom: factor seamount. Stress value =0.11.

A one-way ANOSIM analysis revealed that differences in assemblage composition among seamounts were still significant (Global $R=0.186$; $p=0.04$), albeit with the differences being very small. Pairwise comparisons revealed that only the fish assemblages of Sturge and S-100 were significantly different in composition ($R=0.688$, $p=0.016$). All other comparisons of assemblage composition between seamount were non-significant (Table 13).

Table 13: Pairwise comparison of differences in fish assemblage composition between the Balleny Islands seamounts (data presence-absence transformed). Bold *p*-values indicate significance at a level of $p \leq 0.05$.

Groups compared	<i>R</i> -value	Significance level <i>p</i>
Sturge, S-100	0.688	0.016
Sturge, Young-Buckle	0.091	0.220
Sturge, Balleny	0.291	0.095
S-100, Young-Buckle	0.111	0.242
S-100, Balleny	-0.068	0.629
Young-Buckle, Balleny	0.079	0.285

With the exception of S-100 seamount, similarities in fish assemblage composition were relatively low for the Balleny Island seamounts. The fish assemblage of S-100 had the highest measure of similarity for its composition (61.50%), whereas the similarity of the assemblage of Young-Buckle seamount was the lowest with 27.60% (Table 14).

Table 14: Group-average similarity (%) for fish abundance data obtained from trawl and sled deployments on four Balleny Islands seamounts (data absence-presence transformed).

Seamount	Similarity (%)
Sturge	30.67
S-100	61.50
Young-Buckle	27.60
Balleny	35.07

Only a few fish species contributed to the measures of cumulative similarities for assemblages of three out of four seamounts. For S-100 and Balleny seamounts, only one species, the Antarctic cod *Lepidonotthen kempfi* (Table 15), made up more than 80% of the cumulative similarity. *Lepidonotthen kempfi* was also the species characterising the fish communities of S-100 and Young-Buckle seamounts (with ratios of av.sim./SD of 4.6 for S-100 and 1.3 for Young-Buckle). No other species was identified as a good typifying species for any of the seamount assemblages sampled, even though the occurrence of the rattail *Macrourus whitsoni* contributed over 75% to the measure of similarity for Sturge seamount.

Table 15: Typifying species and their average contribution to cumulative similarity *S* for fish assemblages of the Balleny Islands seamounts. Only the five species contributing most to the measure of similarity are listed. Av. Abund=average abundance per seamount, Av. Sim.=average similarity, SD=standard deviation, Contrib %=contribution to similarity, Cum %=cumulative similarity. Based on presence-absence transformed abundance data.

Seamount	Species	Av. Abund.	Av. Sim.	Sim/ SD	Contrib %	Cum %
Sturge	<i>Macrourus whitsoni</i>	6.18	23.18	1.08	75.59	75.59
	<i>Trematomus eulepidotus</i>	1.76	2.76	0.60	8.99	84.58
	<i>Lepidotothen kempi</i>	1.47	2.14	0.58	6.97	91.55
S-100	<i>Lepidotothen kempi</i>	8.24	50.74	4.59	82.49	82.49
	<i>Lepidonotothen larsoni</i>	3.48	6.90	0.41	11.22	93.72
Young-Buckle	<i>Lepidotothen kempi</i>	3.45	9.86	1.34	35.70	35.70
	<i>Macrourus whitsoni</i>	2.47	3.85	0.59	13.96	49.67
	<i>Lepidonotothen larsoni</i>	2.83	3.55	0.38	12.85	62.51
	<i>Notothenia coriiceps</i>	1.64	3.09	0.59	11.20	73.72
	<i>Trematomus bernacchii</i>	1.31	1.97	0.39	7.13	80.85
Balleny	<i>Lepidotothen kempi</i>	6.88	33.37	0.90	95.16	95.16

The discriminating species for the two seamounts that were significantly different in their assemblage composition, Sturge and S-100, are listed in Table 16. The dissimilarity between these two fish assemblages was 82.78%. The rattail *M. whitsoni*, which only occurred at Sturge but not on S-100 seamount, and the icecod *L. kempi*, which was rather abundant on S-100, but only occurred in low abundances on Sturge, contributed most to the cumulative assemblage dissimilarity between the two seamounts. Both species occurred frequently enough to be good discriminatory species between the fish assemblages of Sturge and S-100.

Table 16: Discriminating species and their average contribution to cumulative dissimilarity for pairwise comparisons of fish assemblages of the Balleny Islands seamounts. Only the five species contributing most to the measure of dissimilarity are listed. Av. Abund=average abundance per seamount, Av. Diss.=average dissimilarity, SD=standard deviation, Contrib %=contribution to dissimilarity, Cum %=cumulative dissimilarity. Only significantly different pairwise combinations are listed. Based on presence-absence transformed abundance data.

Groups compared	Species	Group 1		Group 2		Contrib %	Cum %
		Av. Abund.	Av. Abund.	Av. Diss.	Diss/SD		
Sturge, S-100	<i>Lepidotothen kempi</i>	1.76	8.24	20.85	2.14	24.23	24.23
	<i>Macrourus whitsoni</i>	6.18	0.00	20.63	1.50	23.98	48.21
	<i>Lepidonotothen larsoni</i>	1.13	3.48	10.98	0.96	12.76	60.97
	<i>Trematomus hansonii</i>	1.33	0.86	5.29	0.89	6.14	67.11
	<i>Pleurogramma antarcticum</i>	1.61	0.00	4.95	0.49	5.75	72.86

A BVSTEP analysis was conducted in order to link patterns observed in fish assemblage composition with environmental data obtained at the Balleny Islands seamounts (water depth, mean surface chlorophyll *a* content in summer, mean ice cover summer and mean annual ice cover). Mean ice cover in spring correlated with mean ice cover in summer ($\rho=0.92$) and thus was eliminated from the analysis. Depth was the environmental variable best matching the biological patterns observed with a

Spearman rank correlation of $\rho=0.55$ and $p=0.01$. The combination of depth and the mean ice cover summer had a lower correlation value of $\rho=0.43$.

4. DISCUSSION

4.1 The sampling effort and the taxonomic impediment

During the BioRoss study, extensive sampling was undertaken of the deepwater (50–750 m) benthic macroinvertebrate and fish assemblages of on the northwestern Ross Sea shelf off the Victoria Land coast between Cape Adare and Cape Hallett, as well as the Balleny Islands seamounts. Since the return of the sampling voyage from Antarctica in March 2004, over 8000 specimen lots have been processed, and the identification of 1190 taxa to putative species level took a great deal of effort by a large number of people and three years to complete. In part the delay between sampling and the delivery of data that could be analysed is the result of the small number of available taxonomists (the so-called “taxonomic impediment” of Giangrande 2003), which is a particular concern in the New Zealand context (Nelson & Gordon 1997). However, analysis of data resulting from the BioRoss survey has now allowed for a description and quantification of the diversity of the target assemblages, and a determination of the importance of certain environmental variables that influence benthic assemblage composition in part of New Zealand’s Ross Dependency.

4.2 A wider context for discussing the results

Since the BioRoss study was conceived and conducted, other surveys including a survey of the shallow water biodiversity of the Balleny Islands has been undertaken and reported upon (Nelson et al. 2010). However, no new papers have been published on the deepwater macrofauna communities of the Balleny Islands. Thus, the present results provide the first such data for the islands since the much more limited sampling that was undertaken more than 40 years ago (see Dawson 1970 for summary). The BioRoss survey has provided material from the Balleny Islands that has already contributed to furthering understanding of the colonisation of the Southern Ocean by lithodid crabs (Thatje & Lörz 2005, Ahyong & Dawson 2006). The deepwater fauna of other Antarctic Islands have been the subject of much greater study, in particular the South Shetland Islands (Gallardo & Castillo 1969, Jazdzewski et al. 1986, Mühlenhardt-Siegel 1988, Sáiz -Salinas et al. 1997, Piepenburg et al. 2002, Cranmer et al. 2003, Lovell & Trego 2003) which occur at somewhat more northern latitudes (approximately 62–63° S) than the Balleny Islands (approximately 65–67° S) on the other side of the Antarctic continent. There has in recent years been little in the way of publications that concern themselves with hypotheses that relate to the composition of benthic communities of seamount habitats in general, although those that have been published are of particular significance (e.g., Samadi et al. 2006, O’Hara 2007, McClain 2007, Hall-Spencer et al. 2007). Considering that only four seamounts all within 300 km of one another were sampled during the BioRoss study, an examination of the present results with respect to the ‘stepping-stone’ hypothesis (Hubbs 1959) is bound to be somewhat limited, and even more so for the fish than the macroinvertebrate assemblages. Indeed at the instigation of the BioRoss study it was envisaged that data obtained would be compared to those gathered elsewhere at a later date (see section Future Research). Nonetheless, it is worth examining briefly the results of the present study for the Balleny Islands seamounts in the context of the hypothesis as well as, where possible the other hypotheses that relate more specifically to the Ross Sea component of the BioRoss study, and in comparison to findings from deepwater studies of other Antarctic Islands.

4.3 The environment of the Balleny Islands seamounts

The four Balleny Islands seamounts that were the subject of study, although they occur in a similar depth range, are quite different in size (area). The smallest, S-100 seamount, is over 60 times smaller

than the largest, Young-Buckle seamount. Despite the relatively close proximity of the seamounts to each other, quite large differences in environmental variables occur among them. Balleny seamount had the lowest observed values for surface (spring) and sediment chl *a*, and mean ice cover in summer (0.31 mg m⁻³, 0.81 g µg⁻¹ and 25.8 %, respectively), whilst Young-Buckle seamount had the highest values for the two chl *a* variables (0.96 mg m⁻³ and 4.34 g µg⁻¹, respectively) and S-100 the highest value for summer ice cover (42.8%). Thus, there is some reason to expect that there may be differences in macrofauna assemblage composition between the seamounts that would be independent of the effect of geographic distance.

4.4. Macroinvertebrate assemblages

4.4.1 Univariate analysis

4.4.1.1 Energy-diversity hypothesis

The mean measures of AvTD and VarTD were not significantly different among the study seamounts. However, relative measures of AvTD and VarTD for the assemblages of Young-Buckle and Balleny seamount provide some support for the hypothesis that levels of productivity influence the diversity of macroinvertebrate assemblages. Among the four study seamounts levels of productivity (as measured by both surface water and sediment chl *a*) were highest for Young-Buckle seamount. As initially predicted, mean values of AvTD and VarTD are relatively high and low, respectively, for the assemblage of this seamount. At Balleny seamount, where measures of both productivity proxies were relatively low, the converse prediction was also supported by the relatively low AvTD and high VarTD observed. Previous research on seamount communities has implicated the importance of the overlying primary productivity regime and the deposition of derived detritus on the composition of benthic macrofauna on a seamount (Piepenburg & Muller 2004), but as yet no evidence has similarly been presented to explain differences among seamounts. Further potential reasons for the patterns of biodiversity observed among the Balleny Islands seamounts are discussed below (see multivariate section).

4.4.1.2 Seamounts as islands hypothesis

According to the initial prediction for the seamounts as islands hypothesis, low and high values of AvTD and VarTD for an assemblage (respectively) are in a regional context associated with relative isolation. The mean measures of AvTD and VarTD for macroinvertebrate assemblages of the Balleny Islands seamounts were generally similar to one another, apart from those for S-100. Both TD values for the assemblage of S-100 seamount were significantly different from the regional mean, being lower and higher for AvTD and VarTD, respectively. This result suggests that the fauna of S-100 seamount has a distinct taxonomic structure that is observable on a regional scale, which could possibly be caused by factors related to relative physical isolation. Hall-Spencer et al. (2007) found a similar pattern for coral assemblages on some seamounts in the North Atlantic. However, samples from S-100 seamount were generally taken from shallower water depths, and the influence of this and other factors on biodiversity are discussed further below (see multivariate section).

4.4.2 Multivariate analysis

4.4.2.1 Energy-diversity hypothesis

The results of the ANOSIM test revealed that overall there are statistically significant differences in the composition of the study seamounts for the epifauna and mega-epifauna assemblage types, but not

for the infauna. It should be remembered that there were insufficient infaunal data from S-100 seamount for it to be included in the analysis. The omission of data for this seamount could account for the lack of an overall difference in comparison to the other two assemblage types for which there were sufficient data from all four seamounts. However, previous Antarctic studies have noted the apparent similarity of the polychaete dominated infaunal assemblages between islands within a group and even between groups of islands distant from one another (Jazdzewski et al. 1986, Mühlenhardt-Siegel 1988). The overall difference among seamount assemblages is more pronounced for the epifauna than for the mega-epifauna, although pairwise comparisons indicate that the greatest significant differences in assemblage composition follow a similar pattern for both faunal types. That is, significant differences in assemblage composition exist only between the seamount Young-Buckle and the seamounts S-100 and Balleny. Similarly, the pairwise comparison for the infauna indicated that the assemblage of Young-Buckle is significantly different from that found on Balleny. These results provide some support for the energy-diversity hypothesis, because according to both proxy measures of energy, Young-Buckle (high energy) and Balleny (low energy) seamounts were the most distinct in terms of productivity. S-100 seamount also had relatively low measures of sediment chl *a*. The SIMPER analysis revealed that the contributions by individual species to the level of dissimilarities observed between seamounts are small. Species of polychaete contributed the most to the differences in infaunal assemblages between Young-Buckle and Balleny seamounts, with the lumbrinerid *Augeneria tentaculata* making the highest single contribution (found to be present only on the former seamount) to the observed difference. The capitellid *Notomastus latericeus* was a good discriminating species between the epifaunal assemblages of the same two seamounts (only occurring on Young-Buckle) (*N. latericeus* is an infaunal polychaete which was incidentally sampled as part of the epifauna by the epibenthic sled). The presence of this species, along with two species of ophiuroids (*Ophiacantha pentactis*, *Ophioceres incipiens*), also helped discriminate between epifaunal assemblages of Young-Buckle and S-100 (where the latter two species occurred only on S-100). For the mega-epifaunal assemblages, a demosponge species (*Tedania triraphis*) contributed most to the dissimilarity observed between Young-Buckle and S-100 seamounts, whilst the relative occurrence of two species of asteroids (*Bathyblaster loripes obesus*, *Labidiaster annulatus*) accounted for most of the dissimilarity between Young-Buckle and Balleny seamounts – because all these mega-epifaunal species were not sampled on Young-Buckle seamount. The SIMPER results do not present any obvious indications as to what might account for the differences in assemblage composition between the seamounts as they relate to different productivity regimes. However, in the future, as our appreciation of the biology of the aforementioned organisms improves, it might be possible to use the results to augment the discussion presented below.

4.4.4.2 Stepping-stone hypothesis

Measures of dissimilarity in composition (β -diversity) among assemblages (all types) of the different seamounts are high (75–95%), and according to the stepping-stone hypothesis (Hubbs 1959), it would be expected that these levels increase with increasing geographic distance. Leal & Bouchet (1991) and Richer de Forges et al. (2000) found this pattern among benthic assemblages on chains of seamounts over a 1000 km in the Atlantic and Pacific, respectively. However, an examination for this relationship using data from the present study revealed that no such correlation exists for either the infauna, epifauna or mega-epifauna assemblages (results of regression analysis not shown). As already noted, the lack of such a relationship may be a function of the relative closeness of the seamounts. That is, the geographic distances between the Balleny Islands seamounts (approximately 36–280 km) are not a significant impediment to the dispersal of benthic macroinvertebrates and it is unlikely that this variable alone will account for differences in composition of ‘whole’ benthic assemblages. Thus, the overall differences observed in assemblage composition between the Balleny Island seamounts are likely to be more strongly related to other environmental differences.

4.4.4.3 Other drivers

It is clear that the macroinvertebrate assemblage of the large Young-Buckle seamount is different from those of the smaller S-100 and Balleny seamounts, yet not from the assemblage on the smaller but also sub-aerial Sturge seamount. Whether a seamount is submarine or has an aerial component (i.e., is an oceanic island or emergent seamount) may potentially influence the composition of the feature's benthic assemblage. For example, the summits of submerged seamounts can support assemblages dominated by organisms such as sponges and corals that benefit from the accelerated currents and upwelling of nutrients and particulate matter (see review of Rogers 1994). Such fauna, and others that are better adapted for living at seamount summits, are therefore less likely to occur and be sampled on Young-Buckle and Sturge. This situation might account for the difference in the overall macroinvertebrate assemblage composition observed between these seamounts and the submarine S-100 and Balleny seamounts. Some support for this contention is provided by the SIMPER result which identified a sponge species as discriminating between assemblages on S-100 (where it was found) and Young-Buckle (where it was not sampled). Hall-Spencer et al. (2007) found for deep-sea corals in the northeast Atlantic, that assemblages on oceanic islands were different from those on submerged seamounts. However, O'Hara (2007) concluded that emergence was not a significant factor in his analysis of ophiuroid assemblages of seamounts in the southwest Pacific. O'Hara (2007) argued that this situation is perhaps to be expected where oceanic islands and seamounts are part of the same ridge system/formed by the same geological processes. Thus it is possible that differences in the assemblages on the Balleny Islands seamount are not related to their state of emergence because the submarine and sub-aerial members of this seamount group are part of the same chain formed at roughly the same time by the same geological processes. An alternative explanation is that the area of the seamount has some influence on the composition of the benthic assemblages. According to the theory of island biogeography (MacArthur & Wilson 1967), larger islands will support more species than smaller ones, and thus potentially assemblages of quite different composition. However, recent studies have demonstrated that factors that co-vary with island size can also contribute to the makeup of an island's fauna. These may include, habitat diversity (or large-scale habitat heterogeneity) (Ricklefs & Lovette 1999) and energy related variables (Kalmar & Currie 2006). Thus it is unlikely that the variation in area will alone explain the observed pairwise differences in assemblage composition between seamounts, and that locally varying environmental factors are also responsible for the patterns observed.

Correlation analysis (such as BVSTEP), revealed that a combination of seven environmental variables best explained the overall pattern of assemblage composition for the infauna of the Balleny Islands seamounts. These variables were surface chlorophyll *a* content in spring and the mean ice cover in summer, sediment particulate organic carbon content (POC), sediment sorting coefficient, % fines and % pebbles. The single variable with the highest correlation was % fines of the sediment, followed by the surface chl *a* content in summer, which suggests that differences in the infaunal assemblages of the Balleny Island seamounts are primarily controlled by local sediment conditions rather than differences in larger scale factors like primary productivity, although both are involved. Previous descriptions of the distribution of infaunal assemblages of other Antarctic islands (that include data from the depth range sampled by the present study) have also suggested that both the type of substrate and food availability are important in generating the patterns observed (Piepenburg et al. 2002, Lovell & Trego 2003).

Fewer environmental variables were correlated with the patterns of epifauna and mega-epifauna assemblages for the four Balleny Islands seamounts. Water depth, the surface chl *a* content in spring and the mean annual ice cover (\equiv mean ice cover in spring) are all implicated in possibly explaining the observed pattern for the epifauna, but water depth was by far the most important variable. Depth has been related previously to patterns observed between seamount faunas within seamount groups, and the importance of accounting for differences in depth when making such comparisons emphasised (O'Hara 2007, for ophiuroids - a predominantly epifaunal taxon). The random samples taken during

the present study, although overlapping in depth range among all seamounts were on average from shallower depths on S-100 (111–526 m, mean 291 m) and Balleny (118–764 m, mean 346 m) seamounts than on Young-Buckle (78–1570 m, mean 723 m) and Sturge (222–1382 m, mean 661 m) seamounts. Thus, the assemblage pattern for this faunal type could in part be a result of this depth difference. Water depth *per se* is not an environmental factor that directly affects benthic organisms, rather it is a suite of co-correlated variables (e.g., temperature, oxygen, pressure, current speed, food availability) that are likely to be controlling the epifaunal composition. So the results suggest that in addition to what appears to be a very small contribution from large scale factors that relate to primary productivity, it could be that factors such as current speed which influences the rate of delivery of food material to suspension feeding and mobile-surface deposit feeding epifauna play a role in the epifaunal assemblage composition patterns observed at the Balleny Islands seamounts. Measures of current speed for the Balleny Island region were not available for inclusion in the present analysis but their quantification should be incorporated into future analyses should data or models become available.

Mean ice cover in summer was the single variable best correlated with the patterns for the mega-epifauna assemblages, and combined with water depth provided the highest explanatory power for the patterns observed. For mega-epifauna, it appears that a large scale variable, which is linked to primary productivity (but interestingly here the variable surface chl *a* was not co-implicated as it was for the in- and epifauna), is likely to have a reasonably large influence on mega-epifaunal composition. The reasons for the variations in primary productivity observed above seamounts are many (Dower et al. 1992) and in Antarctic waters can include the variation in ice cover (Cattaneo-Vietti et al. 1999). Clearly for the Balleny Islands seamounts there are quite large differences in the proxy measure of surface chl *a* (three times higher in the vicinity of Young-Buckle than at Balleny seamount). A variant of the energy-diversity hypothesis, the ‘oases of productivity’ hypothesis has been invoked to explain the relatively high species richness and biomass sometimes observed at seamounts compared to other deep-sea habitats (see Samadi et al. 2006). It follows that this hypothesis is applicable to comparisons among seamounts that experience quite different levels of primary productivity. Thus it is possible that seamounts such as Young-Buckle can support a larger number of species than Balleny seamount which could be reflected by different mega-epifaunal assemblage compositions. Water depth, or rather some factors that co-correlate with this variable, are apparently less important for mega-epifaunal than they are for epifaunal assemblages of the Balleny Islands seamounts. The correlation analysis potentially explains only a relatively small portion of the faunal pattern for the epifauna and mega-epifauna (25–35%). Thus other unmeasured variables, operating on a number of spatial scales are also likely to influence the assemblage composition. Previous studies of mega-epifaunal assemblages of South Sandwich islands have concluded that whilst the productivity and depth related variable particulate flux influences assemblage composition and distribution, other environmental conditions are also important. For example, the availability of appropriate settlement substrates was noted to be of importance in a small spatial scale study of Cranmer et al. (2003), whilst Piepenburg et al. (2002) suggested that the benthic organisms would respond differently to driving forces such as the morphology of seabed features. Unfortunately, measures of such environmental variables were either not available for all assemblage types (substrate characteristics) or not available at all (seabed morphology) for the present study but their quantification should be incorporated into future studies.

Overall the results of the analysis of macroinvertebrate data recovered from the Balleny Islands seamounts demonstrate that the diversity and composition of assemblages are controlled by a variety of environmental drivers operating on different spatial scales. Infaunal assemblages, as has been found previously for Antarctic islands, are relatively similar in composition where sediment characteristics are also relatively similar. On the other hand epi- and mega-faunal assemblages can be quite dissimilar between islands/seamounts, even those in relatively close proximity. In the present study oceanographic scale factors such as productivity and ice cover differed considerably between some of the seamounts and appear likely to influence faunal composition. Other factors which may co-vary with seamount size, morphology and depth range are also likely to be playing a role in shaping the macroinvertebrate assemblages. The present study has served to expand considerably

what is known about the Balleny Islands macroinvertebrate fauna, and contributed to an understanding of the environmental factors that influence assemblage composition on seamounts in general. The regional significance of the Balleny Islands seamount biodiversity, however, remains to be fully appreciated via more extensive analyses (see Future section below).

4.5 Fish assemblages

4.5.1 Univariate analysis

4.5.1.1 Energy-diversity hypothesis

Measures of AvTD and VarTD for fish assemblages of the Balleny Islands seamounts were not significantly different from one another. The values for the biodiversity indices do not appear to provide any clear support for the productivity hypothesis. That is, whilst the value of AvTD for fish assemblages was relatively high for the most productive Young-Buckle seamount as predicted, the value of VarTD was high in opposition to the prediction. In similar contradiction to the initial prediction, the value of VarTD was relatively low for the least productive Balleny seamount. These findings confirm the expectation noted earlier, that fish assemblages would not necessarily conform to the pattern expected for macroinvertebrates.

4.5.1.2 Seamounts as islands hypothesis

The ‘average’ values of AvTD and VarTD for the fish assemblages of the Balleny Islands seamounts are generally similar, and are not significantly different from the mean value for the ‘regional’ pool of species from which the species that constituted their assemblages could be theoretically drawn. That is, the prediction that seamount fauna would have significantly lower and higher values of AvTD and VarTD (respectively) than the theoretical regional species pool is not supported. The value of AvTD for the fish assemblages of S-100 seamount is somewhat lower than the values for the other three seamounts, but so was the value for VarTD. It is perhaps not surprising, given the relative mobility of fish, that seamounts do not appear to act as ‘islands’ for this taxonomic group.

4.5.2 Multivariate analysis

4.5.2.1 Energy-diversity hypothesis

The results of the multivariate analysis revealed that overall there is a very small, though statistically significant, difference in the fish assemblage composition of the four seamounts. Pairwise analysis revealed that only the fish assemblages of S-100 and Sturge seamounts are largely, and significantly, different in composition. This pairwise difference in composition does not provide any particular support for the energy-diversity hypothesis for fish assemblages. Sturge and S-100 seamounts have similar levels of overlying water primary productivity as indicated by surface Chl *a* levels. The relative occurrence of two fish, the rattail *M. whitsoni* and the icecod *L. kempfi*, are primarily responsible for discriminating between the highly dissimilar assemblages of S-100 and Sturge seamounts. The former species only occurred on Sturge, whilst the latter species occurs only relatively infrequently on this seamount but much more frequently on S-100. These SIMPER results do not present any obvious indications as to what might account for the differences in assemblage composition between these two seamounts.

4.4.4.2 Stepping-stone hypothesis

Measures of dissimilarity in composition (β -diversity) among fish assemblages of the different seamounts are relatively high (59–82%), and according to the stepping-stone hypothesis (Hubbs 1959), it would be expected that these levels increase with increasing geographic distance. Wilson & Kaufman (1987) reviewed mainly fish data and concluded that seamounts do act as stepping stones in the Atlantic and Pacific. However, an examination of the relationship between dissimilarity and distance among the Balleny seamounts revealed that no such correlation exists for fish assemblages (results of regression analysis not shown). As already noted, the lack of such a relationship may be a function of the relative closeness of the seamounts. That is, the geographic distances between the Balleny Islands seamounts (approximately 36–280 km) are not a significant impediment to the dispersal of fish. Thus, the small overall differences observed in assemblage composition between the Balleny Island seamounts, or in particular the observed difference between S-100 and Sturge, are likely to be related to other environmental differences.

The Balleny Islands seamounts showed a very clear transitional fish fauna between Antarctic and Subantarctic assemblages. Violet cod (*Antimora rostrata*) and Johnsons cod (*Halargyreus johnsoni*) were species from the Ballenys that are well-known temperate water species that are common around New Zealand (Paulin et al. 1989). However, they do not occur in the Ross Sea. Other species that were found predominantly at the Balleny Islands seamounts included *Lepidonotothen kempi*, which was only occasionally caught in the Ross Sea but was locally abundant on the seamounts. Thus, at larger spatial scales the underwater ridges and seamounts such those of the Balleny Islands, Admiralty Seamount, Scott Island seamounts, may act as stepping stones by providing habitat at suitable depths which allow subantarctic species to occur southwards towards the Ross Sea, and more Antarctic species to extend their range north of the shelf and slope regions of the Ross Sea.

4.4.4.3 Other drivers

Unfortunately only a few measured environmental variables were available for inclusion in the correlation analysis used to investigate the possible factors controlling the fish assemblage patterns observed for the Balleny Islands seamounts. Water depth is the single variable that best matches the overall patterns observed, with the inclusion of mean ice cover in summer (which is co-correlated with mean ice cover for spring) reducing the correlation value. As noted before, depth itself does not directly influence benthic life, and it is a range of co-correlating variables that are likely to be influencing the composition of fish assemblages on the Balleny Island seamounts. For example, whilst samples from S-100 and Sturge seamount overlapped in depth range, the depth range for the latter seamount was much greater (117–477 m, 212–1389 m, respectively). Thus, the amount of depth-related habitat is much less on S-100 than on Sturge seamount. S-100 is likely to also provide low habitat heterogeneity by being small and simple in morphology (cone-like). The larger more structurally complex Sturge seamount represents a more heterogenous habitat for fish. The relatively high level of similarity for the S-100 assemblage (a more homogenous environment meaning high within assemblage similarity, Warwick & Clarke 1993), compared to that of Sturge, supports the contention that the differences in habitat heterogeneity (some of which are depth-related) are probably one of the reasons for the observed pattern in fish assemblage composition between these two seamounts.

5. FUTURE RESEARCH AND MANGEMENT IMPLICATIONS

The sampling of the Balleny Island seamounts by the BioRoss Survey of 2004 represents one of the more comprehensive studies of macrofauna communities of seamounts in the Antarctic. Together with data from other biodiversity surveys of seamounts, it is likely that the findings of the BioRoss Survey

will contribute greatly to furthering understanding of which (and how) environmental drivers influence benthic biodiversity of Antarctic seamounts, particularly for the Ross Sea region. However, in the future it will be necessary to continue to undertake research on benthic communities in Antarctica, and particular suggestions for future studies (as they relate to the hypotheses examined by the present study) are briefly detailed below. In addition, some broad suggestions are also made in relation to the wider interests of those who are charged with implementing research in support of New Zealand's Biodiversity Strategy. More specific suggestions regarding the use of samples taken during the BioRoss Survey, but not processed (e.g., meiofauna and bacteria material for trophic food web studies), and the further utilisation of preserved/archived material (e.g., for population genetic studies, biomass measurements for trophic food web studies) have already been made via other avenues.

5.1 Future research in relation to hypotheses tested

Concerning the stepping-stone hypothesis for seamounts, Brodie & Dawson (1965) assert that the Macquarie-Balleny Ridge provides an opportunity for macroinvertebrates with restricted larval life and specific habitat requirements to disperse between New Zealand waters and the Ross Sea. To examine this hypothesis further it will be necessary to undertake a broader analysis that includes data collected by other studies. Specifically, such an analysis could include data obtained from a survey in 2006 that included the Balleny Islands (MacDiarmid & Stewart 2012); the IPY-CAML survey of 2008 that sampled seamounts further south and east of the Ballenys (Hanchet et al. 2008, Bowden et al. 2011); seamounts sampled on an expedition to the northern end of the Macquarie-Balleny Ridge, also in 2008 (Rowden 2008); and seamounts already sampled in the New Zealand region by NIWA (Tracey et al. 2004, Rowden et al. 2002, 2003, 2004, Rowden & Clark 2010). Such an analysis will allow for a more complete assessment of the biogeographical affinities of the benthic macroinvertebrate and fish fauna of the Balleny Islands seamounts (see example for ophiuroids of Macquarie Island by O'Hara 1998).

The measures of habitat heterogeneity utilised in the present study, though reasonably effective for examining this variable at two spatial scales primarily for the infauna, were relatively simplistic. In order to progress understanding of the role of habitat heterogeneity (particularly biogenic) in structuring benthic assemblages it is important that imaging devices (still and video cameras) are utilised to capture images at a number of spatial scales (ideally simultaneously). In addition, there is some need for improvement in the techniques for accurately quantifying structure using images and direct samples of the seabed. It is also of relevance to conduct analyses that will be able to determine the relative importance of biogenic structure for different components of the fauna. Also in the future it would be useful to re-analyse bathymetry data from the multibeam survey of the Balleny Islands seamounts to calculate measures of seafloor rugosity along each sled and trawl track, and topographic heterogeneity for each seamount from a delineation of larger scale seafloor features (e.g. gullies, ridges, flat seabed, steep open slope, shallow open slope) using the Bathymetric Position Index (Iampietro et al. 2005) and Benthic Terrain Modeler (<http://www.csc.noaa.gov/products/btm/>). By addressing these topics it should be possible to better assess the validity of the belief that habitat heterogeneity is a major driver of benthic faunal diversity on seamounts (Raymore 1982).

5.2 Other future research and management implications

5.2.1 Tourism/invasive species

The impact of human activities on Antarctic marine systems is of growing concern. Studies have demonstrated that the presence of humans at even small scientific bases can, through activities such as waste disposal, influence the composition of benthic assemblages (e.g., Stark et al. 2003). Although such impacts appear to be spatially restricted to the vicinity of the base, other human impacts could be much wider reaching. Concern about the impacts of tourism on Antarctica ecosystems are many

(Anon 2004), and include fears about the effect of invasive (alien) species (Frenot et al. 2005) which may be transported to the region by an increasing number of tourist expeditions, some of which originate in the Northern Hemisphere. Research has been ongoing in many parts of the world into the spread of marine non-indigenous species, the effects of biological invasions on benthic communities (including New Zealand) and the means by which to eliminate or mitigate these effects. However, as yet no such research has been undertaken for the Balleny Islands region of Antarctica. Clearly considering the physical and biological particularities of the environment, research carried out elsewhere is not necessarily going to be applicable to the Antarctic. Thus, it would be sensible to establish research priorities to address any Antarctic marine biosecurity risks, especially from hull fouling on tourist, fishing and scientific research vessels.

5.2.2 Fishing

Similarly, concerns about fishing activity in Antarctica are many and are considered to be one of the greatest threats facing this polar environment (Clarke & Harris 2003). Of specific relevance to the Balleny Islands and impacts on deepwater benthic communities is the emerging toothfish longline fishery. The results of the present study and others like it will assist in addressing any non-target species impacts, and may be used by CCAMLR in the management and mitigation of such impacts. For example, data from the BioRoss Survey have recently been used to identify indicator taxa for Vulnerable Marine Ecosystems in the Ross Sea region (including the Balleny Islands) (Parker & Bowden 2010), and can be used to model the potential impacts of fishing in the region (e.g. Pinkerton et al. 2006).

5.2.3 Environmental management

With the need to manage the impact of human activities on the environment more effectively and efficiently, those charged to do so are utilising a range of fairly recently developed data products and tools to select areas which can be protected or conserved in some way. There now exists a range of software tools that can identify in a sophisticated and largely objective manner, areas which alone or together will best preserve the feature of concern (e.g., Leathwick et al. 2008). However, the strength of these tools ultimately relies on the quality of those data or data products (layers) that are incorporated into the mathematical selection procedure. One of the primary data products ideally included in the selection process is an environmental classification which captures an integrated picture of both (or either) of the physical and biological components of the environment. Classifications are many in name and no common method or form has emerged as a standard. Nonetheless, among the numerous schemes there are national classifications for the Australian and New Zealand marine environments (the Benthic Marine Bioregionalisation of Australia by Heap et al. 2005, the Marine Environment Classification (MEC) of New Zealand by Snelder et al. 2006). Australia has already extended its effort beyond its national EEZ to include a classification of the King George V shelf in Antarctica (Beaman & Harris 2005), and considering the usefulness of such classification for environmental management it would seem sensible for any future classification to include the Balleny Islands. Obviously, data gathered during the BioRoss Survey along with data from other voyages makes such an endeavour achievable and worthwhile, and steps towards a bioregionalisation of the Ross Sea region are now underway (Pinkerton et al. 2009, Sharp et al. 2010), as is the selection of MPAs (e.g. Sharp & Watters 2011).

5.2.4 Climate change

The impact of climate change on Antarctic marine systems is a recognised concern (Clarke & Harris 2003), and benthic communities of the Antarctic shelf are considered vulnerable to such an impact (Barnes & Peck 2008). For example, global warming is removing the physiological barriers to the polar distribution of skeleton-crushing fish and crabs, and the invasion of such urophagous predators

is likely to change the character of marine life in Antarctica (Aronson et al. 2007). Geographic range shifts in Antarctic benthos are predicted to occur in response to climate change (Barnes et al. 2009), and shifts in depth distributions would be expected to occur with the shoaling of calcium carbonate horizons as a consequence of ocean acidification (Guinotte et al. 2006). Seamounts have been suggested as refugia from ocean acidification for organisms, such as stony corals, that will be impacted by a change in the calcium carbonate horizon (Tittensor et al. 2010). However, genetic studies indicate that some populations may have limited depth-related dispersal ability, and thus the fauna of seamounts maybe particularly vulnerable to extinction (Miller et al. 2011). While knowledge is increasing about the response of individual species to climate-induced changes, understanding is poor about the effects at the community level and the mechanisms that may control these effects (Ingels et al. 2012). Further research is required that not only seeks to document any changes that may have already occurred in benthic assemblage composition, but also to predict future climate change impacts (via modelling) so that they can be monitored in the Ross Sea region.

6. ACKNOWLEDGMENTS

The BioRoss Survey was a large, complicated and ambitious project that relied upon the efforts and skills of many people, both within NIWA and at other institutes and agencies in New Zealand and elsewhere. Thus it is only proper for the authors of this report to make here a relatively extensive acknowledgement. First, special thanks must be extended to the captain of the RV *Tangaroa*, A. Leachman, and his crew, the voyage leader J. Mitchell, the biodiversity science party (N. Bagley, I. Everson, L. Ghigliotti, A. Hill, G. La Mesa, A.-N. Lörz, P. McMillan, S. Schiaparelli, R. Stewart, J. Visser) and other scientific personnel of the BioRoss Survey (voyage TAN0402) who facilitated the collecting and initial sorting/identification of the samples here reported upon. Special thanks are extended to A.-N. Lörz and others in the NIWA Invertebrate Collection who curated and managed the distribution of the samples after the voyage. Acknowledgments are also due to a number of NIWA staff for their expertise and assistance in providing environmental data after the voyage: D. McGibbon for additional sorting of the grab samples; K. Richardson who processed remotely-sensed chl *a* and sea-ice data, who wishes to thank G. C. Feldman and C. R. McClain for provision of the SeaWiFS data (NASA Goddard Space Flight Center, USA), and J. Stroeve and W. Meier for the provision of sea ice data (National Snow and Ice Data Center, USA); M. Williams who processed current data, who would like to thank L. Smestad (U.S. Naval Research Laboratory) for the provision of Naval Coastal Ocean Model results; C. Chaque-Goff for providing sediment chlorophyll *a* data; L. Northcote for providing sediment size distribution data and sponge spicule content data; M. Crump for sediment carbon and nitrogen content measurements; R. Stewart for analysis of the grab-video images; K. Mackay and M. Dunkin for processing the multibeam bathymetric data, and made available by Land Information New Zealand, contract number (HYD 03/04-HS4 Project No. 1006A); A. Pallentin for the production of Figures 1 and 2. Special acknowledgment must be given to all the taxonomists and parataxonomists who provided confirmations of, or provided fuller identifications for, shipboard identifications (Appendix 3). Without the skill and commitment of these people projects such as this one would be impossible and little progress would be made towards an appreciation of the biodiversity of the study region. Lastly, acknowledgment must be extended to the New Zealand Ministry of Fisheries who funded the project (project number ZBD2003/03), and to the various staff at the ministry who at one time or another supported the management of the project (J. Burgess, B. Sharp, M. Livingston) and to D. Robertson at NIWA who managed the project from inception to completion.

7. REFERENCES

- Ahyong, S.T.; Dawson, E.W. (2006). Lithodidae from the Ross Sea, Antarctica, with descriptions of two new species (Crustacea: Decapoda: Anomura). *Zootaxa* 1303:45–68.
- Anonymous (2000). New Zealand biodiversity strategy: our chance to turn the tide. Department of Conservation and the Ministry for Environment, Wellington. 146 p.
- Anonymous (2004). Concern over tourism in Antarctica. *Marine Pollution Bulletin* 48:814–815.
- Arntz, W.; Thatje, S.; Linse, K.; Avila, C.; Ballesteros, M.; Barnes, D.; Cope, T.; Cristobo, F.; de Broyer, C.; Gutt, J.; Isla, E.; López-González, P.; Montiel, A.; Munilla, T.; Esplá, A.; Raupach, M.; Rauschert, M.; Rodríguez, E.; Teixidó, N. (2005). Missing link in the Southern Ocean: sampling the marine benthic fauna of remote Bouvet Island. *Polar Biology* 29:83–96.
- Aronson, R.B.; Thatje, S.; Clarke, A.; Peck, L.S.; Blake, D.B.; Wilga, C.D.; Seibel, B.A. (2007). Climate Change and Invasibility of the Antarctic Benthos. *Annual Review of Ecology, Evolution, and Systematics* 38: 129–154.
- Barnes, D.K.A.; Griffiths, H.J.; Kaiser, S. (2009). Geographic range shift responses to climate change by Antarctic benthos: where we should look. *Marine Ecology Progress Series* 393:13–26.
- Barnes, D.K.A.; Linse, K.; Waller, C.; Morely, S.; Enderlein, P.; Fraser, K.P.P.; Brown, B. (2006). Shallow benthic fauna communities of South Georgia Island. *Polar Biology* 29:223–228.
- Barnes, D.K.A.; Peck, L.S. (2008). Vulnerability of Antarctic shelf biodiversity to predicted regional warming. *Climate Research* 37:149–163.
- Barry, J.P.; Dayton, P.K. (1988). Current patterns in McMurdo Sound, Antarctica and their relationship to local biotic communities. *Polar Biology* 8(5): 367–376.
- Bates, C.R.; Saunders, G.W.; Chopin, T. (2005). An assessment of two taxonomic distinctness indices for detecting seaweed assemblage responses to environmental stress. *Botanica Marina* 48:231–243.
- Beaman, R.J.; Harris, P.T. (2005). Bioregionalization of the George V Shelf, East Antarctica. *Continental Shelf Research* 25:1657–1691.
- Blackwood, D.; Parolski, K. (2001). Seabed Observation and Sampling System. *Sea Technology* 42: 39–43.
- Bowden, D.; Clark, M.; Cummings, V.; Lörz, A.-N.; Maas, E.; Hewitt, J. (2011). Benthic invertebrate fauna of the Ross Sea and northern seamounts: results from the New Zealand International Polar Year – Census of Antarctic Marine Life survey 2008–2011. Final Research Report for Ministry of Fisheries project IPY2007-01 (Unpublished report held by Ministry for Primary Industries, Wellington.) 139 p.
- Bradford-Grieve, J.; Fenwick, G. (2001). A review of the current knowledge describing the biodiversity of the Ross Sea region. Final Research Report for Ministry of Fisheries Research Project ZBD2000/01. (Unpublished report held in NIWA library, Wellington).
- Bradford-Grieve, J.; Fenwick, G. (2002). A review of the current knowledge describing the biodiversity of the Balleny Islands. Final Research Report for Ministry of Fisheries Research Project ZBD2000/01. (Unpublished report held in NIWA library, Wellington).
- Bray, J.R.; Curtis, T.J. (1957). An ordination of the upland forest communities of Southern Wisconsin. *Ecological Monographs* 27: 325–349.
- Brodie, J.W.; Dawson, E.W. (1965). Morphology of North Macquarie Ridge. *Nature* 207: 844–845.
- Bullivant, J.S. (1967). New Zealand Oceanographic Institute Ross Sea investigations, 1958–60: General account and station list. In: The Fauna of the Ross Sea, Part 5. General accounts, station lists, and benthic ecology. Bullivant, J.S.; Dearborn, J.H. *New Zealand Department of Scientific and Industrial Research Bulletin* 176: 9–29.
- Campbell, J.W.; Blaisdell, J.M.; Darzi, M. (1995). Level-3 SeaWiFS data products: Spatial and temporal binning algorithms. *NASA Technical Memorandum* 104566, NASA Goddard Space Flight Centre, USA, 1992 32. NASA Goddard Space Flight Centre, USA.
- Capblanq, J. (1990). Nutrient dynamics and pelagic food web interactions in oligotrophic and eutrophic environments: an overview. *Hydrobiologia* 207:1–14.

- Cattaneo-Vietti, R.; Chiantore, M.; Misic, C.; Povero, P.; Fabiano, M. (1999). The role of pelagic-benthic coupling in structuring littoral benthic communities at Terra Nova Bay (Ross Sea) and in the Straits of Magellan. *Scientia Marina* 63(Suppl. 1): 113–121.
- Clarke, A.; Harris, C. (2003). Polar marine ecosystems: major threats and future change. *Environmental Conservation* 30:1–25.
- Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18:117–143.
- Clarke, K.R.; Ainsworth, M. (1993). A method of linking multivariate community structure to environmental variables. *Marine Ecology Progress Series* 92:205–219.
- Clarke, K.R.; Gorley, R.N. (2001). PRIMER v5: User manual/tutorial PRIMER-E, PRIMER-E, Plymouth.
- Clarke, K.R.; Warwick, R.M. (1998). A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology* 35: 523–531.
- Clarke, K.R.; Warwick, R.M. (1999). The taxonomic distinctness measure of biodiversity: weighting of step lengths between hierarchical levels. *Marine Ecology Progress Series* 184:21–29.
- Clarke, K.R.; Warwick, R.M. (2001b). Change in marine communities: an approach to statistical analysis and interpretation. PRIMER-E Ltd.
- Clarke, K.R.; Warwick, R.M. (2001a). A further biodiversity index applicable to species lists: variation in taxonomic distinctness. *Marine Ecology Progress Series* 216:265–278.
- Comiso, J.C.; Cavalieri, D.; Parkinson, C.; Gloersen, P. (1997). Passive microwave algorithms for sea ice concentrations: A comparison of two techniques. *Remote Sensing of the Environment* 60(3): 357–84.
- Cranmer, T.L.; Ruhl, H.A.; Baldwin, R.J.; Kaufmann, R.S. (2003). Spatial and temporal variation in the abundance, distribution and population structure of epibenthic megafauna in Port Foster, Deception Island. *Deep Sea Research II* 50:1821–1842.
- Currie, D.J.; Francis, A.P.; Kerr, J.T. (1999). Some general propositions about the study of spatial patterns of species richness. *Ecoscience* 6(3): 392–399.
- Cusson, M.; Archambault, P.; Aitken, A. (2007). Biodiversity of benthic assemblages on the Arctic continental shelf: historical data from Canada. *Marine Ecology Progress Series* 331:291–304.
- Dawson, E.W. (1970). Faunal relationships between the New Zealand Plateau and the New Zealand sector of Antarctica based on echinoderm distribution. *New Zealand Journal of Marine and Freshwater Research* 4(2): 126–140.
- Dower, J.; Freeland, H.; Juniper, K. (1992). A strong biological response to oceanic flow past Cobb Seamount. *Deep-Sea Research part I* 39: 1139–1145.
- Dower, J.F.; Perry, R.I. (2001). High abundance of larval rockfish over Cobb Seamount, an isolated seamount in the NE Pacific. *Fisheries Oceanography* 10: 268–274.
- Eastman, J.T.; Hubold, G. (1999). The fish fauna of the Ross Sea, Antarctica. *Antarctic Science* 11(3): 293–304.
- Ellingsen, K.; Clarke, K.; Somerfield, P.; Warwick, R. (2005). Taxonomic distinctness as a measure of diversity applied over a large scale: the benthos of the Norwegian continental shelf. *Journal of Animal Ecology* 74:1069–1079.
- Folk, R.L.; Ward, W.C. (1957). Brazos River Bar: A study in the significance of grain size parameters. *Journal of Sedimentary Petrology* 27(1): 3–26.
- Forbes, L.M. (1966). New Zealand and United States expedition to the Ross Sea, the Balleny Islands and Macquarie Ridge, 1965. *Polar Record* 13(82): 52–54.
- Frenot, Y.; Chown, S.; Whinam, J.; Selkirk, P.; Convey, P.; Skotnicki, M.; Bergstrom, D. (2005). Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews* 80:45–72.
- Gallardo, V.A. (1987). The sublittoral macrofaunal benthos of the Antarctic shelf. *Environmental International* 13: 71–81.
- Gallardo, V.A.; Castillo, J. (1969). Quantitative benthic survey of the infauna of Chile Bay (Greenwich Island, South Shetland Islands). *Gayana* 16:3–17.

- Gerdes, D.; Klages, M.; Arntz, W.E.; Herman, R.L.; Galéron, J.; Hain, S. (1992). Quantitative investigations on macrobenthic communities of the southeastern Weddell Sea based on multibox corer samples. *Polar Biology* 12: 291–301.
- Giangrande, A. (2003). Biodiversity, conservation, and the ‘taxonomic impediment’ *Aquatic Conservation: Marine and Freshwater Ecosystems* 3:451–459.
- Gon, O.; Heemstra, P.C. (eds) (1990). *Fishes of the Southern Ocean*. JLB Smith Institute of Ichthyology, Grahamstown.
- Gotelli, N.J.; Ellison, A.M. (2004). *A primer of Ecological Statistics*. Sinauer Associates, Sunderland, Massachusetts, USA.
- Griffiths, H.J.; Linse, K.; Barnes, D.K.A. (2008). Distribution of macrobenthic taxa across the Scotia Arc, Southern Ocean. *Antarctic Science* 20: 213–226.
- Guinotte, J.M.; Orr, J.; Cairns, S.; Freiwald, A.; Morgan, L.; George, R. (2006). Will human induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? *Frontiers in Ecology and the Environment* 4: 141–146.
- Gutt, J. (2000). Some “driving forces” structuring communities of the sublittoral Antarctic macrobenthos. *Antarctic Science* 12:297–313.
- Gutt, J.; Schickan, T. (1998). Epibiotic relationships in Antarctic benthos. *Antarctic Science* 10: 398–405.
- Gutt, J.; Starmans, A. (1998). Structure and biodiversity of megabenthos in Weddell and Lazarev Seas (Antarctica): ecological role of physical parameters and biological interactions. *Polar Biology* 20: 229–247.
- Gutt, J.; Starmans, A.; Dieckmann, G. (1998). Phytodetritus deposited on the Antarctic shelf and upper slope: its relevance for the benthic system. *Journal of Marine Systems* 17: 435–444.
- Hall, S.J.; Greenstreet, S.P. (1998). Taxonomic distinctness and diversity measures: responses in marine fish communities. *Marine Ecology Progress Series* 166:227–229.
- Hall-Spencer, J.; Rogers, A.; Davies, J.; Foggo, A. (2007). Deep-sea coral distribution on seamounts, oceanic islands, and continental slopes in the Northeast Atlantic. *In: Conservation and adaptive management of seamount and deep-sea coral ecosystems*. Rosenstiel School of Marine and Atmospheric Science, University of Miami. George, R.Y.; Cairns, S.D. (eds). 135–146
- Hanchet, S.; Mitchell, J.; Bowden, D.; Clark, M.; Hall, J.; O’Driscoll, R.; Pinkerton, M.; Robertson, D. (2008). Ocean Survey 20/20 New Zealand IPY-CAML Final Voyage Report. *NIWA Client Report WLG2008-74*, National Institute of Water and Atmospheric Research Ltd., Wellington, New Zealand. 199 p.
- Hatherton, T.; Dawson, E.W.; Kinsky, F.C. (1965). Balleny Islands reconnaissance expedition, 1964. *New Zealand Journal of Geology and Geophysics* 8: 164–179.
- Heap, A.D.; Harris, P.T.; Hinde, A.; Woods, M. (2005). Benthic Marine Bioregionalisation of Australia’s Exclusive Economic Zone. Report to the National Oceans Office on the Development of a National Benthic Marine Bioregionalisation in support of Regional Marine Planning. Geosciences Australia. 140p.
- Heino, J.; Soininen, J.; Lappalainen, J.; Virtanen, R. (2005). The relationship between species richness and taxonomic distinctness in freshwater organisms. *Limnology and Oceanography* 50:978–986.
- Henry, L.-A.; Roberts, J.M. (2007). Biodiversity and ecological composition of macrobenthos on cold-water coral mounds and adjacent off-mound habitat in the bathyal Porcupine Seabight, NE Atlantic. *Deep-Sea Research Part I* 54: 654–672.
- Hillier, J.K.; Watts, A.B. (2007). Global distribution of seamounts from ship-track bathymetry data. *Geophysical Research Letters* 34:L13304, doi:10.1029/2007GL029874
- Hooker, S.B.; Esaias, W.E.; Feldman, G.C.; Gregg, W.W.; McClain, C.R. (1992). An overview of SeaWiFS and ocean colour, in: Hooker SB, Firestone ER (Eds.), *NASA Technical Memorandum* 104566, vol. 1, NASA Goddard Space Flight Centre, USA.
- Hubbs, C.L. (1959). Initial discoveries of fish faunas on seamounts and offshore banks in the eastern Pacific. *Pacific Science* 13:311–316.

- Humphreys, G.F.; Jeffrey, S.W. (1997). Tests of accuracy of spectrophotometric equations for the simultaneous determination of chlorophylls a, b, c1 and c2. *In: Jeffrey, S.W.; Mantoura, R.F.C.; Wright, S.W. Phytoplankton pigments in oceanography: guidelines to modern methods. Monographs on Oceanographic Methodology 10.* Unesco pp. 616–621.
- Iampietro, P.J.; Kvitck, R.G.; Morris, E. (2005). Recent advances in automated genus-specific marine habitat mapping enabled by high-resolution multibeam bathymetry. *Marine Technology Society Journal 39*:83–93.
- Ingels, J.; Vanreusel, A.; Brandt, A.; Catarino, A.I.; David, B.; De Ridder, C.; Dubois, P.; Gooday, A.J.; Martin, P.; Pasotti, F.; Robert, H. (2012). Possible effects of global environmental changes on Antarctic benthos: a synthesis across five major taxa. *Ecology and Evolution 2*: 453–485.
- Jazdzewski, K.; Jurasz, W.; Kittel, W.; Presler, E.; Presler, P.; Sicinski, J. (1986). Abundance and biomass estimates of the benthic fauna in Admiralty Bay, King George Island, South Shetland Islands. *Polar Biology 6*:5–16.
- Johnson, G.L.; Kyle, P.R.; Vanny, J.R.; Campsie, J. (1982). Geology of Scott and Balleny Islands, Ross Sea, Antarctica, and morphology of adjacent seafloor. *New Zealand Journal of Geology and Geophysics 25*: 427–436.
- Kaiser, S.; Barnes, K.A.; Linse, K.; Brandt, A. (2008). Epibenthic macrofauna associated with the shelf and slope of a young and isolated Southern Ocean island. *Antarctic Science 20*: 281–290.
- Kalmar, A.; Currie, D.J. (2006). A global model of island biogeography. *Global Ecology and Biogeography 15*:72–81.
- Koslow, J.A.; Gowlett-Holmes, K.; Lowry, J.K.; O'Hara, T.; Poore, G.C.B.; Williams, A. (2001). Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. *Marine Ecology Progress Series 213*: 111–125.
- Labrune, C.; Amouroux, J.M.; Sarda, R.; Dutrieux, E.; Thorin, S.; Rosenberg, R.; Grémare, A. (2006). Characterization of the ecological quality of the coastal Gulf of Lions (NW Mediterranean). A comparative approach based on three biotic indices. *Marine Pollution Bulletin 52*:34–47.
- Leal, J.H.; Bouchet, P. (1991). Distribution patterns and dispersal of prosobranch gastropods along a seamount chain in the Atlantic Ocean. *Journal of the Marine Biological Association of the United Kingdom 71*: 11–25.
- Leathwick, J.; Moilanen, A.; Francis, M.; Elith, J.; Taylor, P.; Julian, K.; Hastie, T.; Duffy, C. (2008). Novel methods for the design and evaluation of marine protected areas in offshore waters. *Conservation Letters 1*: 91–102.
- Leonard, D.; Clarke, K.; Somerfield, P.; Warwick, R. (2006). The application of an indicator based on taxonomic distinctness for UK marine biodiversity assessments. *Journal of Environmental Management 78*:52–62.
- Lewis, P.N.; Riddle, M.J.; Hewitt, C.L. (2004). Management of exogenous threats to Antarctica and the sub-Antarctic Islands: balancing risks from TBT and non-indigenous marine organisms. *Marine Pollution Bulletin 49*: 999–1005.
- Lovell, L.L.; Trego, K.D. (2003). The epibenthic megafaunal and benthic infaunal invertebrates of Port Foster, Deception Island (South Shetland Islands, Antarctica) *Deep Sea Research II 50*:1799–1819.
- MacArthur, R.; Wilson, E. (1967). The theory of island biogeography, Vol. Princeton University Press, Princetown, NY.
- MacDiarmid, A.; Stewart, R. (2012). Ross Sea and Balleny Islands biodiversity: routine observations and opportunistic sampling of biota made during a geophysical survey to the Ross Sea in 2006. Final Research Report for Ministry of Fisheries project ZBD2005-03. (Unpublished report held by Ministry for Primary Industries, Wellington.)
- McClain, C.R. (2007). Seamounts: identity crisis or split personality? *Journal of Biogeography 34*:2001–2008.
- McKnight, D.G. (1976a). Echinoids from the Ross Sea and the Balleny Islands. *New Zealand Oceanographic Institute Records 3(1)*: 1–6.
- McKnight, D.G. (1976b). Asteroids from the Ross Sea and the Balleny Islands. *New Zealand Oceanographic Institute Records 3(4)*: 21–32.

- Magurran, A.E. (2004). *Measuring biological diversity*, Vol. Blackwell Publishing. 256 p.
- Martin, A.P.; Humphreys, R.; Palumbi, S.R. (1992). Population genetic structure of the armourhead, *Pseudopentaceros wheeleri*, in the North Pacific Ocean: Application of the polymerase chain reaction to fisheries populations. *Canadian Journal of Fisheries Science* 49: 2368–2391.
- Mérigot, B.; Bertrand, J.A.; Mazouni, N.; Manté, C.; Durbec, J.-P.; Gaertner, J.-C. (2007). A multi-component analysis of species diversity of groundfish assemblages on the continental shelf of the Gulf of Lions (north-western Mediterranean Sea). *Estuarine, Coastal and Shelf Science* 73:123–136.
- Miller, K.J., Rowden, A.A., Williams, A., Hausserman, V. (2011). Out of their depth? Isolated deep populations of the cosmopolitan coral *Desmophyllum dianthus* may be vulnerable to environmental change. *PLoS ONE* 6(5).
- Mitchell, J.S. (2001). NIWA Voyage report TAN00102: Antarctic hydrographic survey and scientific research by RV *Tangaroa* 4 February to 17 March 2001, NIWA, Wellington. (Unpublished report held in NIWA library, Wellington).
- Mittelbach, G.Y.; Steiner, C.F.; Scheiner, S.M.; Gross, K.L.; Reynolds, H.L.; Waide, R.B.; Willig, M.R.; Dodson, S.I.; Gough, L. (2001). What is the observed relationship between species richness and productivity? *Ecology* 82: 2381–2396.
- Mühlenhardt-Siegel, U. (1988). Some results on quantitative investigations of macrozoobenthos in the Scotia Arct (Antarctica). *Polar Biology* 8:241–248.
- Mullineaux, L.S.; Mills, S.W. (1997). A test of the larval retention hypothesis in seamount-generated flows. *Deep-Sea Research I* 4: 745–770.
- Nelson, W.A.; Gordon, D.P. (1997). Assessing New Zealand’s marine biological diversity – a challenge for policy makers and systematists. *New Zealand Science Review* 54: 58–66.
- Nelson, W.; Cummings, V.; D’Archino, R.; Halliday, J.; Marriot, P. (2010). Macroalgae and benthic biodiversity of the Balleny Islands, Southern Ocean. *New Zealand Aquatic Biodiversity and Biodiversity Report* 55.
- O’Hara, T.D. (1998). Origin of Macquarie Island echinoderms. *Polar Biology* 20: 143–151.
- O’Hara, T.D. (2007). Seamounts: centres of endemism or species richness for ophiuroids? *Global Ecology and Biogeography* 16:720–732.
- O’Hara, T.D.; Rowden, A.A.; Williams, A. (2008). Cold-water coral habitats on seamounts: do they have a specialist fauna? *Diversity and Distributions* 14: 925–934.
- O’Reilly, J.E.; Maritorea, S.; Mitchell, G.; Siegel, D.A.; Carder, K.L.; Garver, S.A.; Kahru, M.; McClain, C. (1998). Ocean colour algorithms for SeaWiFS. *Journal of Geophysical Research*. 103 (C11): 24937–24953.
- O’Reilly, J.E.; Mueller, J.L.; Mitchell, B.G. (2000). SeaWiFS postlaunch calibration and validation analyses, part 3. In: Hooker, S.B.; Firestone, E.R. (Eds.), NASA Technical Memorandum 206892 vol. 11. NASA Goddard Space Flight Centre, USA.
- Olabarria, C. (2006). Faunal change and bathymetric diversity gradient in deep-sea prosobranchs from Northeastern Atlantic. *Biodiversity and Conservation* 15:3685–3702.
- Page, M.J.; Alcock, N.; Gordon, D.; Kelly-Shands, M.; Nelson, W.; Neill, K.; Watson, J. (2002). Preliminary assessment of the biodiversity of benthic macrofauna of the western Ross Sea, Antarctica. Final Research Report for Ministry of Fisheries Research Project ZBD2000/02 (Unpublished report held in NIWA library, Wellington).
- Parin, N.; Mironov, A.N.; Nesis, K.N. (1997). Biology of the Nazca and Sala y Gomez submarine ridges, and outpost of the Indo-West Pacific fauna in the Eastern Pacific Ocean: composition and distribution of the fauna, its communities and history. *Advances in Marine Biology* 32: 145–242.
- Parker, S.J.; Bowden, D.A. (2010). Identifying taxonomic groups vulnerable to bottom longlining fishing gear in the Ross Sea region. *CCAMLR Science* 17: 105–127.
- Paulin, C.; Stewart, A.; Roberts, C.; McMillan, P. (1989). *New Zealand fish: a complete guide*. National Museum of New Zealand, Wellington. 279 p.
- Piepenburg, D.; Müller, B. (2004). Distribution of epibenthic communities on the Great Meteor seamount (North-East Atlantic) mirrors pelagic processes. *Archives of Fisheries and Marine Research*. 51: 55–70.

- Piepenburg, D.; Schmid, M.K.; Gerdes, D. (2002). The benthos off King George Island (South Shetland Islands, Antarctica): further evidence for a lack of a latitudinal biomass cline in the Southern Ocean. *Polar Biology* 25:146–158.
- Piepenburg, D.; Voss, J.; Gutt, J. (1997). Assemblages of seastars (Echinodermata: Asteroidea) and brittle stars (Echinodermata: Ophiuroidea) in the Weddell Sea (Antarctica) and off Northwest Greenland (Arctic): a comparison of diversity and abundance. *Polar Biology* 17: 305–322.
- Pinkerton, M.; Hanchet, S.; Bradford-Grieve, J.M.; Cummings, V.; Wilson, P.; Williams, M. (2006). Modelling the effects of fishing in the Ross Sea: Final Research Report for Ministry of Fisheries Research Project ANT2004-2005. (Unpublished report held by NIWA library, Wellington).
- Pinkerton, M.H.; Mormede, S.M.; Bowden, D.A. (2009). Inputs to the Ross Sea Bioregionalisation/Spatial Management planning workshop. Final Research Report for the Ministry of Fisheries Project IFA2009-08. (Unpublished report held by Ministry for Primary Industries, Wellington).
- Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. (Eds.) (2007). Seamounts: Ecology, Fisheries, and Conservation, vol. 12. Oxford, UK: Blackwell. 527 p.
- Price, A.R.G.; Keeling, M.J.; O’Callaghan, J. (1999). Ocean-scale patterns of ‘biodiversity’ of Atlantic asteroids determined from taxonomic distinctness and other measures. *Biological Journal of the Linnean Society* 66: 187–203.
- Raymore, P.A. (1982). Photographic investigations on three seamounts in the Gulf of Alaska. *Pacific Science* 36: 15–34.
- Richer de Forges, B.; Koslow, J.A.; Poore, G.G. (2000). Diversity and endemism of the benthic seamount fauna in the southwest Pacific. *Nature* 405: 944–947.
- Ricklefs, R.E.; Lovette, I.J. (1999). The roles of island area per se and habitat diversity in the species-area relationships of four Lesser Antillean faunal groups. *Journal of Animal Ecology* 68: 1142–1160.
- Rogers, A.D. (1994). The biology of seamounts. *Advances in Marine Biology* 30: 305–350.
- Rogers, S.I.; Clarke, K.R.; Reynolds, J.D. (1999). The taxonomic distinctness of coastal bottom-dwelling fish communities of the North-east Atlantic. *Journal of Animal Ecology* 68: 769–782.
- Rosenzweig, M.L. (1995). Species diversity in space and time. Cambridge University Press, Cambridge.
- Rowden, A.A. (2008). Voyage Report for MacRidge 2 - TAN0803. NIWA Voyage Report. (Unpublished report held by NIWA, Wellington). 60 p.
- Rowden, A.A.; Clark, M.R. (2010). Benthic biodiversity of seven seamounts at the southern end of the Kermadec volcanic arc, northeast New Zealand. *Aquatic Environment and Biodiversity Report No. 62*.
- Rowden, A.A.; Clark, M.R.; O’Shea, S. (2004). Benthic biodiversity of seamounts on the Northland Plateau. *Marine Biodiversity and Biosecurity Report No. 5*. (Unpublished report held by Ministry for Primary Industries, Wellington).
- 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 and Biosecurity Report No. 3*. (Unpublished report held by Ministry for Primary Industries, Wellington).
- Rowden, A.A.; O’Shea, S.; Clark, M.R. (2002). Benthic biodiversity of seamounts on the northwest Chatham Rise. *Marine Biodiversity and Biosecurity Report No. 2*. (Unpublished report held by Ministry for Primary Industries, Wellington).
- Rowden, A.A.; Kröger, K.; Clark, M.R. (2012). Biodiversity of macroinvertebrate and fish assemblages of the northwestern Ross Sea shelf. *New Zealand Aquatic Environment and Biodiversity Report No. 101*. Sáiz-Salinas, J.; Ramos, A.; Garcia, F.; Troncoso, J.; San Martin, G.; Sanz, C.; Palacin, C. (1997). Quantitative analysis of macrobenthic soft-bottom assemblages in South Shetland waters (Antarctica). *Polar Biology* 17:393–400.
- Salas, F.; Patrício, J.; Marcos, C.; Pardal, M.A.; Pérez-Ruzafa, A.; Marques, J.C. (2006). Are Taxonomic Distinctness measures compliant to other ecological indicators in assessing ecological status? *Marine Pollution Bulletin* 52:817–829.

- Samadi, S.; Bottan, L.; Macpherson, E.; Richer De Forges, B.; Boisselier, M.-C. (2006). Seamount endemism questioned by the geographical distribution and population genetic structure of marine invertebrates. *Marine Biology* 149:1463–1475.
- Samadi, S.; Schlacher, T.A.; Richer de Forges, B. (2007). Seamount benthos. In: Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. Eds. (2007). Seamounts: Ecology, Fisheries, and Conservation, vol. 12. Oxford, UK: Blackwell. pp. 119–40.
- San Vicente, C.; Castelló, J.; Corbera, J.; Jimeno, A.; Munilla, T.; Sanz, M.C.; Sorbe, J.C.; Ramos, A. (2007). Biodiversity and structure of the suprabenthic assemblages from South Shetland Islands and Bransfield Strait, Southern Ocean. *Polar Biology* 30:477–486.
- Sharp, B.; Watters, G.M. (2011) Marine Protected Area planning by New Zealand and the United States in the Ross Sea region. CCAMLR Document No. WS-MPA-11/25.
- Sharp, B.R.; Parker, S.J.; Pinkerton, M.H.; Breen, B.B.; Cummings, V.; Dunn, A.; Grant, S.M.; Hanchet, S.M.; Keys, H.J.R.; Lockhart, S.J.; Lyver, P.O'B.; O'Driscoll, R.L.; Williams, M.J.M.; Wilson, P.R. (2010). Bioregionalisation and spatial ecosystem processes in the Ross Sea region. WG-EMM-10/30. 59 p.
- Shin, P.K.S.; Ellingsen, K.E. (2004). Spatial patterns of soft-sediment benthic diversity in subtropical Hong Kong waters. *Marine Ecology Progress Series* 276:25–35.
- Siciński, J.; Gillet, P. (2002). Biogeographical affinities of polychaetes from Îles Crozet. *Antarctic Science* 14:353–363.
- Smith, P.J.; McVeagh, S.M.; Mingoia, J.T.; France, S.C. (2004). Mitochondrial DNA sequence variation in deep-sea bamboo coral (Keratoisidinae) species in the southwest and northwest Pacific Ocean. *Marine Biology* 144:253–261.
- Smith, W.O.; Dunbar, R.B. (1998). The relationship between new production and vertical flux on the Ross Sea continental shelf. *Journal of Marine Systems* 17(1–4): 445–457.
- Snelder, T.; Leathwick, J.; Dey, K.; Rowden, A.; Weatherhead, M.; Fenwick, G.D.; Francis, M.; Gorman, R.; Grieve, J.; Hadfield, M.G.; Hewitt, J.E.; Richardson, K.; Uddstrom, M.; Zeldis, J. (2006). Development of an Ecologic Marine Classification in the New Zealand Region. *Environmental Management* 39:12–29.
- Sommer, U. (1985). Comparison between steady-state and non-steady state competition: experiments with natural phytoplankton. *Limnology and Oceanography* 30:335–346.
- Spatharis, S.; Tsirtsis, G.; Danielidis, D.B.; Chi, T.D.; Mouillot, D. (2007). Effects of pulsed nutrient inputs on phytoplankton assemblage structure and blooms in an enclosed coastal area. *Estuarine, Coastal and Shelf Science* 73:807–815.
- Stark, J.S.; Riddle, M.J.; Simpson, R.D. (2003). Human impacts in soft-sediment assemblages at Casey Station, East Antarctica: spatial variation, taxonomic resolution and data transformation. *Austral Ecology* 28:287–304.
- Stephenson, W.; Williams, W.T.; Lance, G.N. (1970). The macrobenthos of Moreton Bay. *Ecological Monographs* 40: 459–494.
- Stewart, A.L.; Roberts, C. (2001). Fishes collected during the Ross Sea Investigative Fishing Program 2000 and 2001, and registered in the National Fish Collection at the Museum of New Zealand Te Papa Tongarewa. Final Research Report for Ministry of Fisheries Research Project ZBD2000/09. (Unpublished report held in NIWA library, Wellington).
- Summerhayes, C.P. (1974). The Macquarie - Balleny Ridge. In A.M. Spencer (ed), Circum-Pacific Origins: Data for Orogenic Studies vol. 2, Geol. Soc. London, 380–386.
- Thatje, S.; Lörz, A.-N. (2005). First record of lithodid crabs from Antarctic waters off the Balleny Islands. *Polar Biology* 28:334–337.
- Tittensor, D.P.; Baco, A.R.; Hall-Spencer, J.M.; Orr, J.C.; Rogers, A.D. (2010) Seamounts as refugia from ocean acidification for cold-water stony corals. *Marine Ecology* 31: 212–225.
- Tracey, D.M.; Bull, B.; Clark, M.R.; Mackay, K.A. (2004). Fish species composition on seamounts and adjacent slope in New Zealand waters. *New Zealand Journal of Marine and Freshwater Research* 38:163–182.
- Warwick, R.M.; Clarke, K.R. (1991). A comparison of some methods for analysing changes in benthic community structure. *Journal of the Marine Biological Association U.K.* 71: 225–244.

- Warwick, R.M.; Clarke, K.R. (1993). Increased variability as a symptom of stress in marine communities. *Journal of Experimental Marine Biology and Ecology* 172: 215–226.
- Warwick, R.M.; Clarke, K.R. (1995). New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. *Marine Ecology Progress Series* 129: 301–305.
- Warwick, R.M.; Clarke, K.R. (1998). Taxonomic distinctness and environmental assessment. *Journal of Applied Ecology* 35: 532–543.
- Warwick, R.M.; Clarke, K.R. (2001). Practical measures of marine biodiversity based on relatedness of species. *Oceanographical Marine Biological Annual Review* 39: 201–231.
- Warwick, R.M.; Clarke, K.R.; Gee, J.M. (1990). The effect of disturbance by soldier crabs, *Mictyris platycheles* H. Milne Edwards, on meiobenthic community structure. *Journal of Experimental Marine Biology and Ecology* 135:19–33.
- Waterhouse, E.J. (2001). Ross Sea Region 2001: A state of the environment report for the Ross Sea region of Antarctica. New Zealand Antarctic Institute, Christchurch.
- Wessel, P. (2007). Seamount characteristics. In: Pitcher, T.J.; Morato, T.; Hart, P.J.B.; Clark, M.R.; Haggan, N.; Santos, R.S. eds. (2007). Seamounts: Ecology, Fisheries, and Conservation, vol. 12. Oxford, UK: Blackwell. pp.3-25.
- Wilson, R.R.; Kaufman, R.S. (1987). Seamount biota and biogeography. *Geophysics Monographs* 43: 355–377.

APPENDICES

Appendix 1: Main gear types and gear codes used during sampling of the northwestern Ross Sea shelf and the Balleny Islands seamounts (voyage TAN0402).



Gear name: large Van Veen Grab

Gear code: GVVL

Target assemblage: infauna



Gear name: large epibenthic sled

Gear code: SEL

Target assemblage: epifauna and fish



Gear name: Orange Roughy Trawl

Gear code: ORH

Target assemblage: mega-epifauna and fish with wider distribution

Appendix 2: Summary of station and sample data for the Balleny Islands seamounts (voyage TAN0402).

Code to gear methods: SVP= sound-velocity probe and CTD; GVVL= large Van Veen grab; SEL= large epibenthic sled; ORH= orange roughy trawl; BEAM= beam trawl.

Station	Transect	Gear methods	Date	Time	Latitude °	Latitude min	Longitude °	Longitude min	W / E	Start depth (m)	Finish depth (m)	Sample volume and content	Comment
207	Sturge	GVVL	02-Mar	1948	67	34.24	165	2.73	E	665	665		grab failed to fire
208	Sturge	GVVL	02-Mar	2021	67	34.11	165	2.74	E	720	720		grab failed to fire
209	Sturge	SEL	02-Mar	2047	67	34.26	165	2.57	E	640	702	100 kg rock, 100 kg pebbles	few invertebrates
210	Sturge	GVVL	02-Mar	2140	67	35.09	165	1.65	E	732	732	5 l mud and pebbles	
211	Sturge	GVVL	03-Mar	6	67	24.95	165	14.98	E	1370	1370		grab failed to fire
212	Sturge	GVVL	03-Mar	108	67	24.83	165	14.94	E	1360	1360		grab failed to fire
213	Sturge	SEL	03-Mar	237	67	26.17	165	16.45	E	1382	1358	120 kg fine brown mud and pebbles	
214	Sturge	ORH	03-Mar	436	67	25.37	165	15.82	E	1389	1444	rocks, 15 kg mixed fish	
215	Sturge	GVVL	03-Mar	721	67	13.97	164	51.02	E	381	381		grab failed to fire
216	Sturge	GVVL	03-Mar	738	67	14.09	164	51.03	E	368	368		grab failed to fire
217	Sturge	GVVL	03-Mar	757	67	14.20	164	50.84	E	356	356	60 l fine mud	
218	Sturge	ORH	03-Mar	906	67	15.23	164	52.50	E	348	353	40 kg rocks, 10kg fish, 20kg mixed invertebrates	
219	Sturge	SEL	03-Mar	1028	67	13.49	164	49.57	E	336	335	140 kg mud, few animals	
220	Sturge	GVVL	03-Mar	1217	67	15.64	164	31.22	E	225	225		grab failed to fire
221	Sturge	GVVL	03-Mar	1232	67	15.54	164	31.33	E	215	215		grab failed to fire
222	Sturge	SEL	03-Mar	1252	67	15.95	164	31.32	E	212	222	300 kg mud, with ophiuroids and holothurians	
223	Sturge	GVVL	03-Mar	1323	67	15.48	164	31.58	E	189	189		grab failed to fire
224	Sturge	GVVL	03-Mar	1332	67	15.48	164	31.54	E	200	200		grab failed to fire
225	Sturge	ORH	03-Mar	1424	67	16.36	164	31.17	E	212	183	100 kg rock, 15 kg mixed fish, 40 kg asteroidean and holothurians	
226	Sturge	ORH	03-Mar	1915	67	13.22	164	17.78	E	522	538	25 kg mixed fish and invertebrates	
227	Sturge	GVVL	03-Mar	2025	67	12.07	164	14.78	E	537	537		grab failed to fire

Station	Transect	Gear methods	Date	Time	Latitude °	Latitude min	Longitude °	Longitude min	W/E	Start depth (m)	Finish depth (m)	Sample volume and content	Comment
228	S-100	GVVL	04-Mar	702	67	25.33	163	55.00	E	99	99	2 l sand, pebbles	grab not fully closed
229	S-100	GVVL	04-Mar	726	67	25.31	163	56.21	E	97	97		rock jammed in jaws
230	S-100	GVVL	04-Mar	736	67	25.29	163	56.37	E	98	98		grab failed to fire
231	S-100	GVVL	04-Mar	747	67	25.23	163	56.35	E	111	111	8 l sand, small pebbles	
232	S-100	SEL	04-Mar	803	67	25.21	163	56.57	E	117	96	300 kg rubble, ophiuroids, mixed invertebrates	
233	S-100	SEL	04-Mar	833	67	25.07	163	54.93	E	230	227	250 kg rubble, many ophiuroids and asteroids	
234	S-100	SEL	04-Mar	917	67	26.78	163	48.59	E	477	526	250 kg rocks, 100 kg rubble, mixed invertebrates	
235	S-100	ORH	04-Mar	1017	67	26.09	163	52.98	E	124	170	400 kg <i>Lepidonotothen kempi</i>	
236	S-100	ORH	04-Mar	1150	67	25.45	163	53.93	E	135	295	500 kg <i>Lepidonotothen kempi</i>	
237	S-100	ORH	04-Mar	1316	67	25.03	163	57.01	E	129	289	1500 kg <i>Lepidonotothen kempi</i>	
238	Young-Buckle	GVVL	04-Mar	1809	66	54.79	163	13.08	E	102	102		grab failed to fire
239	Young-Buckle	GVVL	04-Mar	1816	66	54.82	163	13.48	E	85	85	8 l fine mud	
240	Young-Buckle	ORH	04-Mar	1841	66	55.48	163	14.41	E	75	85	40 kg mixed fish, 15kg invertebrates	
241	Young-Buckle	SEL	04-Mar	1928	66	54.77	163	13.65	E	70	78	20 kg mixed invertebrates, asteroids, ophiuroids	
242	Young-Buckle	GVVL	04-Mar	2302	66	40.53	162	45.41	E	382	382		grab failed to fire
243	Young-Buckle	GVVL	04-Mar	2319	66	40.44	162	45.58	E	380	380		grab failed to fire
244	Young-Buckle	GVVL	04-Mar	2339	66	40.54	162	46.05	E	378	378		grab failed to fire
245	Young-Buckle	SEL	05-Mar	4	66	40.51	162	45.42	E	380	378	50 kg fine mud, few animals	
246	Young-Buckle	ORH	05-Mar	112	66	40.89	162	46.98	E	383	377	30 kg mixed fish and invertebrates	
247	Young-Buckle	GVVL	05-Mar	207	66	40.21	162	43.65	E	379	379	60 l thick mud	
248	Young-Buckle	GVVL	05-Mar	415	66	33.13	163	0.73	E	562	562		grab failed to fire

Station	Transect	Gear methods	Date	Time	Latitude °	Latitude min	Longitude °	Longitude min	W/E	Start depth (m)	Finish depth (m)	Sample volume and content	Comment
249	Young-Buckle	ORH	05-Mar	506	66	33.50	163	1.08	E	555	574	70 kg rock, 20 kg mixed fish and invertebrates	
250	Young-Buckle	GVVL	05-Mar	705	66	33.09	163	0.23	E	557	557	30 l fine mud	
251	Young-Buckle	SEL	05-Mar	630	66	33.06	163	0.16	E	584	548	200 kg fine mud, few animals	
252	Young-Buckle	GVVL	05-Mar	906	66	21.88	162	34.57	E	942	942	50 l fine mud	
253	Young-Buckle	SEL	05-Mar	938	66	21.93	162	34.49	E	911	909	180 kg rubble/sand, few animals	
254	Young-Buckle	ORH	05-Mar	1208	66	21.59	162	32.51	E	720	985	50 kg rocks, 30 kg; mixed fish and invertebrates	
255	Young-Buckle	GVVL	05-Mar	1417	66	13.60	162	26.79	E	1233	1233		grab failed to fire
256	Young-Buckle	GVVL	05-Mar	1502	66	13.23	162	26.69	E	1250	1250		grab failed to fire
257	Young-Buckle	ORH	05-Mar	1630	66	12.97	162	26.49	E	1261	1395	small catch; mixed fish and invertebrates	
258	Young-Buckle	SEL	05-Mar	1753	66	13.18	162	28.88	E	1570	1505	140 kg mud/rubble, few animals	
259	Young-Buckle	SEL	05-Mar	1927	66	10.81	162	16.77	E	400	398	60 kg mud, few polychaetes	
260	Young-Buckle	GVVL	05-Mar	2005	66	10.49	162	15.89	E	396	396	50 l heavy mud	
261	Young-Buckle	ORH	05-Mar	2045	66	10.52	162	16.04	E	394	404	50 kg mixed fish/invertebrates holothurians	
262	Young-Buckle	GVVL	06-Mar	21	66	6.59	161	59.19	E	1150	1150		grab failed to fire
263	Young-Buckle	ORH	06-Mar	158	66	7.17	162	0.78	E	960	1176	small catch	fast after 10mins
264	Young-Buckle	SEL	06-Mar	330	66	6.70	162	0.79	E	1137	1075	350 kg mud/rubble, some rocks	
265	Balleny	GVVL	07-Mar	536	65	26.80	160	54.76	E	68	68	35 l black fine rocks	
266	Balleny	SEL	07-Mar	557	65	26.88	160	55.46	E	118	84	60 kg scoria, few animals	
267	Balleny	GVVL	07-Mar	745	65	29.43	161	3.05	E	759	759	20 l sand	
268	Balleny	SEL	07-Mar	811	65	29.50	161	2.97	E	764	761	20 kg pebbles	
269	Balleny	BEAM	07-Mar	920	65	28.53	161	2.88	E	760	750	25 kg mixed invertebrates	good catch
270	Balleny	ORH	07-Mar	1050	65	29.90	161	2.64	E	755	764	10 kg fish, some invertebrates	
271	Balleny	ORH	07-Mar	1226	65	29.53	160	56.77	E	376	367	45 kg mixed fish and invertebrates	
272	Balleny	ORH	07-Mar	1334	65	26.66	160	54.83	E	68	96	40 kg fish, mainly <i>Lepidonotothen kempfi</i>	

Station	Transect	Gear methods	Date	Time	Latitude °	Latitude min	Longitude °	Longitude min	W/E	Start depth (m)	Finish depth (m)	Sample volume and content	Comment
273	Balleny	GVVL	07-Mar	1419	65	28.97	160	57.16	E	368	368	7 l fine sand, ophiuroids on surface	
274	Balleny	SEL	07-Mar	1447	65	29.79	160	56.65	E	371	376	35 kg rubble, rock, some invertebrates	
275	Balleny	GVVL	07-Mar	1554	65	24.81	160	52.80	E	128	128		rock jammed in jaws
276	Balleny	GVVL	07-Mar	1606	65	24.80	160	52.90	E	125	25	5 l sand, some ophiuroids	
277	Balleny	SEL	07-Mar	1621	65	24.50	160	53.30	E	103	127	50 kg rubble and echinoderms, <i>Lepidonotothen kemp</i>	
278	Balleny	BEAM	07-Mar	1743	65	24.76	160	53.22	E	114	151	50 kg TOA, 20 kg <i>Lepidonotothen kemp</i> , 40 kg mixed invertebrates	
279	Balleny	ORH	07-Mar	1859	65	24.79	160	53.22	E	107	138	175 kg <i>Lepidonotothen kemp</i>	

Appendix 3: List of taxonomists and parataxonomists who identified (or confirmed onboard identifications) the biological material obtained during the BioRoss study of the northwestern Ross Sea and the Balleny Islands seamounts. Also given is the number of potentially new species

Taxonomist	Taxa	Affiliation	No. of potentially new species
Álvaro L. Peña Cantero	Hydrozoa	Instituto Cavanilles de Biodiversidad y Biología Evolutiva Universidad de Valencia Apdo. Correos 22085 46071 Valencia, Spain	
Alberto Lindner	Stylasteridae	Biology Department Duke University Box 90338 Durham, NC 27708 USA	none; no new records for Ross Sea area
Stephen D. Cairns	Scleractinia, Stylasteridae	Smithsonian Institution P. O. Box 37012 NMNH, W-329, MRC-0163 Washington, D. C. 20013-7012 USA	
Estefania Rodríguez, Pablo J. López-González	Actinaria, Octocoralia	Biodiversidad y Ecología de Invertebrados Marinos Depto. Fisiología y Zoología Facultad de Biología Universidad de Sevilla Reina Mercedes 6 41012 – Sevilla, Spain	2 sea anemones 2 octocorals 1 new genus of octocorals
Katrin Linse	Gastropoda, Bivalvia	British Antarctic Survey, Oxford, UK	
Stefano Schiaparelli	Gastropoda, Bivalvia	Università di Genova Corso Europa, 26 16132 Genova, Italy	
Johanna Nielsen Steve O'Shea Peter Rehm	Pantopoda Cephalopoda Cumacea	Auckland University of Technology Auckland University of Technology Alfred Wegener Institute for Polar and Marine Research Benthic Ecosystems Comparativ Ecosystem Research Columbusstrasse D-27568 Bremerhaven	
Luitfried Salvini-Plawen	Solenogastres	Institut für Zoologie Universität Wien Althanstrasse 14 A-1090 Wien, Austria	
Andrei Yu. Utevsky	Hirudinea	Department of Zoology and Animal Ecology Kharkov National University, Kharkov Ukraine	
Oliver Coleman	Iphimediidae (Amphipoda)	Museum für Naturkunde Berlin Institut für Systematische Zoologie Invalidenstraße 43 D-10115 Berlin F.R.G.	

Taxonomist	Taxa	Affiliation	No. of potentially new species
Mariachiara Chiantore Francesca de Domenico Maria Paola Ferranti Serena Ghione Sabrina Buongiovanni Carlotta Ghirardo Giada Ciribilli	Echinodermata	Dip.Te.Ris. Università di Genova Corso Europa, 26 16132 Genova, Italy	
John Buckeridge	Cirripedia	Head of School of Civil & Chemical Engineering RMIT University Melbourne, Vic 3001 Australia	
Andrew Hosie	Cirripedia	NIWA Wellington	
Graham Bird	Tanaidacea	not affiliated at present	
Stephen Eager	Ostracoda	Victoria University Wellington	
Sven Thatje	Decapoda	NOC Southampton	
Shane Ahyong	Decapoda	NIWA - Wellington	<i>Neolithodes yaldwyn</i>
Jeff Robinson	Brachiopoda	University of Auckland	
Daphne Lee	Brachiopoda	University of Otago, Dunedin	
Michelle Kelly	Porifera	NIWA-Auckland	
Mike Page	Ascidians	NIWA - Nelson	
Anna Bradley	Ascidians	NIWA - Nelson	
Kerstin Kröger	Polychaeta,	NIWA - Wellington	
Geoff Read	Polychaeta, Sipuncula, Priapulida, Echiurida	NIWA - Wellington	
Anne-Nina Lörz	Amphipoda	NIWA - Wellington	<i>Epimeria schiaparelli</i>
Graham Fenwick	Amphipoda	NIWA - Christchurch	
Janet Grieve	Ostracoda	NIWA - Wellington	
Dennis Gordon	Bryozoa	NIWA - Wellington	
Niel Bruce	Isopoda	NIWA - Wellington	<i>Cirolana mclaughlinae</i> (Cirolanidae)
Angelika Brandt	Isopoda	Universität Hamburg, Germany	<i>Ediotia tangaroa</i> (Idoteidae)
Peter McMillan	Fish	NIWA - Wellington	
Inigo Everson	Fish	Senior Visiting Research Fellow Anglia Ruskin University, Cambridge, UK	

Appendix 4: Additional information on taxonomic distinctness biodiversity metrics and use in hypotheses testing.

A wider understanding of the usefulness of measures of taxonomic distinctness as biodiversity metrics

Since arguments were made for the use of taxonomic distinctness as a biodiversity metric for the present study (see Introduction) such measures have been used in a plethora of studies that have extended their use beyond studies of fish and benthic invertebrates of intertidal and shallow water habitats to those of other groups of organisms (e.g., microflora Spatharis et al. 2007, macroalgae Bates et al. 2005), and other habitats (freshwater Heino et al. 2005, deep-sea Olabarria 2006). Such studies have allowed further evaluation of the usefulness of taxonomic distinctness measures and a number of issues have been raised by the results of these studies, some of which potentially impact upon the validity of using the taxonomic distinctness metrics in the present study. Considering that MFish was particular keen to support the use of measures of taxonomic distinctness in the BioRoss study, it is thought appropriate to consider these issues here before discussing the results that involve the use of these metrics.

Taxonomic distinctness versus other metrics

Whilst the potential usefulness of taxonomic distinctness as a biodiversity metric has been largely accepted (Magurran 2004), studies show that taxonomic distinctness is not consistently related to other diversity indices and thus it is not a straightforward substitute for other diversity measures (Ellingsen et al. 2005). Nonetheless, in those cases where a thorough evaluation of the relationship between the taxonomic distinctness metrics and other indices reveals a consistent and concurrent pattern for a variety of spatial and temporal scenarios, taxonomic distinctness metrics can have a singular applicability. For example, Leonard et al. (2006) demonstrated convincingly the general utility of measures of taxonomic distinctness for national marine biodiversity assessment programmes in the United Kingdom. However, the aforementioned appears to be the exception (see Salas et al. 2006 for an alternative conclusion for the European Community's Water Framework Directive), and taxonomic distinctness indices are now seen largely as complementary indices which used with other metrics provide a more complete understanding of biodiversity patterns (e.g., Labruno et al. 2006, Cusson et al. 2007, Merigot et al. 2007). Although the previous is now considered desirable, it is not always possible to employ multiple indices, largely because of differences in sampling effort that are frequently involved in large-scale studies of biodiversity. This situation was the case for the BioRoss study, where different gears were employed which sampled essentially in a qualitative way, and the number of samples varied slightly between sampling strata. Thus, here taxonomic distinctness indices are the sole univariate measure of biodiversity used.

Multi-taxa versus phylum by phylum

After the initial utilisation of taxonomic distinctness measures it became apparent that different taxa displayed different patterns of taxonomic distinctness in response to the same environmental gradients (Shin and Ellingsen 2004). This finding is not entirely surprising, and as well as questioning the surrogacy of one taxon for others, the concern was raised that some of the differences between taxa could be attributable to the different taxonomic structures used for classifying different phyla. Thus, if any general understanding was to be achieved about biodiversity pattern the suggestion was made that taxonomic distinctness measures should be applied to single phyla rather than to a combination of taxa (Ellingsen et al. 2005). Despite this sensible call studies have continued to calculate taxonomic distinctness measures for 'whole assemblages', perhaps in order to avoid the additional computation, reporting and discussion required, or most likely in order to maintain a consistent approach within a study (other diversity indices calculated for whole assemblages). For the BioRoss study taxonomic distinctness measures were separately calculated for fish, but for a combination of

macroinvertebrate taxa. This approach was taken in order to maintain consistency with the multivariate analysis of biodiversity pattern. However, in the future/elsewhere it will be worth exploring in greater detail the response of the different phyla to the environmental variables measured in the present study.

Regional species pool ('Master list')

One of the perceived problems relating to the use of taxonomic distinctness measures for assessing how different a site's assemblage is from a null expectation (the TAXDTEST) is the definition of the regional species pool (or Master list) to which it is compared (rather a random selection of species from it). The addition to the species list derived from the sites of a particular study, of species from sites in the general region (i.e., the regional species pool), has been shown to alter very little the overall mean taxonomic distinctness value as the 'new' species are likely to be spread across the taxonomic tree. However, the confidence limits (the funnel) around the mean are likely to change and therefore affect the result of the test to determine whether a sample/site/strata possesses an assemblage that is significantly different from the theoretical regional assemblage (Bates et al. 2005). Bates et al. (2005) and others have demonstrated that even the addition to the Master list of species from a single site can influence the result of the TAXDTEST. Thus these authors suggested that the most conservative approach would be to use the biggest possible regional species pool available. For the present study it wasn't deemed possible, given the amount of effort required and uncertainties about the suitability of some data, to construct a Master List for the entire Ross Sea that could be used for analysing the whole macroinvertebrate assemblage data. In the future it maybe possible to create reasonable Master lists for certain taxa, e.g., Polychaeta, Mollusca, and even the fish.

Appendix 5: List of sampling stations and environmental data as obtained from the Balleny Islands seamounts. Stations excluded from multivariate analyses due to not being part of the *a priori* sampling design, containing fewer than two fish species, being invalid or being beamtrawl stations are indicated.

Station	Gear	Seamount	Max depth (m)	Surface chl <i>a</i> spring (mg/m ³)	Surface chl <i>a</i> summer (mg/m ³)	Mean ice cover spring (%)	Mean ice cover summer (%)	Mean ice cover autumn (%)	Mean ice cover winter (%)	Mean annual ice cover (%)	Stations excluded
207	GVVL	Sturge	665	66.83	0.78	89.37	41.83	40.80	89.53	65.38	invalid
208	GVVL	Sturge	720	66.83	0.78	89.37	41.83	40.80	89.53	65.38	invalid
209	SEL	Sturge	702	66.83	0.78	89.37	41.83	40.80	89.53	65.38	
210	GVVL	Sturge	732	66.83	0.78	89.37	41.83	40.80	89.53	65.38	
211	GVVL	Sturge	1370	0.15	0.42	88.20	36.17	37.30	89.17	62.71	invalid
212	GVVL	Sturge	1360	0.15	0.42	88.20	36.17	37.30	89.17	62.71	invalid
213	SEL	Sturge	1382	0.15	0.42	88.20	36.17	37.30	89.17	62.71	
214	ORH	Sturge	1444	0.15	0.42	88.20	36.17	37.30	89.17	62.71	
215	GVVL	Sturge	381	0.17	0.55	86.37	36.77	38.30	87.43	62.22	invalid
216	GVVL	Sturge	368	0.17	0.55	86.37	36.77	38.30	87.43	62.22	invalid
217	GVVL	Sturge	356	0.17	0.55	86.37	36.77	38.30	87.43	62.22	
218	ORH	Sturge	353	0.17	0.55	86.37	36.77	38.30	87.43	62.22	
219	SEL	Sturge	336	0.18	0.59	86.37	36.77	38.30	87.43	62.22	
220	GVVL	Sturge	225	66.83	0.50	87.90	41.43	42.10	88.70	65.03	invalid
221	GVVL	Sturge	215	66.83	0.50	86.37	36.77	38.30	87.43	62.22	invalid
222	SEL	Sturge	222	66.83	0.50	87.90	41.43	42.10	88.70	65.03	
223	GVVL	Sturge	189	66.83	0.50	86.37	36.77	38.30	87.43	62.22	invalid
224	GVVL	Sturge	200	66.83	0.50	86.37	36.77	38.30	87.43	62.22	invalid
225	ORH	Sturge	218	66.83	0.50	87.90	41.43	42.10	88.70	65.03	
226	ORH	Sturge	538	66.83	0.99	85.50	37.83	39.73	86.07	62.28	
227	GVVL	Sturge	537	66.83	0.99	85.50	37.83	39.73	86.07	62.28	invalid
228	GVVL	S-100	99	0.13	0.78	88.17	42.10	43.37	87.87	65.38	invalid
229	GVVL	S-100	97	0.13	0.78	88.17	42.10	43.37	87.87	65.38	invalid
230	GVVL	S-100	98	0.13	0.78	88.17	42.10	43.37	87.87	65.38	invalid
231	GVVL	S-100	111	0.13	0.78	88.17	42.10	43.37	87.87	65.38	
232	SEL	S-100	117	0.13	0.78	88.17	42.10	43.37	87.87	65.38	
233	SEL	S-100	230	0.13	0.78	88.17	42.10	43.37	87.87	65.38	
234	SEL	S-100	526	0.15	0.78	92.23	46.80	48.13	91.60	69.69	

Station	Gear	Seamount	Max depth (m)	Surface chl <i>a</i> spring (mg/m ³)	Surface chl <i>a</i> summer (mg/m ³)	Mean ice cover spring (%)	Mean ice cover summer (%)	Mean ice cover autumn (%)	Mean ice cover winter (%)	Mean annual ice cover (%)	Stations excluded
235	ORH	S-100	170	0.15	0.78	88.17	42.10	43.37	87.87	65.38	
236	ORH	S-100	295	0.13	0.78	88.17	42.10	43.37	87.87	65.38	
237	ORH	S-100	289	0.13	0.78	88.17	42.10	43.37	87.87	65.38	≤1 fish sp
238	GVVL	Young-Buckle	102	66.83	0.83	80.07	32.77	39.67	83.07	58.89	invalid
239	GVVL	Young-Buckle	85	66.83	0.83	80.07	32.77	39.67	83.07	58.89	
240	ORH	Young-Buckle	85	66.83	0.83	80.07	32.77	39.67	83.07	58.89	
241	SEL	Young-Buckle	78	66.83	0.83	80.07	32.77	39.67	83.07	58.89	
242	GVVL	Young-Buckle	382	0.13	2.04	79.33	34.30	41.10	82.07	59.20	invalid
243	GVVL	Young-Buckle	380	0.13	2.04	74.57	28.73	37.07	79.87	55.06	invalid
244	GVVL	Young-Buckle	378	0.13	2.04	74.57	28.73	37.07	79.87	55.06	invalid
245	SEL	Young-Buckle	382	0.13	2.04	79.33	34.30	41.10	82.07	59.20	
246	ORH	Young-Buckle	383	0.13	2.04	74.57	28.73	37.07	79.87	55.06	
247	GVVL	Young-Buckle	379	0.13	2.04	79.33	34.30	41.10	82.07	59.20	
248	GVVL	Young-Buckle	562	0.18	1.14	74.57	28.73	37.07	79.87	55.06	invalid
249	ORH	Young-Buckle	574	0.18	1.14	74.57	28.73	37.07	79.87	55.06	
250	GVVL	Young-Buckle	557	0.18	1.14	74.57	28.73	37.07	79.87	55.06	
251	SEL	Young-Buckle	584	0.18	1.14	74.57	28.73	37.07	79.87	55.06	

Station	Gear	Seamount	Max depth (m)	Surface chl <i>a</i> spring (mg/m ³)	Surface chl <i>a</i> summer (mg/m ³)	Mean ice cover spring (%)	Mean ice cover summer (%)	Mean ice cover autumn (%)	Mean ice cover winter (%)	Mean annual ice cover (%)	Stations excluded
252	GVVL	Young-Buckle	942	0.38	0.53	77.17	27.00	36.83	83.00	56.00	
253	SEL	Young-Buckle	911	0.38	0.53	77.17	27.00	36.83	83.00	56.00	
254	ORH	Young-Buckle	985	0.22	0.50	77.17	27.00	36.83	83.00	56.00	
255	GVVL	Young-Buckle	1233	0.24	0.48	77.17	27.00	36.83	83.00	56.00	invalid
256	GVVL	Young-Buckle	1250	0.24	0.48	77.17	27.00	36.83	83.00	56.00	invalid
257	ORH	Young-Buckle	1395	0.24	0.48	77.17	27.00	36.83	83.00	56.00	
258	SEL	Young-Buckle	1570	0.24	0.48	77.17	27.00	36.83	83.00	56.00	
259	SEL	Young-Buckle	400	0.20	0.72	77.17	27.00	36.83	83.00	56.00	
260	GVVL	Young-Buckle	396	0.20	0.72	77.17	27.00	36.83	83.00	56.00	
261	ORH	Young-Buckle	404	0.20	0.72	77.17	27.00	36.83	83.00	56.00	
262	GVVL	Young-Buckle	1150	66.83	0.36	82.00	30.53	39.53	86.33	59.60	invalid
263	ORH	Young-Buckle	1176	0.24	0.55	82.00	30.53	39.53	86.33	59.60	invalid
264	SEL	Young-Buckle	1137	0.24	0.55	82.00	30.53	39.53	86.33	59.60	
265	GVVL	Balleny	68	0.20	0.31	88.23	25.60	40.40	90.93	61.29	
266	SEL	Balleny	118	0.20	0.31	88.23	25.60	40.40	90.93	61.29	≤1 fish sp
267	GVVL	Balleny	759	0.20	0.31	88.23	25.60	40.40	90.93	61.29	
268	SEL	Balleny	764	0.20	0.31	88.23	25.60	40.40	90.93	61.29	
269	BEAM	Balleny	760	0.20	0.31	88.23	25.60	40.40	90.93	61.29	beam

Station	Gear	Seamount	Max depth (m)	Surface chl <i>a</i> spring (mg/m ³)	Surface chl <i>a</i> summer (mg/m ³)	Mean ice cover spring (%)	Mean ice cover summer (%)	Mean ice cover autumn (%)	Mean ice cover winter (%)	Mean annual ice cover (%)	Stations excluded
270	ORH	Balleny	764	0.14	0.34	89.63	28.07	41.07	91.80	62.64	
271	ORH	Balleny	376	0.20	0.31	88.23	25.60	40.40	90.93	61.29	≤1 fish sp
272	ORH	Balleny	96	0.20	0.31	88.23	25.60	40.40	90.93	61.29	
273	GVVL	Balleny	368	0.20	0.31	88.23	25.60	40.40	90.93	61.29	
274	SEL	Balleny	376	0.16	0.26	88.23	25.60	40.40	90.93	61.29	
275	GVVL	Balleny	128	66.83	0.31	88.23	25.60	40.40	90.93	61.29	invalid
276	GVVL	Balleny	125	66.83	0.31	88.23	25.60	40.40	90.93	61.29	
277	SEL	Balleny	127	66.83	0.36	88.23	25.60	40.40	90.93	61.29	
278	BEAM	Balleny	151	66.83	0.36	88.23	25.60	40.40	90.93	61.29	beam
279	ORH	Balleny	138	66.83	0.31	88.23	25.60	40.40	90.93	61.29	

Appendix 6: Sediment characteristics from grab samples taken on the Balleny Islands seamounts (- no data available).

Stn	Transect	Sponge spicule/ 100 g	PN (%)	POC (%)	Chl a (ng/g)	Median (phi)	Mean (phi)	Sort. coeff.	%<63 mm (fines)	% >4 mm (pebbles)	BHC
210	Sturge	240	<0.02	0.16	0.95	-2	1.5	3.64	32.59	52.92	0
217	Sturge	132	<0.02	0.23	5.79	6	6	2.57	87.47	1.84	0.9
231	S-100	148	<0.02	0.03	1.24	-0.5	0	2	3.78	22.27	-
239	Young-Buckle	14	<0.02	<0.01	1.23	2.5	2.25	1.31	3.40	0.00	0
247	Young-Buckle	644	<0.02	0.21	4.66	5.75	5.75	2.01	85.43	0.00	0
250	Young-Buckle	180	<0.02	0.11	2.35	5	5	1.91	64.06	1.34	2.3
252	Young-Buckle	33276	<0.02	0.19	6.31	2.25	3	4.19	38.78	11.96	0.57
260	Young-Buckle	480	<0.02	0.25	7.14	6	6	2.7	86.99	1.87	0
265	Balleny	0	<0.02	<0.01	0.57	-1.5	-1.5	0.85	0.20	38.29	0
267	Balleny	57	-	-	0.57	2.75	3	2.44	21.08	6.49	0
273	Balleny	12	-	-	0.27	2	1.75	1.43	3.23	0.00	-
276	Balleny	110	<0.02	0.23	1.83	-1	-0.25	1.82	1.26	30.61	2

Appendix 7: List of macroinvertebrate species from stations used in qualitative analysis of data obtained from the Balleny Islands seamounts.

Species	Family	Order	Class	Phylum
Artemisina plumosa Hentschel, 1914	Microcionidae	Poecilosclerida	Demospongiae	Porifera
Artemisina tubulosa Koltun, 1964	Microcionidae	Poecilosclerida	Demospongiae	Porifera
Bubaris vermiculata (Bowerbank, 1866)	Bubaridae	Halichondrida	Demospongiae	Porifera
Cercidochela lankasteri Kirkpatrick, 1907	Myxillidae	Poecilosclerida	Demospongiae	Porifera
Haliclona altera (Topsent, 1902) cf	Chalinidae	Haplosclerida	Demospongiae	Porifera
Isodictya cactoides (Kirkpatrick, 1908) cf	Isodictyidae	Poecilosclerida	Demospongiae	Porifera
Isodictya obliquidens (Hentschel, 1914) cf	Isodictyidae	Poecilosclerida	Demospongiae	Porifera
Latrunculia brevis Ridley & Dendy, 1887	Latrunculiidae	Poecilosclerida	Demospongiae	Porifera
Mycale (Oxymycale) acerata Kirkpatrick, 1907	Mycalidae	Poecilosclerida	Demospongiae	Porifera
Mycale fibrosa Boury-Esnault & Bevern, 1982	Mycalidae	Poecilosclerida	Demospongiae	Porifera
Radiella n. sp. 1 (sun disc)	Polymastiidae	Hadromerida	Demospongiae	Porifera
Stylocordyla borealis (Loven, 1868)	Stylocordylidae	Hadromerida	Demospongiae	Porifera
Suberites papillatus Kirkpatrick, 1908	Suberitidae	Hadromerida	Demospongiae	Porifera
Tedania (Hemitedania) oxeata Topsent, 1916	Tedaniidae	Poecilosclerida	Demospongiae	Porifera
Tedania (Tedaniopsis) triraphis Koltun, 1964 cf	Tedaniidae	Poecilosclerida	Demospongiae	Porifera
Tedania vanhoeffeni Hentschel, 1914 cf	Tedaniidae	Poecilosclerida	Demospongiae	Porifera
Tetilla coronida Sollas, 1888	Tetillidae	Spirophorida	Demospongiae	Porifera
Hyalascus hodgsoni Kirkpatrick, 1907 cf	Rossellidae	Lyssacinosida	Hexactinellida	Porifera
Rossella antarctica Carter, 1872	Rossellidae	Lyssacinosida	Hexactinellida	Porifera
Rossella nuda Topsent, 1901 ?	Rossellidae	Lyssacinosida	Hexactinellida	Porifera
Rossella villosa Burton, 1929	Rossellidae	Lyssacinosida	Hexactinellida	Porifera
Alcyonium sp. 1	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Alcyonium sp. 2	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Anthomasthus cf. antarcticus	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Anthomasthus cf. bathyproctus	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Inflatocalyx sp.	Alcyoniidae	Alcyonacea	Anthozoa	Cnidaria
Clavularia sp. 1	Clavulariidae	Alcyonacea	Anthozoa	Cnidaria
Gersemia sp. 1	Nephtidae	Alcyonacea	Anthozoa	Cnidaria
Gersemia sp. 2	Nephtidae	Alcyonacea	Anthozoa	Cnidaria
Plexauridae gen. sp.	Plexauridae	Alcyonacea	Anthozoa	Cnidaria
Acanthogorgia sp.	Acanthogorgiidae	Gorgonacea	Anthozoa	Cnidaria
Acanthogorgiidae gen. sp.	Acanthogorgiidae	Gorgonacea	Anthozoa	Cnidaria
Echinisis sp	Isididae	Gorgonacea	Anthozoa	Cnidaria
Arntzia gracilis	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Convexella sp.	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Dasystenella sp.	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Fannyella nodosa	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Fannyella spinosa	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Fannyella sp. 1	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Primnoella sp. 2	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Thouarella sp. 1	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Thouarella sp. 2	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Thouarella sp. 4	Primnoidae	Gorgonacea	Anthozoa	Cnidaria
Pennatula cf. phosphorea var antarctica	Pennatulidae	Pennatulacea	Anthozoa	Cnidaria
Umbellula sp. 1	Umbellulidae	Pennatulacea	Anthozoa	Cnidaria
Glyphoperidium sp.	Actiniidae	Actiniaria	Anthozoa	Cnidaria
Actinostola sp.	Actinostolidae	Actiniaria	Anthozoa	Cnidaria
Stomphia sp.	Actinostolidae	Actiniaria	Anthozoa	Cnidaria
Capnea sp.	Capneidae	Actiniaria	Anthozoa	Cnidaria
Halcampella sp.	Halcampoididae	Actiniaria	Anthozoa	Cnidaria
Actinauge sp.	Hormathiidae	Actiniaria	Anthozoa	Cnidaria
Hormathia sp.	Hormathiidae	Actiniaria	Anthozoa	Cnidaria
Hormathiidae sp.	Hormathiidae	Actiniaria	Anthozoa	Cnidaria
Isanthidae sp.	Isanthidae	Actiniaria	Anthozoa	Cnidaria
Liponema sp.?	Liponematidae	Actiniaria	Anthozoa	Cnidaria
Parazoanthus sp.	Parazoanthidae	Actiniaria	Anthozoa	Cnidaria
"Atenaria" sp. 4	"Atenaria" fam.	Actiniaria	Anthozoa	Cnidaria
Flabellum impensum	Flabellidae	Scleractinia	Anthozoa	Cnidaria

Species	Family	Order	Class	Phylum
<i>Errina fissurata</i>	Stylasteridae	Filifera	Anthozoa	Cnidaria
<i>Errina laterorifa</i>	Stylasteridae	Filifera	Anthozoa	Cnidaria
<i>Eudendrium</i> sp.	Eudendriidae	Anthoathecata	Hydrozoa	Cnidaria
<i>Hydractinia</i> sp.	Hydractiniidae	Anthoathecata	Hydrozoa	Cnidaria
<i>Hydrodendron arboreum</i>	Haleciidae	Leptothecata	Hydrozoa	Cnidaria
<i>Schizotricha nana</i>	Halopterididae	Leptothecata	Hydrozoa	Cnidaria
<i>Schizotricha trinematotheca</i>	Halopterididae	Leptothecata	Hydrozoa	Cnidaria
<i>Oswaldella incognita</i>	Kirchenpaueriidae	Leptothecata	Hydrozoa	Cnidaria
<i>Staurotheca compressa</i>	Sertulariidae	Leptothecata	Hydrozoa	Cnidaria
<i>Staurotheca pachyclada</i>	Sertulariidae	Leptothecata	Hydrozoa	Cnidaria
<i>Paramphinome australis</i>	Amphinomidae	Amphinomida	Polychaeta	Annelida
<i>Augeneria tentaculata</i>	Lumbrineridae	Eunicida	Polychaeta	Annelida
<i>Paraninoe antarctica</i>	Lumbrineridae	Eunicida	Polychaeta	Annelida
<i>Glycera kerguelensis</i>	Glyceridae	Phyllodocida	Polychaeta	Annelida
<i>Aglaophamus trissophyllus</i>	Nephtyidae	Phyllodocida	Polychaeta	Annelida
<i>Neanthes</i> aff. <i>kerguelensis</i>	Nereidae	Phyllodocida	Polychaeta	Annelida
<i>Anaitides longipes</i>	Phyllodocidae	Phyllodocida	Polychaeta	Annelida
<i>Steggoa magalhensis</i>	Phyllodocidae	Phyllodocida	Polychaeta	Annelida
<i>Laetmonice producta</i>	Aphroditidae	Phyllodocida	Polychaeta	Annelida
<i>Antinoella setobarba</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Barrukia cristata</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Eucranta mollis</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Eulagisca uschakovi</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Eunoe eupalina</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Eunoe hartmanae</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Harmothoe fuliginum</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Harmothoe fullo</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Harmothoe magellanica</i>	Polynoidea	Phyllodocida	Polychaeta	Annelida
<i>Antarctinoe ferox</i>	Polynoidae	Phyllodocida	Polychaeta	Annelida
<i>Polynoe laevis</i>	Polynoidae	Phyllodocida	Polychaeta	Annelida
<i>Polynoe antarctica</i>	Polynoidae	Phyllodocida	Polychaeta	Annelida
<i>Typosyllis</i> sp. 1	Syllidae	Phyllodocida	Polychaeta	Annelida
<i>Typosyllis</i> sp. 2	Syllidae	Phyllodocida	Polychaeta	Annelida
<i>Typosyllis</i> sp. 3	Syllidae	Phyllodocida	Polychaeta	Annelida
<i>Myriochele</i> sp. 1	Oweniidae	Sabellida	Polychaeta	Annelida
<i>Euchone pallida</i>	Sabellidae	Sabellida	Polychaeta	Annelida
? <i>Jasmineira caeca</i>	Sabellidae	Sabellida	Polychaeta	Annelida
<i>Perkinsiana littoralis</i>	Sabellidae	Sabellida	Polychaeta	Annelida
<i>Potamethus scotiae</i>	Sabellidae	Sabellida	Polychaeta	Annelida
<i>Helicosiphon biscoensis</i>	Serpulidae	Sabellida	Polychaeta	Annelida
<i>Serpula narconensis</i>	Serpulidae	Sabellida	Polychaeta	Annelida
<i>Notomastus latericeus</i>	Capitellidae	Scolecida	Polychaeta	Annelida
<i>Capitella</i> spp. (complex)	Capitellidae	Scolecida	Polychaeta	Annelida
<i>Isocirrus yungi</i>	Maldanidae	Scolecida	Polychaeta	Annelida
<i>Praxillella kerguelensis</i>	Maldanidae	Scolecida	Polychaeta	Annelida
<i>Maldane sarsi antarctica</i>	Maldanidae	Scolecida	Polychaeta	Annelida
<i>Rhodine intermedia</i>	Maldanidae	Scolecida	Polychaeta	Annelida
<i>Nicomache</i> indet.	Maldanidae	Scolecida	Polychaeta	Annelida
<i>Ophelia breviata</i>	Opheliidae	Scolecida	Polychaeta	Annelida
<i>Scoloplos marginatus mcleani</i>	Orbiniidae	Scolecida	Polychaeta	Annelida
<i>Leitoscoloplos kerguelensis</i>	Orbiniidae	Scolecida	Polychaeta	Annelida
<i>Levinsenia gracilis</i>	Paraonidae	Scolecida	Polychaeta	Annelida
<i>Paraonis belgicae</i>	Paraonidae	Scolecida	Polychaeta	Annelida
<i>Asclerocheilus</i> indet.	Scalibregmatidae	Scolecida	Polychaeta	Annelida
<i>Pseudoscalibregma bransfieldium</i>	Scalibregmatidae	Scolecida	Polychaeta	Annelida
<i>Travisia kerguelensis</i>	Scalibregmatidae	Scolecida	Polychaeta	Annelida
<i>Phyllochaetopterus ?socialis</i>	Chaetopteridae	Spionida	Polychaeta	Annelida
<i>Laonice weddellia</i>	Spionidae	Spionida	Polychaeta	Annelida
<i>Laonice</i> aff. <i>antarctica</i>	Spionidae	Spionida	Polychaeta	Annelida
<i>Scoelepis eltaninae</i>	Spionidae	Spionida	Polychaeta	Annelida
<i>Spiophanes tchernai</i>	Spionidae	Spionida	Polychaeta	Annelida
<i>Ampharete kerguelensis</i>	Ampharetidae	Terebellida	Polychaeta	Annelida
<i>Amphicteis gunneri antarctica</i>	Ampharetidae	Terebellida	Polychaeta	Annelida
? <i>Melinnoides nelsoni</i>	Ampharetidae	Terebellida	Polychaeta	Annelida
<i>Neosabellides elongatus</i>	Ampharetidae	Terebellida	Polychaeta	Annelida
<i>Cauleriella andersenensis</i>	Cirratulidae	Terebellida	Polychaeta	Annelida

Species	Family	Order	Class	Phylum
<i>Tharyx cincinnatus</i>	Cirratulidae	Terebellida	Polychaeta	Annelida
<i>Fauveliopsis</i> indet.	Fauveliopsidae	Terebellida	Polychaeta	Annelida
<i>Flabelligera mundata</i>	Flabelligeridae	Terebellida	Polychaeta	Annelida
<i>Amphitrite kerguelensis</i>	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Pista corrientis</i>	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Pista ?cristata</i>	Terebellidae	Terebellida	Polychaeta	Annelida
? <i>Leaena</i> sp. indet.	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Lysilla loveni macintoshi</i>	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Thelepus cincinnatus</i>	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Thelepides koehleri</i>	Terebellidae	Terebellida	Polychaeta	Annelida
<i>Terebellides stroemi kerguelensis</i>	Trichobranchiidae	Terebellida	Polychaeta	Annelida
<i>Trichobranchus glacialis antarcticus</i>	Trichobranchiidae	Terebellida	Polychaeta	Annelida
<i>Golfingia margaritacea</i>	Golfingiidae	Sipunculiformes	Sipunculidea	Sipuncula
<i>Nephasoma</i> sp.2	Golfingiidae	Sipunculiformes	Sipunculidea	Sipuncula
<i>Echiurus antarcticus</i>	Echiuridae	Echiuroidea	Echiuroida	Echiura
<i>Priapulus tuberculatospinosus</i>	Priapulidae	Priapulida	Priapulida	Priapulida
<i>Psychroteuthis glacialis</i>	Psychroteuthidae	Teuthida	Cephalopoda	Mollusca
<i>Slosarczykovia circumantarctica</i>	Brachioteuthidae	Teuthida	Cephalopoda	Mollusca
<i>Bathyteuthis cf. abyssicola</i>	Bathyteuthidae	Teuthida	Cephalopoda	Mollusca
<i>Pareledone</i> sp. 2	Octopodiade	Octopoda	Cephalopoda	Mollusca
<i>Pareledone</i> sp. 5	Octopodiade	Octopoda	Cephalopoda	Mollusca
<i>Adacnarca nitens</i>	Philobryidae	Arcoida	Bivalvia	Mollusca
<i>Astarte longirostris</i>	Astartidae	Veneroida	Bivalvia	Mollusca
<i>Batharca sinuata</i>	Arcidae	Pteriomorpha	Bivalvia	Mollusca
<i>Cuspidaria kerguelensis</i>	Cuspidariidae	Septibranchia	Bivalvia	Mollusca
<i>Cyclocardia astartoides</i>	Carditidae	Veneroida	Bivalvia	Mollusca
<i>Genaxinus debilis</i>	Thyasiridae	Lucinoida	Bivalvia	Mollusca
<i>Limatula hodgsoni</i> Smith, 1907	Limidae	Pteriomorpha	Bivalvia	Mollusca
<i>Limopsis marionensis</i>	Limopsidae	Pteriomorpha	Bivalvia	Mollusca
<i>Lissarca notocardensis</i>	Phyllobryidae	Arcoida	Bivalvia	Mollusca
<i>Mysella cf. charchoti</i>	Montacutidae	Veneroida	Bivalvia	Mollusca
<i>Pseudokellia gradata</i>	Kelliidae	Veneroida	Bivalvia	Mollusca
<i>Thracia meridionalis</i>	Thraciidae	Anomalodesmata	Bivalvia	Mollusca
<i>Thyasira dearboni</i>	Thyasiridae	Lucinoida	Bivalvia	Mollusca
<i>Yoldiella antarctica</i>	Sareptidae	Nuculoida	Bivalvia	Mollusca
<i>Amauropsis grisea</i>	Naticidae	Caenogastropoda	Gastropoda	Mollusca
<i>Austrodoris kerguelensis</i>	Doridae	Nudibranchia	Gastropoda	Mollusca
<i>Bathyberthella</i> sp	Pleurobranchidae	Notaspidea	Gastropoda	Mollusca
<i>Calliotropis antarctica</i>	Trochidae	Vetigastropoda	Gastropoda	Mollusca
<i>Calliotropis eltaninii</i>	Trochidae	Vetigastropoda	Gastropoda	Mollusca
<i>Chlanidota lamyi</i>	Buccinidae	Caenogastropoda	Gastropoda	Mollusca
<i>Cylichna gelida</i>	Cylichnidae	Cephalaspidea	Gastropoda	Mollusca
<i>Eatoniella glacialis</i>	Eatoniellidae	Caenogastropoda	Gastropoda	Mollusca
<i>Kergeulenatica bioperkulata</i>	Naticidae	Caenogastropoda	Gastropoda	Mollusca
<i>Laevilittorina antartica</i>	Littoriniidae	Caenogastropoda	Gastropoda	Mollusca
<i>Marseniopsis cf. spherica</i>	Lamellariidae	Caenogastropoda	Gastropoda	Mollusca
<i>Marseniopsis cf. syowaensis</i>	Lamellariidae	Caenogastropoda	Gastropoda	Mollusca
<i>Marseniopsis conica</i>	Lamellariidae	Caenogastropoda	Gastropoda	Mollusca
<i>Neobuccinum eatoni</i>	Buccinidae	Caenogastropoda	Gastropoda	Mollusca
<i>Nothoadmete antarctica</i>	Cancellariidae	Caenogastropoda	Gastropoda	Mollusca
<i>Onoba gelida</i>	Rissoidae	Caenogastropoda	Gastropoda	Mollusca
<i>Onoba kergueleni</i>	Rissoidae	Caenogastropoda	Gastropoda	Mollusca
<i>Onoba subantartica</i>	Rissoidae	Caenogastropoda	Gastropoda	Mollusca
<i>Paradmete cf. fragillima</i>	Volutidae	Caenogastropoda	Gastropoda	Mollusca
<i>Pellilitorina setosa</i>	Littorinidae	Caenogastropoda	Gastropoda	Mollusca
<i>Tritonia challengeriana</i>	Tritoniidae	Nudibranchia	Gastropoda	Mollusca
<i>Leptochiton kerguelensis</i>	Lepidopleuridae	Neoloricata	Polyplacophora	Mollusca
<i>Cavibelonia</i> sp. 4		Cavibelonia	Aplacophora	Mollusca
<i>Cavibelonia</i> sp. 11	?Proneomeniidae	Cavibelonia	Aplacophora	Mollusca
<i>Neomenia</i> sp. 2		Neomeniamorpha	Aplacophora	Mollusca
<i>Cadulus dalli</i>	Siphonodentaliidae	Gadilida	Scaphopoda	Mollusca
<i>Dentalium majorinum</i>	Dentaliidae	Dentaliida	Scaphopoda	Mollusca
<i>Siphonodentalium dalli antarcticus</i>	Gadilidae	Gadilida	Scaphopoda	Mollusca
<i>Aega antarctica</i>	Cirolanidae	Isopoda	Malacostraca	Arthropoda
<i>Natatolana meridionalis</i>	Cirolanidae	Isopoda	Malacostraca	Arthropoda
<i>Cymodocella tubicauda</i>	Sphaeromatidae	Isopoda	Malacostraca	Arthropoda

Species	Family	Order	Class	Phylum
<i>Ceratoserolis</i> sp. nov. 1 (aff. trilobitoides)	Serolidae	Isopoda	Malacostraca	Arthropoda
<i>Ceratoserolis</i> sp. nov. 2	Serolidae	Isopoda	Malacostraca	Arthropoda
<i>Cuspidoserolis</i> sp. nov.	Serolidae	Isopoda	Malacostraca	Arthropoda
<i>Frontoserolis</i> sp. nov.	Serolidae	Isopoda	Malacostraca	Arthropoda
<i>Eurycope</i> sp.	Munnopsididae	Isopoda	Malacostraca	Arthropoda
<i>Notopais</i> sp. B	Munnopsididae	Isopoda	Malacostraca	Arthropoda
<i>Epimeria inermis</i>	Epimeriidae	Amphipoda	Malacostraca	Arthropoda
<i>Lepechinella drygalskii</i>	Lepechinellidae	Amphipoda	Malacostraca	Arthropoda
<i>Liljeborgia georgiana</i>	Liljeborgiidae	Amphipoda	Malacostraca	Arthropoda
<i>Podocerus septemcarinatus</i>	Podoceridae	Amphipoda	Malacostraca	Arthropoda
<i>Schraderia gracilis</i>	Eusiridae	Amphipoda	Malacostraca	Arthropoda
<i>Nematocarcinus lanceopes</i> , Bate 1888	Nematocarcinidae	Decapoda	Malacostraca	Arthropoda
<i>Euphausia (superba?)</i> sp. 1	Euphausiacea	Decapoda	Malacostraca	Arthropoda
<i>Paralomis stevensi</i> sp. nov.	Lithodidae	Decapoda	Malacostraca	Arthropoda
<i>Neolithodes yaldwyni</i> sp. nov.	Lithodidae	Decapoda	Malacostraca	Arthropoda
<i>Nototanais antarcticus</i> (Beddard, 1886)	Nototanaidae	Tanaidacea	Eumalacostraca	Arthropoda
<i>Nototanais dimorphus</i> (Hodgson, 1902)	Nototanaidae	Tanaidacea	Eumalacostraca	Arthropoda
<i>Akanthophoreus australis</i> (Beddard, 1886)	Anarthruridae	Tanaidacea	Eumalacostraca	Arthropoda
<i>Akanthophoreus</i> sp.RS#1	Anarthruridae	Tanaidacea	Eumalacostraca	Arthropoda
<i>Scleroconcha gallardoi</i> Kornicker	Philomedidae	Myodocopida	Ostracoda	Arthropoda
<i>Vargula antarctica</i> Müller	Philomedidae	Myodocopida	Ostracoda	Arthropoda
<i>Arcoscalpellum acicularum</i> (Newman & Ross, 1971)	Scalpellidae	Pedunculata	Maxillopoda	Arthropoda
<i>Colossendeis australis</i>	Colossendeidae	Pantopoda	Pycnogonida	Arthropoda
<i>Colossendeis notalis</i>	Colossendeidae	Pantopoda	Pycnogonida	Arthropoda
<i>Nymphon australe</i> sp.	Nymphonidae	Pantopoda	Pycnogonida	Arthropoda
<i>Nymphon longicoxa</i>	Nymphonidae	Pantopoda	Pycnogonida	Arthropoda
<i>Ammothea carolinesis</i>	Ammotheidae	Pantopoda	Pycnogonida	Arthropoda
<i>Achelia spicata</i>	Ammotheidae	Pantopoda	Pycnogonida	Arthropoda
<i>Austrodecus frigorifugum</i>	Austrodecidae	Pantopoda	Pycnogonida	Arthropoda
<i>Acodontaster conspicuus</i>	Odontasteridae	Phanerozonida	Asterozoa	Echinodermata
<i>Bathyblaster loripes obesus</i>	Astropectinidae	Phanerozonida	Asterozoa	Echinodermata
<i>Diplasterias brucei</i>	Asteriidae	Forcipulatida	Asterozoa	Echinodermata
<i>Labidiaster annulatus</i>	Asteriidae	Forcipulatida	Asterozoa	Echinodermata
<i>Leptychaster flexuosus</i>	Astropectinidae	Phanerozonida	Asterozoa	Echinodermata
<i>Luidiaster gerlachei</i>	Benthopectinidae	Phanerozonida	Asterozoa	Echinodermata
<i>Lophaster gaini</i>	Solasteridae	Spinulosida	Asterozoa	Echinodermata
<i>Lysasterias joffrei</i>	Asteriidae	Forcipulatida	Asterozoa	Echinodermata
<i>Odontaster meridionalis</i>	Odontasteridae	Phanerozonida	Asterozoa	Echinodermata
<i>Odontaster validus</i>	Odontasteridae	Phanerozonida	Asterozoa	Echinodermata
<i>Perknaster densus</i>	Echinasteridae	Spinulosida	Asterozoa	Echinodermata
<i>Porania antarctica</i>	Poranidae	Phanerozonida	Asterozoa	Echinodermata
<i>Porania antarctica glabra</i>	Poranidae	Phanerozonida	Asterozoa	Echinodermata
<i>Psalidaster mordax</i>	Asteridae	Forcipulatida	Asterozoa	Echinodermata
<i>Psilaster charcoti</i>	Astropectinidae	Phanerozonida	Asterozoa	Echinodermata
<i>Pteraster stellifer</i>	Pterasteridae	Spinulosida	Asterozoa	Echinodermata
<i>Ctenocidaris geliberti</i>	Cidaridae	Cidaroida	Echinoidea	Echinodermata
<i>Ctenocidaris</i> sp.	Cidaridae	Cidaroida	Echinoidea	Echinodermata
<i>Sterechinus antarcticus</i>	Echinidae	Echinoidea	Echinoidea	Echinodermata
<i>Sterechinus neumayeri</i>	Echinidae	Echinoidea	Echinoidea	Echinodermata
<i>Amphiura algida</i>	Amphiuridae	Ophiurida	Asterozoa	Echinodermata
<i>Amphiura belgicae</i>	Amphiuridae	Ophiurida	Asterozoa	Echinodermata
<i>Astrochlamys bruneus</i>	Gorgonocephalidae	Ophiurida	Asterozoa	Echinodermata
<i>Astrohamma tuberculatum</i>	Gorgonocephalidae	Ophiurida	Asterozoa	Echinodermata
<i>Astrotoma agassizii</i>	Gorgonocephalidae	Ophiurida	Asterozoa	Echinodermata
<i>Gorgonocephalus chilensis</i>	Gorgonocephalidae	Ophiurida	Asterozoa	Echinodermata
<i>Glaciacantha jason</i>	Ophiacanthidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiacantha antarctica</i>	Ophiacanthidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiacantha pentactis</i>	Ophiacanthidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiacantha vivipara</i>	Ophiacanthidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophioceres incipiens</i>	Ophiuridae	Ophiurida	Asterozoa	Echinodermata
<i>Ophionotus victoriae</i>	Ophiuridae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiopyren regularis</i>	Ophioleucidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiosparte gigas</i>	Ophiacanthidae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiuroglypha carinifera</i>	Ophiuridae	Ophiurida	Asterozoa	Echinodermata
<i>Ophiuroglypha</i> sp.A	Ophiuridae	Ophiurida	Asterozoa	Echinodermata

Species	Family	Order	Class	Phylum
Ophiurolepis gelida	Ophiuridae	Ophiurida	Asterozoa	Echinodermata
Toporkovia antarctica	Ophiuridae	Ophiurida	Asterozoa	Echinodermata
Abyssocucumis liouvillei	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
Abyssocucumis sp. B	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
Abyssocucumis sp. D	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
Bathyplores sp. A	Synallactidae	Aspidochirotida	Holothuridea	Echinodermata
Bathyplores sp. B	Synallactidae	Aspidochirotida	Holothuridea	Echinodermata
Ekmocucumis steineni	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
fam. Cucumariidae sp. C	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
fam. Molpadiidae	Molpadiidae	Molpadida	Holothuridea	Echinodermata
Laetmogone sp.	Laetmogonidae	Elasipodida	Holothuridea	Echinodermata
Psolidium sp. A	Psolidae	Psolida	Holothuridea	Echinodermata
Psolus sp. A	Psolidae	Psolida	Holothuridea	Echinodermata
Trachythone sp. A	Cucumariidae	Dendrochirotida	Holothuridea	Echinodermata
Ypsilocucumis sp.	Paracucumidae	Dendrochirotida	Holothuridea	Echinodermata
Compsothyris racovitzae Smith, 1908	Laqueidae	Terrebratulida	Articulata	Brachiopoda
Liothyrella sp.	Terebratellidae	Terrebratulida	Articulata	Brachiopoda
Magellania fragilis Smith, 1908	Terebratellidae	Terrebratulida	Articulata	Brachiopoda
Magellania joubini	Terebratellidae	Terrebratulida	Articulata	Brachiopoda
Macandrevia vanhoeffeni Blochmann, 1907	Laqueidae	Terrebratulida	Articulata	Brachiopoda
Macandrevia sp.	Laqueidae	Terrebratulida	Articulata	Brachiopoda
Novocrania lecontei Joubin, 1901	Craniidae	Craniida	Craniata	Brachiopoda
Amphithyris hallettensis Foster	Platidiidae	Terrebratulida	Articulata	Brachiopoda
Acanthophragma polaris	Lepraliellidae	Cheilostomata	Gymnolaemata	Bryozoa
Adelascopora jeqolqa	Microporellidae	Cheilostomata	Gymnolaemata	Bryozoa
Amphiblestrum inermis	Calloporidae	Cheilostomata	Gymnolaemata	Bryozoa
Annectocyma sp.	Annectocymidae	Cyclostomata	Stenolaemata	Bryozoa
Buffonellaria frigida	Celleporidae	Cheilostomata	Gymnolaemata	Bryozoa
Buffonellodes antarctica	Buffonellodidae	Cheilostomata	Gymnolaemata	Bryozoa
Caberea darwini	Candidae	Cheilostomata	Gymnolaemata	Bryozoa
Camptoplites bicornis	Bugulidae	Cheilostomata	Gymnolaemata	Bryozoa
Camptoplites giganteus	Bugulidae	Cheilostomata	Gymnolaemata	Bryozoa
Camptoplites tricornis	Bugulidae	Cheilostomata	Gymnolaemata	Bryozoa
Cellarinella rogiackae	Cellarinellidae	Cheilostomata	Gymnolaemata	Bryozoa
Celleporella calculosa	Hippothoidae	Cheilostomata	Gymnolaemata	Bryozoa
Cornucopina pectogemma	Bugulidae	Cheilostomata	Gymnolaemata	Bryozoa
Crassimarginatella inconstantia	Calloporidae	Cheilostomata	Gymnolaemata	Bryozoa
Dakariella concinna	Smittinidae	Cheilostomata	Gymnolaemata	Bryozoa
Diaperoecia buski	Diaperoeciidae	Cyclostomata	Stenolaemata	Bryozoa
Disporella octoradiata	Lichenoporidae	Cyclostomata	Stenolaemata	Bryozoa
Entalophorecia sp.	Annectocymidae	Cyclostomata	Stenolaemata	Bryozoa
Escharella mamillata	Romancheinidae	Cheilostomata	Gymnolaemata	Bryozoa
Escharella watersi	Romancheinidae	Cheilostomata	Gymnolaemata	Bryozoa
Escharoides praestita	Romancheinidae	Cheilostomata	Gymnolaemata	Bryozoa
Fenestrulina cervicornis	Microporellidae	Cheilostomata	Gymnolaemata	Bryozoa
Fenestrulina parvipora	Microporellidae	Cheilostomata	Gymnolaemata	Bryozoa
Hippothoa flagellum	Hippothoidae	Cheilostomata	Gymnolaemata	Bryozoa
Hornera antarctica	Horneridae	Cyclostomata	Stenolaemata	Bryozoa
Kymella polaris	Incertae sedis	Cheilostomata	Gymnolaemata	Bryozoa
Melicerita obliqua	Cellariidae	Cheilostomata	Gymnolaemata	Bryozoa
Micropora brevis	Microporidae	Cheilostomata	Gymnolaemata	Bryozoa
Microporella stenopora	Microporellidae	Cheilostomata	Gymnolaemata	Bryozoa
Notoplites drygalskii	Candidae	Cheilostomata	Gymnolaemata	Bryozoa
Orthoporidra compacta	Lekythoporidae	Cheilostomata	Gymnolaemata	Bryozoa
Osthimosia bicornis	Celleporidae	Cheilostomata	Gymnolaemata	Bryozoa
Osthimosia fusticula	Celleporidae	Cheilostomata	Gymnolaemata	Bryozoa
Reteporella erugata	Phidoloporidae	Cheilostomata	Gymnolaemata	Bryozoa
Reteporella hippocrepis	Phidoloporidae	Cheilostomata	Gymnolaemata	Bryozoa
Rhamphosmittina bassleri	Bryocryptellidae	Cheilostomata	Gymnolaemata	Bryozoa
Romancheina asymmetrica	Romancheinidae	Cheilostomata	Gymnolaemata	Bryozoa
Smittina anecdota	Smittinidae	Cheilostomata	Gymnolaemata	Bryozoa
Stomatopora sp.	Oncousociidae	Cyclostomata	Stenolaemata	Bryozoa
Thrypticocirrus rogiackae	Smittinidae	Cheilostomata	Gymnolaemata	Bryozoa
Toretocheilum turbinatum	Lacernidae	Cheilostomata	Gymnolaemata	Bryozoa
Tracheloptyx antarctica	Smittinidae	Cheilostomata	Gymnolaemata	Bryozoa
Xylochotridens rangifer	Calloporidae	Cheilostomata	Gymnolaemata	Bryozoa

Species	Family	Order	Class	Phylum
Synoicum adareanum	Polyclinidae	Enterogona	Asciacea	Chordata
Synoicum georgiana	Polyclinidae	Enterogona	Asciacea	Chordata
Synoicum sp.	Polyclinidae	Enterogona	Asciacea	Chordata
Aplidium circumvolutum	Polyclinidae	Enterogona	Asciacea	Chordata
Aplidium fuegiense	Polyclinidae	Enterogona	Asciacea	Chordata
Distaplia cylindrica	Clavelinidae	Enterogona	Asciacea	Chordata
Ascidia challengeri	Asciidae	Enterogona	Asciacea	Chordata
Ascidia sp.	Asciidae	Enterogona	Asciacea	Chordata
Cnemidocarpa verrucosa	Styelidae	Pleurogona	Asciacea	Chordata
Styela nordenskjöldi	Styelidae	Pleurogona	Asciacea	Chordata
Mogula pyriformis	Mogulidae	Pleurogona	Asciacea	Chordata

Appendix 8: Number of solitary and colonial species, total species number (S) and number of individuals (N) (solitary taxa only) per station for macroinvertebrate assemblages and number of species and individuals per station for fish assemblages from the Balleny Islands seamounts. Only stations included in assemblage composition analysis are listed.

Stn	Gear	Macroinvertebrates				Fish	
		S solitary	S colonial	S total	N solitary	S	N
209	SEL	20	7	27	45		
210	GVVL	18	0	18	34		
213	SEL	17	0	17	42	1	23
214	ORH	4	2	6	13	6	31
217	GVVL	17	1	18	28		
218	ORH	27	6	33	107	5	19
219	SEL	6	1	7	35		
222	SEL	12	6	18	135		
225	ORH	13	7	20	90	8	59
226	ORH	13	2	15	27	6	79
231	GVVL	36	14	50	194		
232	SEL	19	14	33	190	2	6
233	SEL	20	6	26	292	2	3
234	SEL	10	5	15	25		
235	ORH	8	2	10	18	4	23
236	ORH	6	13	19	13	3	53
237	ORH	13	17	30	53		
239	GVVL	39	1	40	459		
240	ORH	13	8	21	46	5	225
241	SEL	19	7	26	260	3	16
245	SEL	27	4	31	81		
246	ORH	9	4	13	25	7	17
247	GVVL	4	0	4	4		
249	ORH	11	7	18	49	8	30
250	GVVL	15	0	15	34		
251	SEL	10	3	13	19		
252	GVVL	9	0	9	12		
253	SEL	3	1	4	4		
254	ORH	8	1	9	82	7	23
257	ORH	9	1	10	28	5	15

Stn	Gear	Macroinvertebrates				Fish	
		<i>S</i> solitary	<i>S</i> colonial	<i>S</i> total	<i>N</i> solitary	<i>S</i>	<i>N</i>
258	SEL	9	1	10	26		
259	SEL	8	0	8	12		
260	GVVL	11	0	11	14		
261	ORH	11	3	14	62	7	135
264	SEL	4	0	4	8		
265	GVVL	5	0	5	18		
266	SEL	5	3	8	24		
267	GVVL	24	0	24	48		
268	SEL	9	3	12	24		
270	ORH	5	3	8	15	4	13
271	ORH	6	2	8	12		
272	ORH	1	2	3	2	3	62
273	GVVL	16	0	16	37		
274	SEL	19	13	32	623		
276	GVVL	10	16	26	34		
277	SEL	18	10	28	271	3	32
279	ORH					2	11

Appendix 9: Fish species list for the Balleny Islands seamounts.

Species	Family	Order	Class
Rajidae - undifferentiated*	Rajidae	Rajiformes	Chondrichthyes
<i>Raja georgiana</i>	Rajidae	Rajiformes	Chondrichthyes
<i>Bathylagus antarcticus</i>	Bathylagidae	Salmoniformes	Osteichthyes
Alepocephalidae - undifferentiated*	Alepocephalidae	Salmoniformes	Osteichthyes
<i>Notolepis coatsi</i>	Paralepididae	Aulopiformes	Osteichthyes
<i>Antimora rostrata</i>	Moridae	Gadiformes	Osteichthyes
<i>Halargyreus johnsonii</i> *	Moridae	Perciformes	Osteichthyes
<i>Seleniolycus laeifasciatus</i> *	Zoarcidae	Perciformes	Osteichthyes
? <i>Lycodapus antarcticus</i>	Zoarcidae	Gadiformes	Osteichthyes
<i>Cynomacrurus piriei</i>	Macrouridae	Gadiformes	Osteichthyes
<i>Macrourus whitsoni</i>	Macrouridae	Perciformes	Osteichthyes
Nototheniidae - undifferentiated*	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus bernacchii</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus hansonii</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus newnesi</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus nicolai</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus pennellii</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus scotti</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Pleuragramma antarcticum</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Trematomus eulepidotus</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Dissostichus eleginoides</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Aethotaxis mitopteryx</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Dissostichus mawsoni</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Lepidonotothen larsoni</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Notothenia coriiceps</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Lepidontohen kempii</i>	Nototheniidae	Perciformes	Osteichthyes
<i>Gymnodraco acuticeps</i>	Bathydraconidae	Perciformes	Osteichthyes
<i>Neopagetopsis ionah</i> *	Channichthyidae	Perciformes	Osteichthyes
<i>Paradiplospinus gracilis</i>	Gempylidae	Perciformes	Osteichthyes

*Fish species not used in analyses