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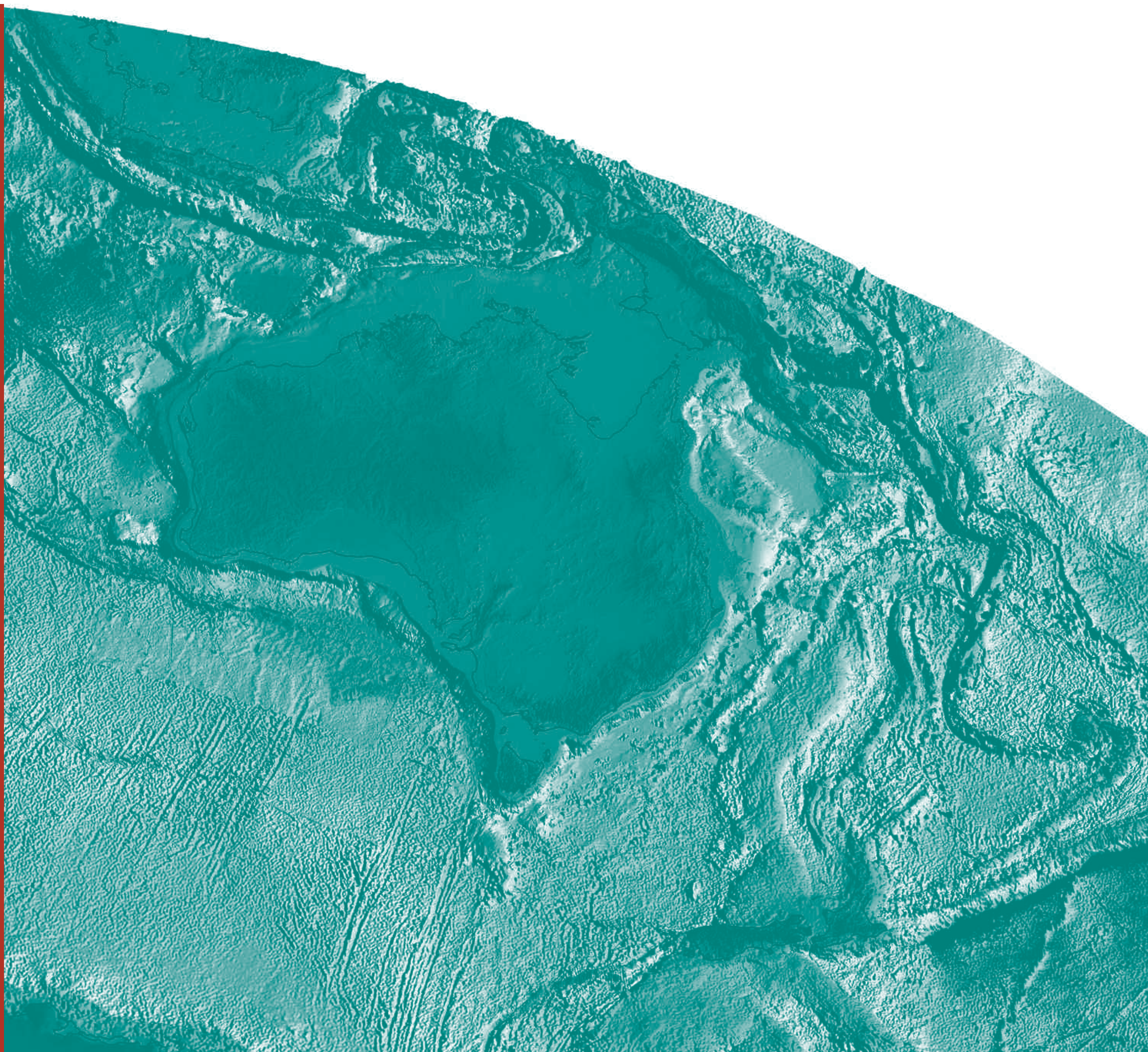

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Sediments and Benthic Biota of Bass Strait: An Approach to Benthic Habitat Mapping

GEOSCIENCE AUSTRALIA
RECORD 2004/23

by

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Executive Summary

This record documents the work carried out by Museum Victoria and Geoscience Australia (GA) to quantitatively describe and assess benthic (seafloor) invertebrate faunas and sediments from Bass Strait and to integrate the understanding of both biological and sedimentological processes in a way which could provide an effective means of assessing biodiversity and sedimentary processes on the continental shelf and other parts of south-eastern Australia.

Two surveys, GA Survey 226 and Australian Hydrographic Office Survey HI339, in which Geoscience Australia personnel participated (GA Survey 233), undertook swath mapping and seabed sampling of parts of Bass Strait. Participation in survey HI339 provided a significant advance in that both swath mapping and underwater video footage were utilised. The results provided information with which both the biological data and previous sedimentological sampling programs (Bureau of Mineral Resources) of the entire Bass Strait region can be better understood. The approaches used in the two surveys and the results generated indicate that a combination of swath mapping, video and seabed characterisation via acoustic facies mapping, may provide a cost-effective means of regional biodiversity assessment.

The biological material on which this study was based was collected from 1979 to 1983 by Museum Victoria, as part of a larger-scale study, co-ordinated by the Victorian Institute of Marine Sciences (VIMS). Analysis of the biological data indicates that Bass Strait supports a particularly diverse faunal assemblage. The similarity in species composition even between adjacent samples, was very low, indicating that there is a large amount of small-scale variation in the fauna. Correlation of species distribution with physical variables, such as sediment grain size, was also low. Longitude and depth were the most important gradients influencing the distribution of biota. Examination of the composition and preservation of fossil material in seabed sediments indicates that sediments more strongly reflect post-depositional processes, such as reworking by waves and tides, than they reflect input from the modern fauna.

The results of this study have important implications for the application of bioregionalisation in Australia. The biotic patterns in Bass Strait broadly support patterns identified for this region in the current Interim Marine and Coastal Regionalisation of Australia (IMCRA). However, the recurrent species assemblages are too variable to be mapped. In contrast to much of the work carried out to date, both in Australia and overseas, this study examined patterns over a broad region. While at the small scale, relationships between biota and sediment are well correlated, over broader scales, such as the entire Bass Strait area, these relationships are not as obvious. Other methods of approaching the data analysis, which emphasise grouping of physical data into regions, are the subject of further research by Geoscience Australia.

Abstract

The biological data used in this study was collected by Museum Victoria in an extensive survey of the fauna of Bass Strait between 1979 and 1983. Additional sediment sampling and swath mapping of parts of Bass Strait were undertaken on GA Survey 226 and Australian Hydrographic Office Survey HI339, in which Geoscience Australia personnel participated (GA Survey 233). Survey HI339 also collected underwater video footage.

Biological material from a range of taxonomic groups was identified as a basis for identification and analysis of biological communities. The results indicate that Bass Strait supports a particularly diverse fauna. A high degree of small-scale variation occurs, with even adjacent samples having low similarity. Video footage from sites to the east of Bass Strait corroborates the high degree of faunal diversity over small spatial scales. Analysis of physical variables, derived from data collected on the original survey and supplemented by more recent data, show that longitude and depth are important factors in explaining the biological diversity. Despite this, overall correlation of faunal composition with physical factors is poor, indicating that other environmental variables influence the composition of benthic assemblages, and that different groups of species react to different environmental variables. It is likely that the biota reflect a series of intergrading assemblages rather than a group of discrete and repeatable species associations.

Sediment facies identified can be correlated with facies from the Otway margin (Boreen *et al*., 1993) and those mapped previously in Bass Strait (Jones and Davies, 1983). Analysis of sediments taken from sites previously targeted by Jones and Davies (1983) indicate that sampling technique has had little impact on retention of fines. Rather, the lack of fines is a reflection of the high energy environment of much of Bass Strait. Examination of the composition of sand and gravel fractions indicates that extensive bioerosion acts in concert with physical processes to produce carbonate mud. Biogenic content in sediments shows little correlation with living communities, due in part to the abundance of soft-bodied organisms in the biota, as well as the strong imprint of post-depositional processes on sediments.

The biological patterns identified in this study broadly support the divisions of the current Interim Marine and Coastal Regionalisation of Australia (IMCRA Technical Group, 1998) for Bass Strait. However, the biological assemblages are not consistent enough to be mapped. The lack of relationships between biota and sediments over the scale of the study area may reflect the scale of the study area and limitations of the statistical analyses used.

Introduction

1.1 BACKGROUND

The Federal Government's key policy goal for management of the marine environment is the protection and maintenance of biodiversity. Knowledge of the spatial distribution and abundance of biota is crucial to assess biodiversity. Because it is impractical to survey and map the distribution of benthic biota itself in detail, environmental managers have begun to investigate the use of proxies to predict the occurrence of different assemblages of benthic organisms. For example, rocky substrates tend to support a different benthic assemblage than a muddy seafloor. A major issue for environmental management in Australia is that so much essential, basic data has yet to be collected. Much of the marine biota around Australia remains poorly known or undescribed. Seafloor geological data is more abundant, but its distribution is patchy. Few studies have attempted to link the physical, chemical and biological processes that control and characterise seafloor environments. Of those studies that do, only a few extend beyond near-shore or State waters (e.g. Ferns and Hough, 2000; Williams and Bax, 2001).

In seabed mapping and characterisation studies carried out in Australia and overseas a range of direct and indirect techniques is commonly applied (e.g. Kostylev *et al*., 2001; Ferns and Hough, 2002). Australia Hydrographic Office Survey HI339 to Bass Strait, in which Geoscience Australia personnel participated (Geoscience Australia Survey 233), provided the first opportunity to collect and integrate such datasets and to evaluate their effectiveness. Additional geological sampling was carried out on Geoscience Australia Survey 226. In particular, this survey targeted sites previously sampled in Bass Strait (Jones and Davies, 1983) to examine the effect of sample collection techniques on grain size distribution.

From 1979 to 1983, Museum Victoria conducted an extensive survey of the benthic invertebrate fauna of Bass Strait, as part of a larger-scale study, co-ordinated by the Victorian Institute of Marine Sciences (VIMS) (Wilson and Poore, 1987). Quantitative samples were taken from over 200 stations throughout Bass Strait using trawls, dredges and grabs. The primary objective of the Museum's survey was to generate museum collections that could be used to describe the species present throughout the region. The material was sorted to higher taxonomic groups and passed on to appropriate taxonomists for further study.

The Bass Strait Survey (BSS) material remains the most comprehensive collection of marine invertebrates from Bass Strait. The survey used quantitative collection techniques that are suitable for analysis using modern statistical techniques. Ecological data were also collected, including latitude and longitude, depth, substrate descriptions, sediment size and carbonate content. The dataset available from the BSS is unique in providing biological and geological data from the same sites, allowing direct data comparisons. Completing the identification and analysis of the BSS biological material was the most cost-effective method of generating data for a baseline biological study of Bass Strait against which to evaluate geological proxies.

In May 2001, Geoscience Australia commissioned Museum Victoria to quantitatively describe benthic (seafloor) assemblages from the Bass Strait region by completing the identification and analysis of selected faunal samples from the BSS material.

1.2 OBJECTIVES

The principle aim of this work was to evaluate techniques for mapping bioregions and, in particular, to evaluate the effectiveness of geological proxies for biodiversity through statistical evaluation of links between biota and geological parameters.

Museum Victoria holds the biological material collected by the BSS. Other than initial identification, little work had been carried out on this material. As part of this study, museum personnel carried out the identification of the material and the statistical analyses to identify biological communities. Geoscience Australia supplemented the geological data, collected as part of the original BSS, with more recently-collected samples and remotely-sensed data of the seabed to enhance the integration of geological data with the biological data. Some of this was done through new analysis of sample material, including some of the original samples collected as part of the BSS.

The objectives for the biological data were:

1. to complete the identification of benthic material based on the 220 BSS samples (Wilson and Poore, 1987). Since the identification of all groups was beyond the scope of this project; faunal groups that were included were:
    - Molluscs (gastropods, chitons)
    - Echinoderms (seastars, sea-urchins, etc)
    - Decapods (crabs, crayfish, shrimps, prawns, etc)
    - Selected isopods (slaters, etc)
    - Selected polychaetes (2 families of sea-worms)
    - Pycnogonids (sea-spiders); and
    - Brachiopods (lamp-shells).
2. to develop a biological classification scheme for the Bass Strait benthic fauna;
3. to supplement the geological data available from the original report; and
4. to integrate the faunal classification scheme with physical (including geological) data, using multivariate statistical analysis.

Geoscience Australia’s approach for mapping habitats in Bass Strait was to collect multiple datasets, including:

- multibeam sonar bathymetry;
- multibeam sonar backscatter or side-scan sonar;
- sub bottom profiler data (3.5kHz, chirper or other);
- sediment grab samples; and
- underwater video footage.

The aim was to evaluate the effectiveness of these techniques in identifying spatial variability in substrates, large-scale morphologies, and biological habitats. To assist with the process of habitat mapping and seabed classification, it is important to evaluate the applicability of each dataset, and in particular identifying limitations of each surveying technique. Only by combining a number of different methods can a full assessment of remotely sensed data be undertaken for rapid assessment and mapping of seabed habitats.

The objectives for the geological datasets were:

1. to supplement existing sediment data from Bass Strait;
2. to determine if there is any difference in fines content between samples collected by Smith McIntyre grabs and pipe dredges;
3. to evaluate potential proxies for benthic biota using sediment fossil data;

4. to evaluate the effectiveness of other data types, such as seafloor video and swath, in supplementing geological data for seabed characterisation and habitat mapping; and
5. to provide a framework for the integration of video footage and still images of the seafloor into a database.

Use of video and still images is important for seabed characterisation because the images provide a visualisation of the biological and geological information, rather than relying on interpretations or extrapolations from sampled data. The juxtaposition of both biological and geological data within video footage provides, in addition to sediment samples, a means of testing the use of geological features as habitat proxies. In this report, only preliminary attempts have been made to integrate video footage of the seabed with sediment samples and bathymetry. A database scheme for storage of information obtained from images is outlined. Future revisions to the scheme will be undertaken; it is still in its infancy and has only been tested on a limited number of environments. The evolution of a standard method and format for logging video and stills is considered an important step in facilitating the exchange of data between organisations.

1.3 MORPHOLOGY AND SEDIMENTS OF BASS STRAIT

Bass Strait forms a 250 km wide, shallow seaway, with average water depths less than 60 m, between mainland Australia and Tasmania (Fig. 1.1; Jennings, 1958). The central portion of Bass Strait contains a shallow depression, with a maximum depth near its centre of 83 m. On the eastern and western margins, Palaeozoic basement rocks form shallow sills (von der Borch *et al*., 1970). The eastern ridge, known as the Bassian Rise, is associated with the Furneaux Group of islands, of which the largest is Flinders Island. Water depths across the sill are approximately 55 m. In the south-west, the King Island High forms a strait between King Island and Tasmania. Water depths in this area are also around 55 m. The King Island – Mornington Peninsula Basement Ridge in the north-east forms a slightly deeper (to 83 m maximum), less well-defined sill, between King Island and the mainland (Fig. 1.1).

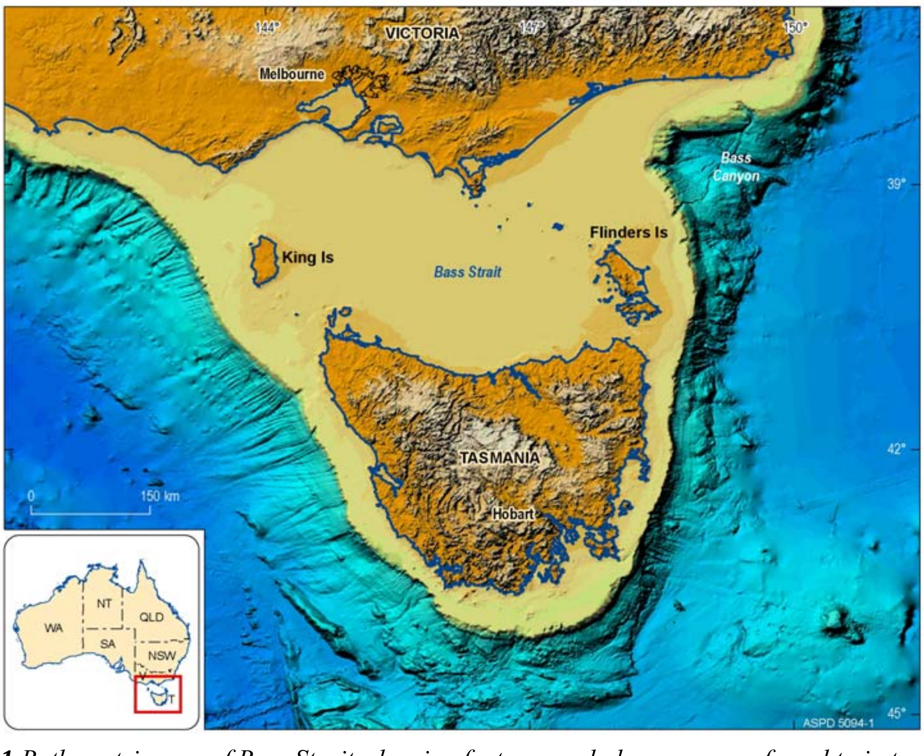


Figure 1.1 *Bathymetric map of Bass Strait, showing features and place names referred to in text.*

Surface sediments of Bass Strait have been described by a number of workers. The two most significant studies were undertaken by Jones and Davies (1983) and Blom and Alsop (1988). Jones and Davies (1983) mapped grain size distribution and carbonate content on the eastern and western margins. Blom and Alsop (1988) described the sediments in central Bass Strait. In general, the seabed is characterised by cool-water carbonates with a low terrigenous content. Fine-grained sediments (muds and silty sands) are restricted to the deeper waters of Bass Basin. Gravels and sands cover the remainder of the shelf (Jones and Davies, 1983). Fine shelly sands occur along the inner shelf of the south-eastern Victorian coast and north of Flinders Island. Moderately well- and well-sorted sediments are restricted to nearshore environments and to areas between Flinders Island and Mornington Peninsula. Sediments over the remainder of Bass Strait are poorly to very poorly sorted and include quartzose sands, and bryozoan sands and gravels. The grain size distribution of surficial sediments, derived from the auSEABED database, which includes the data of Jones and Davies (1983) and Blom and Aslop (1988), is shown in Fig. 1.2.

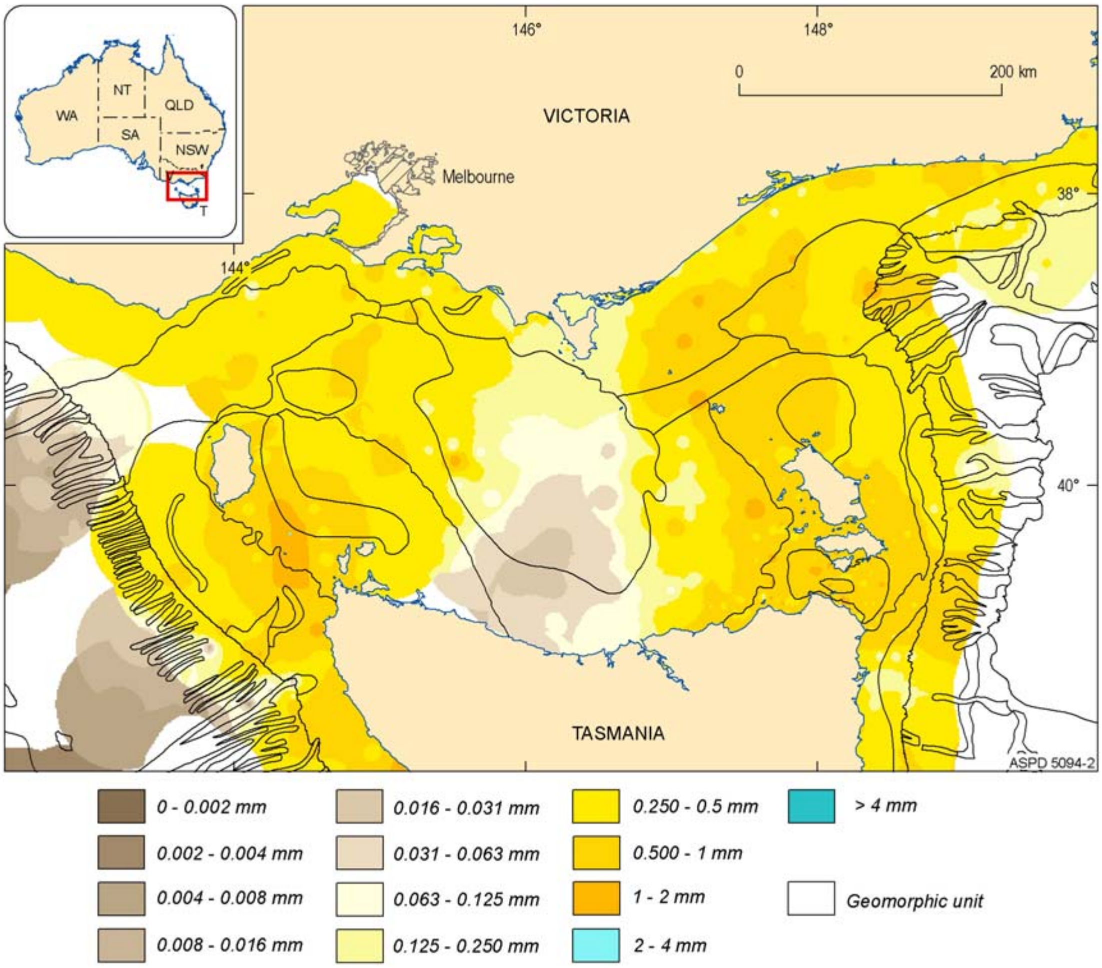


Figure 1.2 *Map showing mean grain size in Bass Strait.*

Carbonate content of sediments in Bass Strait is generally greater than 50%, ranging to over 90% in central Bass Strait (Fig. 1.3; Jones and Davies, 1983; Blom and Alsop, 1988). With the exception of restricted occurrences of limestone and beach rock, the carbonate fraction in coarse sediments consists of recognisable skeletal debris derived from bryozoans, molluscs and foraminifera (Jones and Davies, 1983). In central Bass Strait, sediments contain a high proportion of carbonate mud derived from the breakdown of carbonate material and containing the remains of coccoliths, benthic foraminfera and tunicate spicules (Blom and Alsop, 1988). The sand fraction of these sediments contains benthic foraminifera, bryozoans and molluscs, with minor amounts of echinoids, brachiopods, ostracods and worm tubes, while the gravel fraction is dominated by bryozoans (Blom and Alsop, 1988)

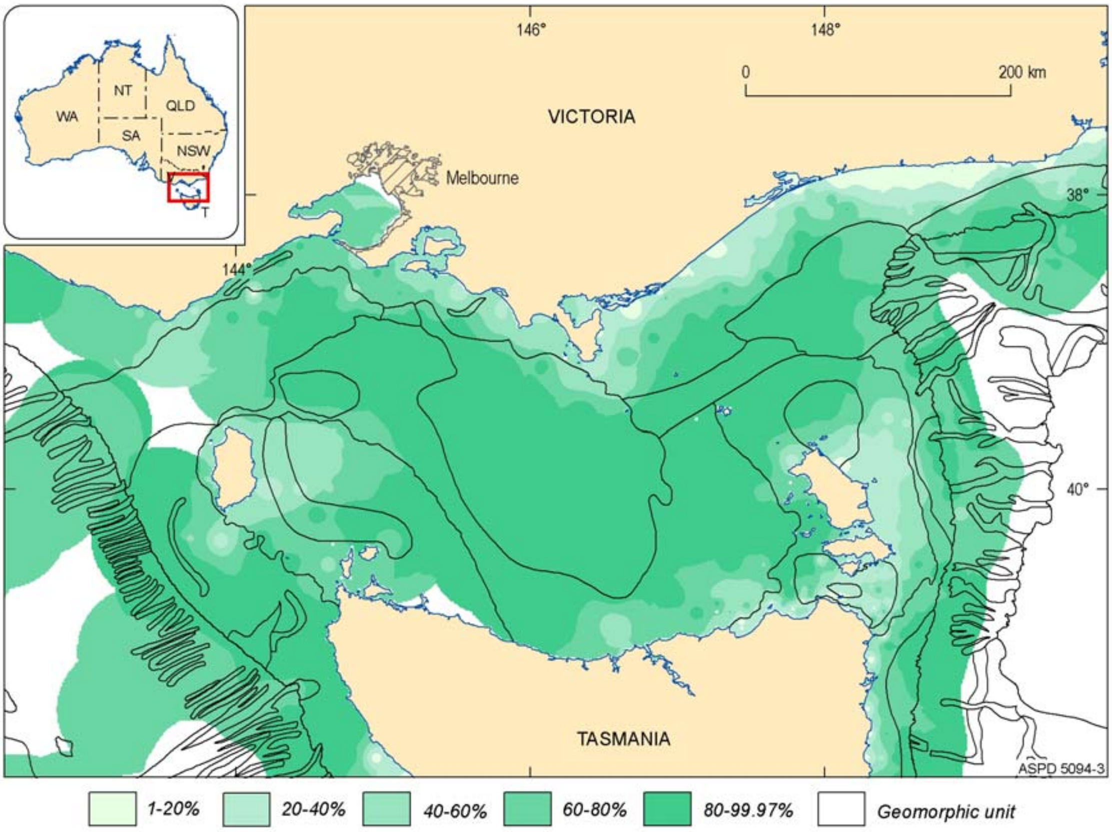


Figure 1.3 *Map of carbonate concentrations in surface sediments in Bass Strait*

The non-carbonate fraction generally consists of quartz, with minor amounts of lithic fragments, feldspar and ferromagnesian minerals (Jones and Davies, 1983; Blom and Alsop, 1988). Silica, in the form of sponge spicules, is present in small quantities throughout. Quartz and clay are present also in the mud fraction of basin sediments (Blom and Alsop, 1988). Distinction of modern and relict material, both in the biogenic and siliciclastic fractions, is difficult in many sediment types. Relict material, characterised by poor sorting and multi-modal grain size distribution, may comprise up to 50% of some sediments (Jones and Davies, 1983). Readily-identifiable relict shell material typically shows surface staining, extensive algal borings and glauconitic infill. (Jones and Davies, 1983).

Wave and tide modelling studies (Harris and Coleman, 1998; Harris *et al*., 2000) have shown that tidal mobilisation of sediments dominates along the periphery of Bass Strait, while in the central basin, tidal speeds are lower and wave mobilisation dominates (Fig. 1.4). Sediment accumulation is largely limited to the central basin, with estimated rates of <12 cm/1000 yr in the basin and <6 cm/1000 yr at the margins (Blom and Alsop, 1988). In Bass Strait, the high energy conditions transport fine-grained sediments away from the basin rim and deposit them in the lower-energy central basin or out onto the shelf (Fandry, 1981; Harris, 1994; Harris and Coleman, 1998).

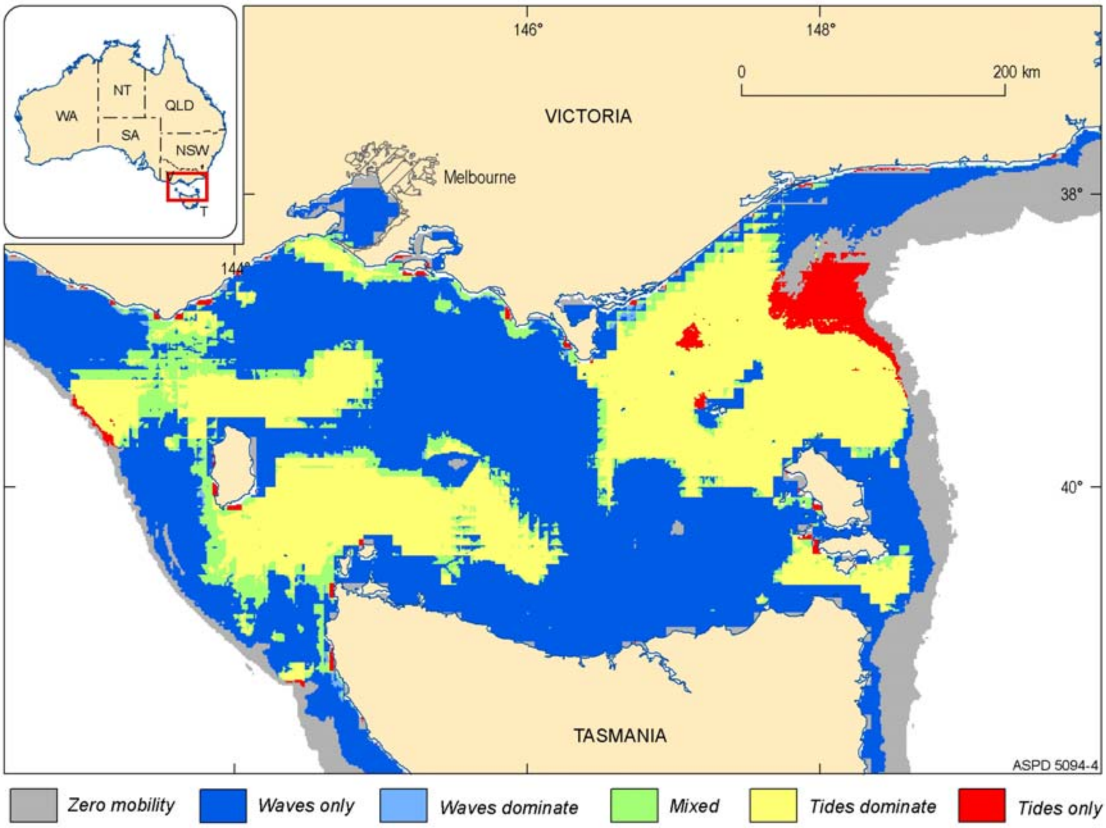


Figure 1.4 *Regionalisation of Bass Strait based on wave and tide data modelling.*

Several studies have investigated the distribution and dynamics of bedforms in Bass Strait (Malikides, 1988; Malikides *et al*., 1988, 1989; Morrow and Jones, 1988; Black and Hatton, 1992). The distribution of dunes is restricted to areas on the eastern and western margins, and appears to coincide with regions where tidal flow is enhanced by constriction between land masses. Malikides *et al*. (1989) found that dune sediments consisted of coarse sand with a mean grain size of 0.71mm and carbonate concentrations of between 42% and 92%.

1.4 REGIONALISATION AND SEAFLOOR CHARACTERISATION STUDIES

A national approach to developing an ecosystem-based classification (regionalisation) of Australia's marine and coastal waters was first endorsed by the Council of Nature Conservation Ministers (CONCOM, 1985). The more recent Interim Marine and Coastal Regionalisation for Australia (IMCRA Technical Group, 1998) was the result of work focussed on the development of a consistent regional-scale framework for planning with the involvement of the States and Northern Territory. IMCRA meso-scale regions were identified using a variety of parameters, including biological and physical data, and oceanography. However, the datasets used differed between state agencies. In the Bass Strait region, six meso-scale regions were identified in open waters (Fig. 1.5). These regions were distinguished on a variety of characteristics including flora and fauna, geomorphology and geology. However, the divisions are not consistent: for example, in the eastern and western margins, no distinction is made between coastal and open marine areas, while in central Bass Strait, coastal regions are separated.

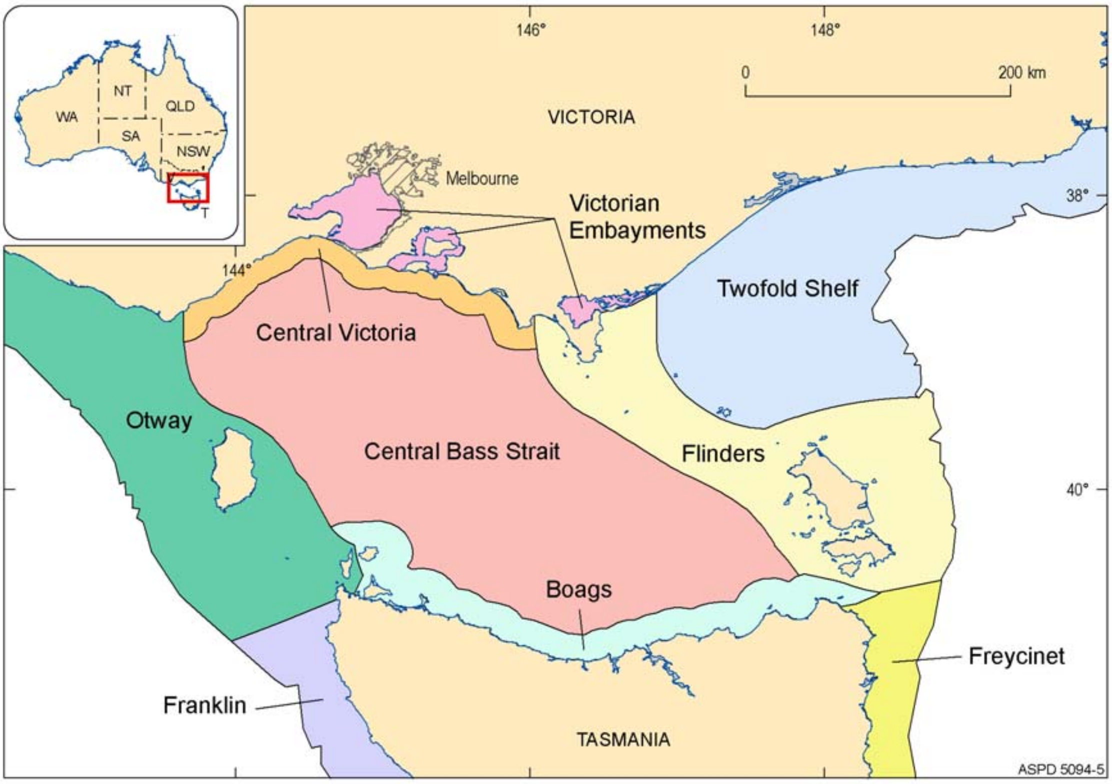


Figure 1.5 *IMCRA bioregions for Bass Strait (IMCRA, 1998).*

Numerous other studies of habitats and bioregionalisations in Bass Strait have since been undertaken. While some of these studies have covered extensive areas, most focus on the coastal marine environment, especially rocky reef habitats, or have been restricted to state waters (i.e., less than 3 nautical miles from the coast). No comprehensive bioregionalisation of Bass Strait has been carried out. Examples of studies include:

1. Edgar *et al*. (1997) carried out a reef bioregionalisation using Tasmanian examples, including Bass Strait sites. A major finding of this study was that Bass Strait sites differed from those on the eastern, western and southern margins of Tasmania. This work has provided a basis for subsequent monitoring of short-term change in marine reserves (Edgar and Barrett, 1997, 1999).

2. Underwood *et al*. (1991) described a mosaic of habitats from shallow subtidal rocky reefs along the NSW coast. The distribution of the seven habitats identified was related to water depth, wave exposure and various biological processes, particularly herbivory. Subsequently, Andrew and O'Neill (2000) used aerial photography to map large-scale patterns in these habitats and relate them to likely impacts on marine harvesting.

3. Detailed mapping and characterisation of habitats have been carried out by the CSIRO (Bax and Williams, 2001; Kloser et al., 2001; Williams and Bax, 2001) on the continental shelf off southeastern Australia, covering the area from southern NSW to the Bass Canyon. This work used a variety of datasets, including acoustic methods (Kloser et al., 2001), video and existing geological data, to classify seabed habitats (Bax and Williams, 2001) and relate these to distributions of fish communities (Williams and Bax. 2001). Bax and Williams (2001) also identified and mapped mega-scale seabed habitats, which they identified as massive sediment flats, extending kms to tens of kms, and containing dispersed patches of hard grounds, comprising reefs or bedrock outcrops.

4. In Victoria, studies have mapped habitats within coastal rocky reef environments (Ferns and Hough, 2000; 2002) and soft sediment ecosystems (Ferns, 1999; 2000) using a variety of techniques, including remote sensing, hydro-acoustic imaging, video photography and scientific diving. These studies have also examined patterns of marine biodiversity on temporal and spatial scales, and associations between physical variables and biota. The aim of the research program in Victoria has been to contribute to the national Representative System of Marine Protected Areas and to provide a basis for planning and management of marine protected areas (Ferns and Hough, 2000). The studies there have been carried out both at the meso-scale, compatible with IMCRA, and at a more detailed level.

2. Methods

2.1 SAMPLE COLLECTION

Biological samples for this study were part of the collection from the BSS (Wilson and Poore 1987). Three collection techniques were used: grabs, dredges, and trawls. Grabs included Paterson and Smith-McIntyre type grabs; dredges included a naturalist dredge, pipe dredge, rock dredge and epibenthic sled; and bottom trawls included Agassiz, Otter, and Engle's trawls. In some sites more than one sampling method was employed, depending on the nature of the substrate, and to allow for collection of different biological material. All biological sample sites are shown in Fig. 2.1 and a summary of the sampling program is provided in Appendix A (refer to CD-ROM).

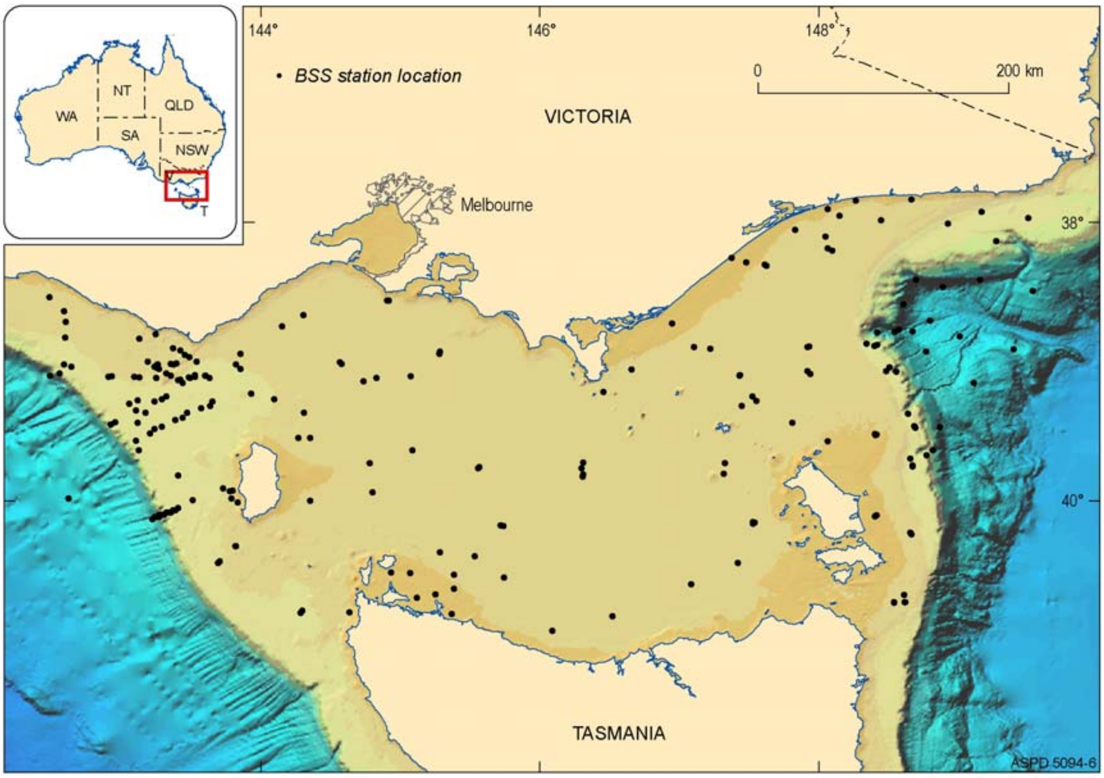


Figure 2.1 *Map of BSS sample sites for biological data.*

Geological data for this study came from several sources. Some sedimentological analyses had been carried out by the BSS (Wilson and Poore, 1987). The auSEABED database provided a source of other existing sample data. A total of 69 grab and dredge samples, collected on RV *Tangaroa* Survey 81-T-1 as part of the BSS (Wilson and Poore, 1987), was made available to Geoscience Australia by the New Zealand National Institute of Water and Atmospheric Research (NIWA). A further 6 sea bed samples collected in Bass Strait on Geoscience Australia Survey 226 (Exon *et al.*, 2001) were studied. These samples provided additional data applicable to interpretation of sediment properties, as they targeted sites previously sampled by Jones and Davies (1983). In addition, 14 sediment samples from 8 stations, seabed video footage from 9 stations and 30 km^2 of swath bathymetry were collected over the New Zealand Star Bank, north-east of Bass Strait, on board HMAS *Melville* as part of Australian Hydrographic Office Survey HI339 (also known as GA Survey 233). The locations of geological samples obtained from these three surveys are shown in Fig. 2.2 and summaries of the sampling programs are listed in Appendix A (refer to CD-ROM).

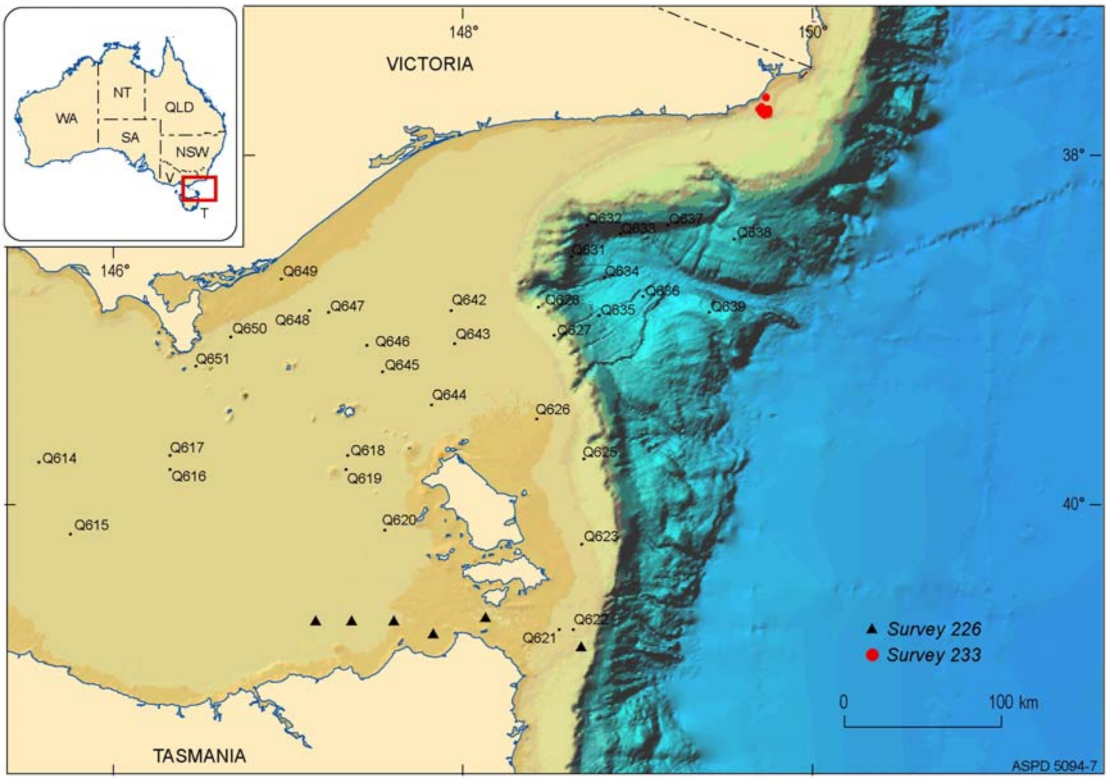


Figure 2.2 *Map of geological samples processed as part of this study, including samples collected on RV Tangaroa Cruise 81-T-1 (BSS), GA Survey 226 and Australian Hydrographic Office Survey HI339 (GA Survey 233).*

2.2 BIOLOGICAL DATA

The three collection techniques used in the BSS to collect biological samples targeted different species assemblages. Grab samples collected a consistent volume of sediment (0.1 m^2) that was typically dominated by small, infaunal animals. Dredges and sleds were towed for 3-5 minutes and collected epifauna and shallow infauna. The mesh size of the netting was 1 mm so each catch collected large and small species. Trawls had a much larger mesh size (e.g., 2 cm) and were towed for 15-30 minutes. Trawled specimens typically included large invertebrates such as sponges and sea stars as well as associated smaller epifauna (e.g., worms). Some trawl hauls were very large; sufficient to fill the back deck. These were sub-sampled on deck.

All three sample types were analysed independently in this study. Grab samples were analysed quantitatively as they are based on a consistent sample size. Abundance data, based on counts of species per sample, was $\log_e(x+1)$ transformed to down-weight abundant species. Dredge and trawl samples were transformed to presence-absence data to allow for the semi-quantitative nature of these collection techniques. Samples with less than five species, or without any geological data, were excluded from the analysis, as were samples taken from deeper waters (>150 m). The resulting samples included in statistical analyses are listed in Table 2.1.

The taxonomic groups identified to species level included: gastropods, chitons, brachiopods, echinoderms, pycnogonids, decapods, isopods (excluding the Asellotes and Sphaeromatidae), and two families of polychaete worms (Nereidae and Spionidae). This suite of species includes larger mobile fauna (e.g., shells, seastars, crabs), sedentary animals (e.g., brachiopods), animals indicative of colonial fauna (e.g., pycnogonids, gastropods), and smaller epifauna and infauna (e.g., ophiuroids, isopods, gastropods, and polychaetes). Other groups, including sponges, ascidians, bryozoans, hydroids, small crustaceans (e.g., amphipods, tanaids, and cumaceans), bivalves and the majority of polychaetes were not identified due either to lack of resources or of taxonomic expertise.

2.3 STATISTICAL ANALYSES

2.3.1 Environmental Variables

Environmental data available for incorporation into the statistical analyses included: latitude, longitude, bathymetry, % rock cover, % gravel, %sand, % mud, % carbonate, and mean grain size. To account for the dominant morphology of Bass Strait, and in particular the low north-south sills at the eastern and western side of Bass Strait, the region was divided into three zones: a) a region west of a line from Cape Otway-King Island-NW tip of Tasmania, b) a region east of a line from Wilsons Promontory-Flinders Island-NE tip of Tasmania, and c) a central region between the other two. IMCRA bioregions were not used, as sampling was uneven in these regions, particularly for the Tasmanian inshore regions.

As the number of samples actually analysed for geological variables was low (Wilson and Poore, 1987), some variables (% gravel, % sand, % mud, % carbonate, and mean grain size) were supplemented by interpolated data derived from the auSEABED database. Where available, values for % rock were taken from direct observation of samples collected from the RV *Tangaroa* (New Zealand Oceanographic Institute, 1981), NIWA records (L. Northcote, *pers. comm*., 2000) and BSS records (Wilson and Poore, 1987). Interpolated values of % rock cover are based either on measured values or estimated from written sample descriptions. Unknown values were assigned as 50% and modified accordingly where descriptions implied higher or lower rock abundance.

Two different sets of mean grain size data were used in statistical analysis. The first set is compiled from grain size measurements determined by the Geology Department of University of Melbourne (Wilson and Poore, 1987), supplemented by interpolated data. The “alternative” grain size was compiled from newly-generated laser data (discussed in detail below), supplemented by measured data, where available, or interpolated data.

2.3.2 Multivariate Statistical Analyses

Analysis of the biological data was undertaken using the multivariate statistical framework outlined by Clarke (1993) and Clarke and Warwick (1994) and the PRIMER software package.

Samples collected from the lower continental shelf and slope (below 150 m water depth) and depauperate samples, i.e. those with less than five identified taxa, were excluded from the analysis because both of these sets of samples were statistical outliers. The relatively few samples collected from the lower continental shelf and slope (>150 m) contained a substantially different fauna. Samples for which no geological data were available were also excluded, as biological data would not be able to be correlated. The remaining samples, on which analyses were based, are listed in Table 2.1.

Table 2.1: List of all sample stations used in statistical analyses in this study, grouped by collection method.

COLLECTION TECHNIQUE	NUMBER OF SAMPLES	STATION NUMBERS
Grabs	92	49, 50, 51, 55, 56, 57, 58, 60, 61, 62, 63, 64, 67, 68, 69, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 83, 84, 85, 89, 97, 98, 99, 100, 101, 103, 104, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 125, 126, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 181, 182, 184, 185, 188, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205
Epibenthic sleds and dredges	90	31, 32, 35, 38, 48, 49, 50, 52, 55, 56, 57, 59, 64, 67, 73, 75, 77, 78, 81, 82, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 138, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 201, 202, 203, 204, 205, 206, 207, 208, 209, 212
Trawls	36	115, 119, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 152, 153, 166, 171, 177, 178, 181, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 219

The remaining data were transformed to reduce the emphasis on dominant species. The grab, dredge/sled and trawl data were analysed independently. The grab data were transformed using a $\log_e(x+1)$ transformation, reflecting the two orders of magnitude difference between the most and least abundant species. The dredge/sled and trawl data were transformed into presence-absence (binary) data to reflect the semi-quantitative nature of these samples.

The Bray-Curtis coefficient was then used to compute a similarity measure between each pair of samples. The Bray-Curtis similarity measure is particularly suitable for ecological applications, as it does not include joint absences of species, and is not dependent on the scale of measurement (Clarke and Warwick, 1994)

Clustering techniques are designed to find “natural groupings” of samples (i.e., those samples that are more similar to each other than samples in other groups; Clarke and Warwick, 1994). The data were then clustered using a hierarchical agglomerative clustering technique (Clarke and Warwick, 1994), which outputted the results as a dendrogram that grouped samples into progressively larger clusters.

The data were then subject to Multi-Dimensional Scaling (MDS), a non-parametric ordination technique suitable for ecological analyses (Clarke and Warwick, 1994). Ordination techniques map similarities between samples in a two or three-dimensional diagrammatic representation. The distance between sample points on the diagram reflects the similarity between samples. Ordinations display interrelationships between samples on a continuous scale rather than by creating discrete clusters. The reduction of the multi-dimensional relationship between samples into 2 or 3 dimensions can produce some distortions. The degree of distortion, or “stress”, is an indication of the reliability of the ordination. Stress values of greater than 0.3 indicate an almost random ordination. Stress increases naturally with the number of samples and with the reduced dimensionality of the ordination (Clarke and Warwick, 1994).

Ecological and geographical variables were then correlated against the ordinations using Principle Axis Correlation (PCC) technique, sometimes known as Perceptual Mapping. PCC is a multiple-linear regression routine designed to see how well variables correlate with the ordination plot (Belbin, 1993). The PCC correlation coefficients give an indication of the strength of the correlation. The correlation vectors can then be superimposed on the ordination to produce biplots. In this study, %rock cover, %gravel, %sand, %mud, and %carbonate) were arcsin(√) transformed before the multiple regression to reduce the skewed nature of their distributions. The multiple regression was performed using the computer software package Statistica 5 with missing data deleted in a pairwise operation to minimise loss of data.

Environmental variables also can be matched against the ordination using the BIOENV procedure outlined by Clarke and Warwick (1994). This procedure computes ranked similarity coefficients for samples based on various combined groups of environmental variables. These coefficients are then compared against samples ranked by species similarity coefficients by using the Spearman-Rank correlation. The highest rank correlation indicates which group of environmental variables best reflects the species composition of the samples. For this study the environmental variables similarity coefficients were computed by using normalised Euclidean distance, which standardises the variables from their different respective scales.

2.4 SEDIMENTOLOGICAL ANALYSES

For the 69 samples from RV *Tangaroa*, grain size distributions were determined using a Malvern Mastersizer 2000 laser particle sizer. Additional analyses were carried out on those samples which had not previously been analysed as part of the BSS (Wilson and Poore, 1987). These analyses included percent gravel, sand, and mud; carbonate content of bulk samples and separate gravel, sand, and mud fractions, where sample fraction sizes were sufficiently large. Twenty-nine of the NIWA samples (Table 3.10) were selected for microscopic examination to determine colour, and composition and preservation of the biogenic fraction. Six of the samples collected as part of GA Survey 226, together with two of the samples from Australian Hydrographic Office Survey HI339 (GA Survey 233) were processed to provide sieve, laser grain size, carbonate content of separate fractions and general composition and preservation. Sediment terminology for all samples is based on Feary (2000), rather than terms for carbonates (Lewis and McConchie, 1994) as the latter are often inappropriate for mixed carbonate/siliciclastic sediments. Details of the methods used to carry out sedimentological analyses are provided in the following sections.

2.4.1 Sample Preparation and Sieve Grain Size Analysis

Sub-samples of ~50 g were taken from bulk samples held at NIWA and forwarded to Geoscience Australia. Because of quarantine restrictions, the samples were irradiated on arrival in Australia. Only two of the samples from Survey HI339 were of sufficient size to analyse. At Geoscience Australia, all samples were photographed, the colour was determined by direct comparison with soil colour charts (Munsell, 2000), and permanent smear slides, fixed with Eukitt, were made. Sub-samples were taken from the centre of each sample for grain size determination. Sieve analysis of percent gravel, sand, mud, and carbonate concentration were carried out for samples which had not been analysed as part of the BSS (Wilson and Poore, 1987). Because sub-sample size used for sieving was small, the gravel fraction may be under-represented. Sample residues (gravel and sand fractions) were washed in tap water for descriptive analysis, where required. The residues were dried, labelled, and, following description, archived in Geoscience Australia's repository.

2.4.2 Laser Grain Size Analysis

Laser grain size analysis was carried out using a Malvern Mastersizer 2000 laser particle sizer, following standard operating procedures (Appendix B – refer to CD-ROM). Samples were first treated with hydrogen peroxide to remove organic material. The fraction >2 mm was removed by sieving. Samples were then suspended in tap water and passed in front of the laser. The particle standard was set as $CaCO_3$, based on the high carbonate concentrations using a refractive index of 1.572. Separation of the gravel, sand, and mud fractions was undertaken by wet sieving the bulk sample through sieves with mesh spacings of 2 mm and 63 μm.

2.4.3 Carbonate Analysis

Carbonate concentrations were determined using the vacuum-gasometric technique (Muller and Gastner, 1971). Concentrations were calculated for bulk samples to supplement BSS data (Wilson and Poore, 1987). Carbonate concentrations were also calculated for gravel, sand, and mud fractions where there was sufficient material for measurement. Carbonate concentrations were estimated visually for gravel fraction, where possible.

2.4.4 Analysis of Composition and Preservation

The composition of the gravel and sand fractions was determined using a Leitz MZ12 stereozoom microscope. Representative views of the sand fraction were then photographed using an Olympus DP10 or DP11 digital camera top-mounted on the microscope. The gravel fraction was photographed using a Nikon digital coolpix 950 camera. Photographs of representative and unusual biota were also taken to provide a guide to identification.

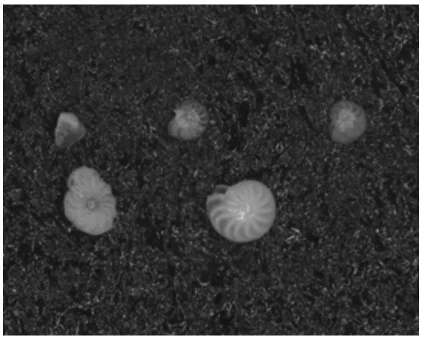
Description of the samples was based on the method used by Radke, in Harris *et al*. (2001). Estimation of bioclast abundance was based on volume percentage, rather than weight, because of the difficulties involved in estimating weights and the likelihood of large errors (Harris *et al*., 2001). For all samples the whole gravel fraction was examined. Representative samples of sand fractions were obtained using a microsplitter. Estimates of composition were determined separately for each fraction then combined using the relative weight of each fraction. The preservation of the biogenic components in the sand and gravel fraction of each sample was assessed as modern, intermediate or relict. The terminology used was based on Radke (in Harris *et al*., 2001).

The preservation of the biogenic components was based on a number of factors, including: the presence of fragile taxa or fine structures, (e.g., very fine sponge spicules, pteropods), degree of bioerosion, original colouration, presence of articulated carapaces or zooaria, and the extent of fragmentation (Table 2.2; Fig. 2.3).

Table 2.2: Description of preservation states and their characteristics

PRESERVATION STATE	FORM	DETAIL	SURFACE	COLOUR
MODERN	components whole with unbroken edges; valves and zooids may be articulated	fine features preserved, eg delicate spines; juvenile specimens preserved	vitreous or nacreous	original colour present
INTERMEDIATE	components disarticulated	fine details broken or abraded; edges showing wear	external surface lacks vitreous lustre, although interior may be still vitreous;	original colour faded or lacking

			evidence of surface wear such as pitting, bioerosion, or encrustation	
RELICT	components disarticulated, broken and/or abraded	edges heavily abraded; specimens may be cracked	surface chalky, pitted and bioeroded, often heavily encrusted; may be altered, or polished by heavy abrasion	often stained; original colour usually absent



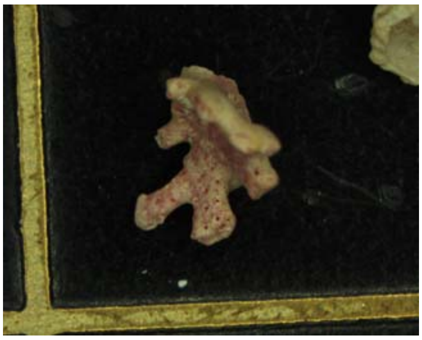
1A

1B

2A

2B

2C



2D

(Figure 2.3 continued on next page)

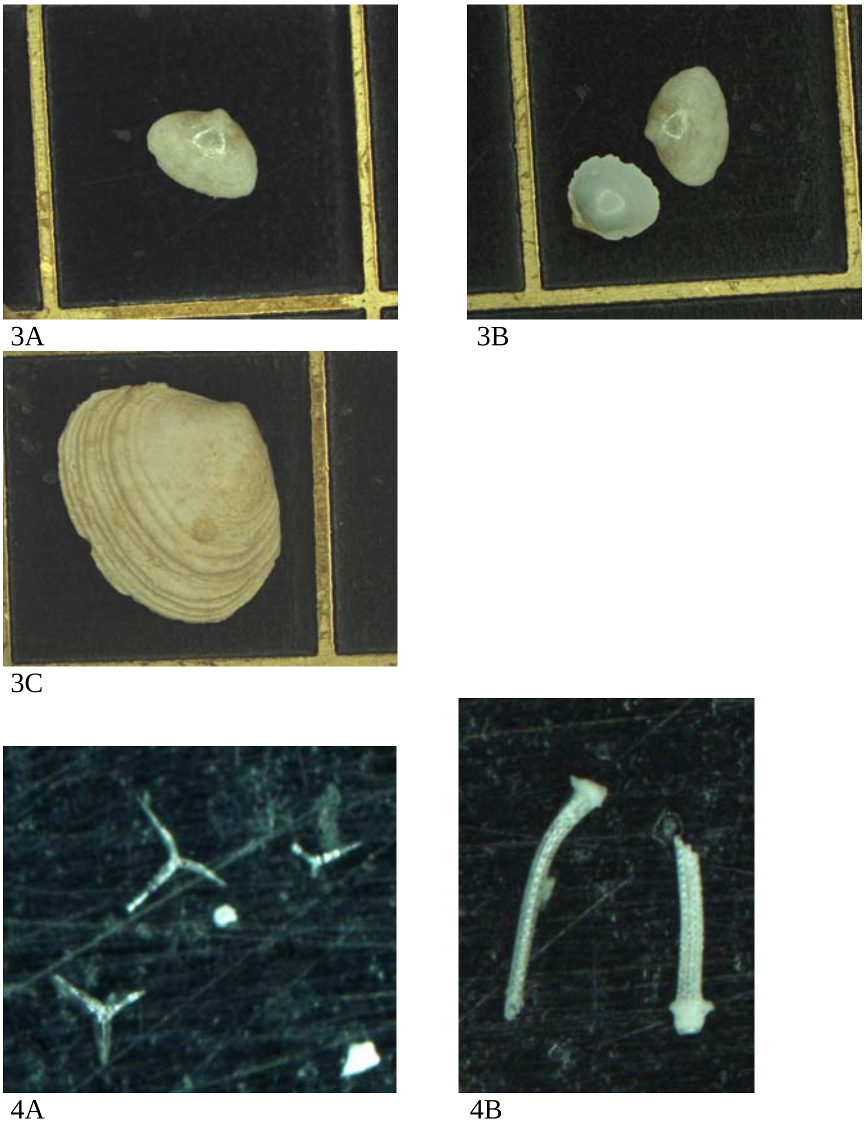


Figure 2.3 *Examples of preservation states in individual specimens: 1 Benthic foraminifera (A) left modern, centre 2 specimens intermediate, left 2 specimens relict; (B) relict specimens which are stained and highly polished. Note pitting on surface. 2. (A) fresh, articulated bryozoa with original colour present; (B) Intermediate preservation; (C) relict material showing abrasion and encrustation (D) relict material with some original colour retained. 3. (A) Bivalve valve modern showing vitreous surface and original colouration; (B) Bivalves valves showing intermediate preservation interior (left) and exterior views. Note abrasion of valves edges and loss of vitreous outer, but not inner surface. 4. Modern material: (A) Sponge spicules with fine details preserved; (B) Very fine echinoid spines with minor abrasion of points.*

Biota present in each sample were identified to a high taxonomic level, at least class level where possible, with the exception of bryozoans. In both the sand and gravel fractions, where fragments of bioclasts could be clearly recognized, they were assigned to the relevant group. Otherwise fragments were classified as *other bioclasts*. Bryozoa were classified using the zooarial growth form terminology of Nelson *et al*. (1988), modified to take into account additional forms identified by Bone and James (1993) (Table 2.3). Unlike other zooarial classification schemes, this scheme does not rely on specialist taxonomic knowledge, and has previously been applied to the interpretation of sedimentary environments in southeast Australia (James and Bone, 1991; Bone and James, 1993).

Table 2.3: Zooarial types recognised in this study. The classification scheme used is based on Nelson *et al*. (1988), modified after Bone and James (1993). Comparative types in both schemes are provided for reference.

GROWTH FORM		EXAMPLE	CODE (THIS STUDY)	NELSON *ET AL*., 1988	BONE & JAMES, 1993
ENCRUSTING	unilaminar		**ENul**	ENul	
	multilaminar		**ENml**	ENml	ENCRUSTING
ERECT RIGID	fenestrate		**ERfe**	Erfe	FENESTRATE
	foliaceous		**ERfo**	ERfo	FOLIOSE
	robust branching		**ERro**	ERro	FLAT ROBUST BRANCHING
	delicate branching		**ERde**	ERde	DELICATE BRANCHING
	radiate		**ERra**	ERra	

ERECT FLEXIBLE	articulated branching		**EFab**	EF	ARTICULATED BRANCHING
	articulated zooidal		**EFaz**		ARTICULATED ZOOIDAL
FREE-LIVING	free-living		**FL**	FL	VAGRANT

2.5 BANKS STRAIT SEDIMENT ANALYSIS

Six sediment samples collected on GA Survey 226 (Exon *et al*., 2002) were selected to examine the properties of sediments in tide-dominated Banks Strait, on the eastern side of Bass Strait (Fig. 1.2). These samples were collected along a transect though Banks Strait, from the outer shelf into Bass Strait (Fig. 2.4). The grain size distributions of the sand and mud fractions were analysed using the Malvern Mastersizer 2000 laser particle sizer. Gravel and sand fractions were examined by microscope to determine the main constituents and their preservation.

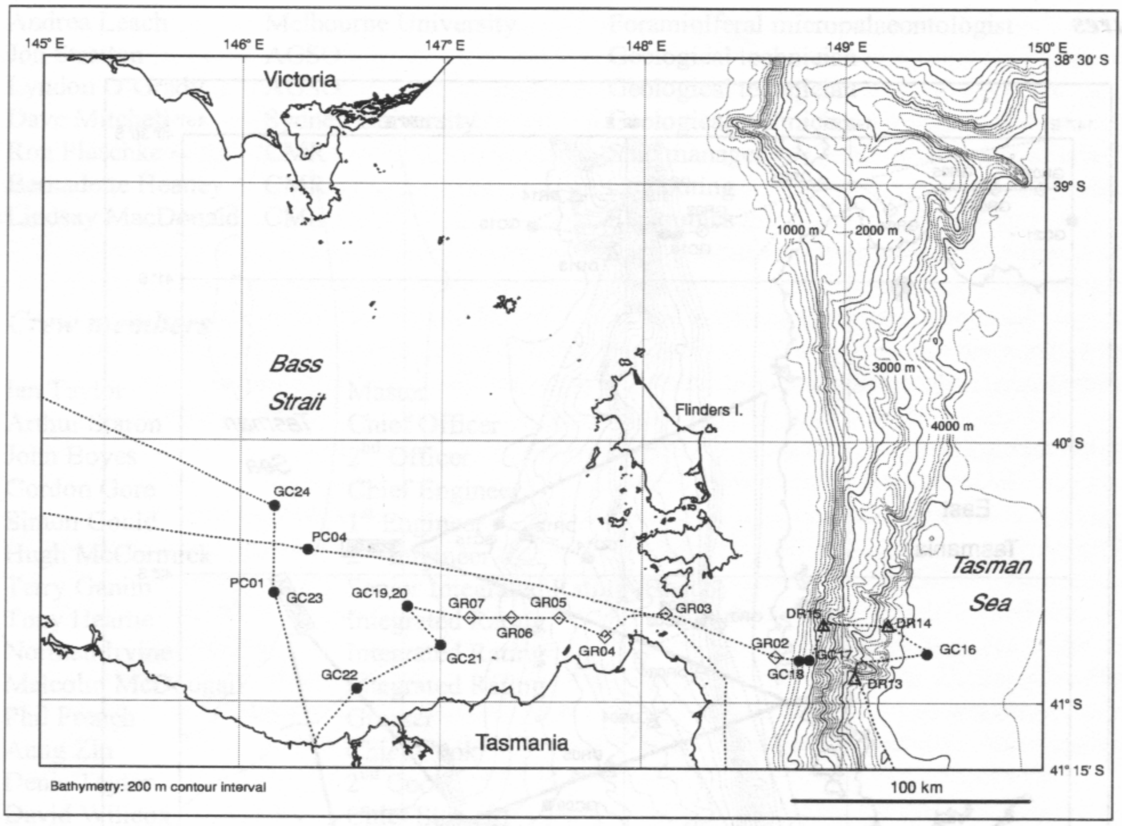


Figure 2.4 *Locations of grab samples from Banks Strait (GA Survey 226).*

2.6 COMPARISON OF SEDIMENT SAMPLING TECHNIQUES

Approximately 80% of surface sediment samples in offshore southeast Australia were collected by pipe-dredges during research surveys in the 1970's to late 1980's. These samples provided the basis for the regional sediment mapping of Jones and Davies (1983). Since that time, improved recovery methods have demonstrated that mud and fine sand can be lost during dredging operations. Thus, the existing analyses from pipe dredges may be skewed towards medium to coarse sand and gravel fractions, and not reflect the true nature of the seabed.

To test the reliability of pipe dredges in obtaining representative samples, GA Survey 226 targeted 6 sites in eastern Bass Strait which had been dredged by Jones and Davies (1983). These sites were sampled using a Smith-McIntyre grab (Exon *et al*., 2002; Fig. 2.4). Grain size distributions and carbonate concentrations for the gravel, sand, and mud fractions were determined according to the techniques described above, and the results were compared with the original sediment samples from Jones and Davies (1983).

2.7 NEW ZEALAND STAR BANK DATA

New Zealand Star Bank is a series of topographic highs centred on S37° 47', W149° 44'. The Bank was surveyed on 11-12th October 2001 on HMAS *Melville* during Survey HI339 of the Australia Hydrographic Office (also referred to as GA Survey 233). High-resolution bathymetry was planned to be collected over 39 km^2 using a Fansweep 20 multibeam sonar, with 45 track lines bearing 050/230 (alternating) and line spacing of 140 m. The survey was not completed due to time restrictions and inclement weather. As a result, only about 30 km^2 was surveyed and significant gaps in the bathymetry remain. Expendable Bathythermographs (XBT) were collected for sound velocity profiles.

At total of 14 surface sediment samples was taken using a Shipek grab. At each station approximately 5 minutes of video footage of the sea floor was also collected. The main objective for collecting underwater video data was to appraise the technique as a means of surveying the seabed for habitat, morphology, and sediment distributions.

A detailed account of Survey HI339 is contained in Appendix C (refer to CD-ROM).

2.8 VIDEO CLASSIFICATION

Video camera deployment allowed for visualisation of the sea bed at a coarser scale than that represented by grab samples. This then enabled the identification and quantification of both biotic diversity and geomorphology present in the study area for both reef and off reef sites. A list of terms was collated to describe the seabed habitats contained in the video images. This list was derived from the work of Greene *et al*. (1999) and is intended as a trial with the purpose of developing a universal scheme for habitat classification. Revisions made to the scheme of Greene *et al*. (1999) included:

- addition of morphological terms that were not in the original scheme; and
- inclusion of biological/ecological data that were logged according to what substrate(s) they were associated with.

Most of the table fields are answered as a 'Y' (yes) determining that that feature exists within the video (or still photo). Some characteristics, such as faunal coverage, have multiple fields to best describe that feature (i.e., sparse, clumps, dense).

At present, the classification scheme is largely qualitative, and this may be a disadvantage to groups who wish to make more quantitative habitat assessments. However, for the purposes of this study, qualitative links between different survey techniques is sufficient.

Data from the video footage was logged into a spread sheet on board ship (see attached CD-ROM) and then imported into a GIS database.

2.8.1 Video Metadata

In this case, metadata associated with the video images corresponded to information about geo-referencing and source of each image (Table 2.4). Files included in the metadata field are subject to change depending on how the video data will be integrated into Geoscience Australia's corporate databases in the future.

Table 2.4: Metadata fields for video footage.

Lat	
Lon	
Depth	
Reference Number	
Source	
Survey	
Date/Julian Day	
Time	

2.8.2 Scope.

The term "scope" was applied to the area covered by the image (assumed to be roughly square and measured in meters), which is largely dependant on the zoom of the video camera and distance from the seabed (Table 2.5). The term transect was used for video footage that covered a roughly linear path as opposed to a single patch of ground.

Table 2.5: Scope field for video footage.

SCOPE (METERS)	SMALL ~1X1	MEDIUM ~5X5	LARGE >10X10	TRANSECT
View				

2.8.3 Gross Morphology

Morphology described multiple features occurring on the seabed and combinations of features for both unconsolidated sediments and bedrock (Table 2.6).

Table 2.6: Gross Morphology fields for video footage (non exhaustive list).

GROSS MORPHOLOGY	Y	COMMENTS
Bars		
Banks		
Channels		
Dunes - Regular (wavelength and height)		
Dunes - Irregular (continuous, non uniform)		
Ripples - Regular (wavelength and height)		
Ripples - Irregular (continuous, non uniform)		
Hummocky (mounds and depressions)		
Depression		
Pockmarks		

Seep		
Abyssal Plain		
Debris Fields		
Ledges		
Walls		
Slabs		
Massive Biogenic Reefs		
Delicate Biogenic Reefs		
Non Biogenic Reefs		
Pinnacle		
Crevices		
Walls		
Vent		
Terrace		
Scarp		

2.8.4 Sediment Cover

Sediment cover requires an estimate of rock exposure. In regions covered by only a thin layer of sediment (with exposed rock) there would be wider variety of substrates available for benthic organisms compared to areas with a more homogeneous substrate (Table 2.7).

Table 2.7: Sediment Coverage fields for video footage.

SEDIMENT COVER	Y	COMMENTS
Exposed Rock		
Dusting (mostly rock)		
Thin (some rock exposed)		
Thick (no rock exposed)		

2.8.5 Bottom Slope

Bottom slope refers to the inclination on the sea floor, relative to horizontal (Table 2.8). It is difficult to estimate accurately as the orientation and tilt of the camera are not known. By way of comparison bottom slope can be accurately measured by multibeam bathymetry. In our scheme, the bottom slope field allows characterization of overhanging and complex topographies that multibeam bathymetry may have difficulty resolving.

Table 2.8: Bottom Slope fields for video footage.

BOTTOM SLOPE	Y	COMMENTS
Slight (0-5)		
Sloping (5-30)		
Steep (30-45)		
Vertical (45-90)		
Overhang (>90)		
Complex Topography		

2.8.6 Bottom Texture

Bottom texture is a qualitative measure of the grain size and composition of the seabed (Table 2.9). Ideally these data would be supplemented by (or ground-truthed by) grab samples.

Table 2.9: Bottom Texture fields for video footage.

BOTTOM TEXTURE (QUALITATIVE)	Y	COMMENTS
Organic Debris		
Shell Hash		
Shelly Sediment		
Shelly Macrofossils		
Mud		
Sand		
Gravel		
Cobble		
Boulder		
Sediment Mixture		
Bedrock - Not Classified		
Bedrock – Igneous		
Bedrock – Metamorphic		
Bedrock – Sedimentary		
Bedrock Outcrop – massive		
Bedrock Outcrop – bedding		
Bedrock Outcrop – small		
Hard ground		
Cementation – Minor		
Rhodoliths		
Oolites/Oncolites		
Shelly Lag Deposits		

2.8.7 Benthic Biota (Dominant)

Dominant benthic biota are logged according to the type of substrate(s) on which they occur (reef, rock, sediment; Table 2.10). Actual species associations (groups) are not logged because presumably the existence of one species spatially is not necessarily related to the existence of another. Species distributions can occur along environmental gradients and their distributions might not always be 'discrete'.

Table 2.10: Dominant benthic biota fields for video footage.

Biota (dominant)	Yes- sediments	Yes - rock	Yes - reef
Encrusting (various)			
Mollusc beds			
Ascidians			
Seawhips/pens			
Sponge communities			
Crinoids			
Algae			
Corals			
Seagrass			
Complex Community Structure (Reef)			

2.8.8 Benthic Biota (Minor)

The minor biota in a community are also identified and logged according to what substrate they occur on (Table 2.11).

Table 2.11: Minor Benthic Biota for video footage.

MINOR BIOTA PRESENT	YES - SEDIMENTS	YES - ROCK	YES - REEF
Encrusting only			
Mollusc beds			
Ascidians			
Seawhips/pens			
Sponge communities			
Crinoids			
Algae			
Corals			
Seagrass			

2.8.9 Biological Cover

Biological cover is a measure of the degree to which biological organisms cover the seabed (Table 2.12). 'Clumps' refers to widely spaced groups for organisms whilst 'sparse' refers to widely spaced individuals.

Table 2.12: Biological Coverage fields for video footage.

Coverage	Sparse	Clumps	Intermediate	Dense	Very Dense - Total Cover
Coverage					

2.8.10 Bioturbation

Bioturbation is a measure of the degree of sediment reworking by benthic organisms (Table 2.13). It can also be used as an indirect measure of species density on, or within, the substrate.

Table 2.13: Surficial bioturbation fields for video footage

BIOTURBATION	MINOR	INTERMEDIATE	INTENSE	COMMENTS
Burrows - Large				
Burrows - Small				
Trails				
Excavations				
Mounds				

2.8.11 Water Column

Water column is used to identify organisms and features in the water column (Table 2.14). This field is mostly used for characterizing features when the camera is being lowered and raised through the water column.

Table 2.14: Water Column fields for video footage.

Water Column	Y	Comments
Jelly Fish		
Abundant Fish		
Scarce Fish species		
Rays		
Snow		
Suspended Sediment.		

2.8.12 Anthropogenic Features

Anthropogenic features are included to capture the impacts of human activities (Table 2.15).

Table 2.15: Anthropogenic feature fields for video footage

FEATURES	Y	COMMENTS
Dredge Spoil Piles		
Ballast		
Trawl Tracks		
Artificial Reef		
Wreaks		
Misc Debris		

Four important aspects of this classification scheme are:

1. It allows for more than one 'habitat' to co-exist with another (i.e. rocky and sandy substrates can contain different benthic biota but can also be found in close proximity to each other). The ability of the footage to incorporate multiple habitats depends on the amount of camera 'wander', distance from the sea bed, and duration.
2. This scheme is only intended to provide brief descriptions of habitats. This allows for rapid assessment to determine basic linkages between geology and biology. This scheme is not intended to classify biological habitats in detail, though a similar scheme could be adapted for that purpose. One advantage that video has over sediment samples is that it allows visualisation of geological and/or geomorphic features that can not be determined from sediment samples.
3. This scheme does not attempt to give a 'name' to habitats, rather it identifies the various attributes of video footage that are later be analysed using principal component analysis to statistically examine relationships between geology/geomorphology and biology. However, due to the few stations where reliable video footage was obtained statistical analysis of the classified data was unachievable.
4. This scheme is equally applicable to still photography as it is to video.

3. Results

3.1 THE BASS STRAIT FAUNA

Bass Strait is renowned for the diversity and productivity of the sessile invertebrate fauna, particularly for sponges and bryozoans (Wiedenmeyer, 1989; Boreen *et al*., 1993). Due to lack of taxonomic expertise and of resources, this study did not include those groups in the analysis. However, the abundance of habitat-forming animals, such as sponges and bryozoans, is reflected in other seafloor fauna.

A total of 19,227 individuals in 554 species were identified in this study from the biological material collected on the BSS (Table 3.1). The dredges and epibenthic sled collected the majority of species (>87%) and individuals (>75%). Fewer gastropods were collected than pycnogonids (sea spiders), possibly reflecting the very diverse bryozoan and hydroid fauna that exists in Bass Strait, all of which support pycnogonids. The most abundant species for each collection technique are given in Table 3.2.

Table 3.1: Number of species (s) and individuals (n) of different taxonomic groups for the different collection methods.

TAXONOMIC GROUP	GRAB SAMPLES (N=111)		DREDGE/ SLED SAMPLES (N=129)		TRAWL SAMPLES (N=56)		TOTAL (N=303)	
	S	N	S	N	S	N	S	N
Polychaeta (spionids and nereids)	25	776	31	1018	13	142	39	1936
Pycnogonida	21	147	48	1884	6	52	49	2083
Brachiopoda	11	121	11	411	5	71	12	603
Decapoda	31	310	70	4565	42	644	79	5519
Isopoda (valviferans, anthurideans and flabelliferans, excluding sphaeromatids)	71	479	106	2150	6	47	115	2676
Asteroidea	2	4	9	49	10	111	13	164
Crinoidea	1	14	8	146	6	12	11	172
Echinoidea	6	35	15	194	10	77	15	306
Ophiuroidea	22	374	42	2917	15	491	44	3782
Gastropoda	60	232	142	1297	58	363	177	1892
Polyplacophora	3	22	5	59	2	13	6	94
TOTAL	**253**	**2514**	**487**	**14690**	**173**	**2023**	**554**	**19227**

The species collected represent almost 6% of Victoria's marine invertebrate fauna in water depths of 0-100 m (O'Hara, 2002). Some speciose groups such as amphipods, sponges, and bryozoans were not included in this study, largely due to the extensive time and taxonomic resources required to complete such a task. Of the included taxonomic groups, some were better represented than others. This is partly a reflection of the paucity of nearshore environments (e.g., rocky shores, mud flats, estuaries, and seagrass beds) sampled in the BSS. Nevertheless, the number of species from the recorded groups indicates that Bass Strait supports a particularly diverse faunal assemblage.

Some 120 species were found only in eastern Bass Strait. Of these, 69 (57.5%) represent collection artefacts as the taxa have been found along the southern coast of Australia in other surveys. A further

24 species (20 %) are poorly known or undescribed while 27 species (22.5 %) are known only from eastern Australia.
In southern Bass Strait, trawls collected substantial amounts of sponge (Table 3.3). Some trawl hauls were so large that they filled the trawl deck, particularly at stations 131-136 (Fig. 3.1). These sites formed an arc along the 65-75 m bathymetric contour (Fig. 3.2). Smaller amounts of sponge were collected throughout Bass Strait, particularly south of Cape Otway and on the Gippsland Shelf. The region was not comprehensively surveyed for sponge gardens and large beds may also exist elsewhere. The sponge fauna of Bass Strait is known to be particularly species-rich (Wiedenmayer, 1989), and has been regarded as internationally significant (Ray and McCormack-Ray, 1992).

Numerous specimens of the introduced species *Maoricolpus roseus* (New Zealand Screw Shell) were collected from two stations (163 and 164) off northeast Tasmania (Fig. 2.1). This species was introduced into southeast Tasmania before 1945 (Furlani, 1996). The BSS records indicate that it had reached northeast Tasmania by 1981, and Museum Victoria records show that this species was off East Gippsland by 1990.

Table 3.2: List of the most numerous species collected using grabs, dredges and trawls, n=number of samples, s=number of individuals

			GRAB		DREDGE		TRAWL	
PHYLUM NAME	GENUS	SPECIES	N	S	N	S	N	S
Echinodermata	*Ophiothrix*	*caespitosa*	16	69	65	688	30	211
Crustacea	*Phylladiorhynchus*	*pusillus*	18	83	56	764	14	123
Crustacea	*Leptochela*	*sydniensis*	25	62	45	763	0	0
Annelida	*Prionospio*	*kulin*	63	347	44	257	3	3
Echinodermata	*Ophiura*	*kinbergi*	26	87	43	1415	8	113
Arthropoda	*Austrodecus*	*staplesi*	10	28	39	474	5	17
Arthropoda	*Achelia*	*assimilis*	18	31	38	219	1	28
Arthropoda	*Pseudopallene*	*ambigua*	11	26	37	177	0	0
Crustacea	*Phlyixia*	*intermedia*	6	9	37	103	7	12
Crustacea	*Halicarcinus*	*rostratus*	3	3	35	159	3	3
Echinodermata	*Ophiacantha*	*alternata*	13	42	35	137	3	4
Crustacea	*Galathea*	*australiensis*	2	3	34	290	10	33
Annelida	*Neanthes*	*kerguelensis*	6	7	34	115	14	34
Echinodermata	*Ophiocentrus*	*pilosa*	7	9	33	122	3	3
Echinodermata	*Amphipholis*	*squamata*	14	29	33	118	3	12
Crustacea	*Nauticaris*	*marionis*	3	4	31	118	0	0
Crustacea	*Pilumnus*	*etheridgei*	2	2	31	134	21	39
Annelida	*Neanthes*	*flindersi*	3	9	30	103	6	26
Crustacea	*Leptomithrax*	*sternocostulatus*	0	0	29	43	3	7
Crustacea	*Lophopagurus*	*nanus*	4	6	29	149	4	17
Crustacea	*Ebalia*	*tuberculosa*	5	7	28	306	3	6
Crustacea	*Philocheras*	*flindersi*	5	6	28	294	0	0
Echinodermata	*Microcyphus*	*annulatus*	10	10	27	41	6	14
Arthropoda	*Callipallene*	*emaciata*	14	22	27	80	0	0
		micracantha						
Annelida	*Prionospio*	*nirripa*	31	87	26	134	1	3
Echinodermata	*Ophiactis*	*resiliens*	11	20	24	85	3	6
Crustacea	*Chlorotocella*	*spinicaudus*	1	15	24	304	3	10
Crustacea	*Alpheopsis*	*trispinosa*	4	5	22	368	6	7
Echinodermata	*Goniocidaris*	*tubaria*	4	8	21	56	14	27

			GRAB		DREDGE		TRAWL	
PHYLUM NAME	**GENUS**	**SPECIES**	**N**	**S**	**N**	**S**	**N**	**S**
Crustacea	*Phlyixia*	*crassipes*	2	2	20	59	0	0
Crustacea	*Neastacilla*	*attenuata*	2	19	20	175	0	0
Crustacea	*Leptanthura*	*diemenensis*	19	19	20	40	0	0
Crustacea	*Pilumnus*	*tomentosus*	0	0	20	48	36	85
Crustacea	*Halicarcinus*	*ovatus*	0	0	19	71	3	14
Brachiopoda	*Anakinetica*	*cumingi*	8	13	19	135	3	24
Crustacea	*Gnathia*	*calamitosa*	2	2	19	157	0	0
Annelida	*Nereis*	*maxillodentata*	6	7	19	29	3	3
Annelida	*Neanthes*	*cricognatha*	8	16	19	43	7	10
Crustacea	*Actaea*	*peronii*	1	1	18	34	17	35
Crustacea	*Alpheus*	*parasocialis*	4	10	18	80	1	2
Arthropoda	*Oropallene*	sp. 2	5	9	18	415	1	1
Echinodermata	*Ophiacantha*	*clavigera*	10	39	18	72	0	0
Crustacea	*Austrarcturella*	*hirsuta*	1	3	16	33	0	0
Brachiopoda	*Parakinetica*	*stewarti*	5	10	16	128	1	1
Crustacea	*Achaeus*	*curvirostris*	0	0	15	17	7	10
Mollusca	*Cystiscus*	*inaequidens*	2	4	15	34	2	3
Crustacea	*Austrarcturella*	*callosa*	2	4	15	34	1	1
Echinodermata	*Ptilometra*	*macronema*	5	14	14	114	0	0
Crustacea	*Neoarcturus*	sp. s4	5	5	13	66	0	0

Table 3.3: List of BSS stations from which large amounts of sponge were trawled. Smaller amounts of sponge were collected throughout Bass Strait, particularly near Cape Otway and off Gippsland.

STATION	LATITUDE	LONGITUDE	DEPTH	SHIPBOARD DESCRIPTION
STN 131	39 45.55'S	145 33.82'E	78 m	Abundant pumpkin sponges
STN 132	40 10.75'S	145 43.17'E	76 m	Good sponge collection
STN 133	40 33.07'S	145 44.69'E	68 m	Huge load sponge with mud and bryozoan rubble
STN 134	40 56.04'S	146 05.39'E	68 m	Big haul of sponges
STN 135	40 49.75'S	146 31.33'E	68 m	Huge haul of sponges
STN 136	40 35.90'S	147 05.11'E	70 m	Huge load of sponge and mud

Figure 3.1 *Massive hauls of sponges collected from southern central Bass Strait, enough to fill the entire trawl deck.*

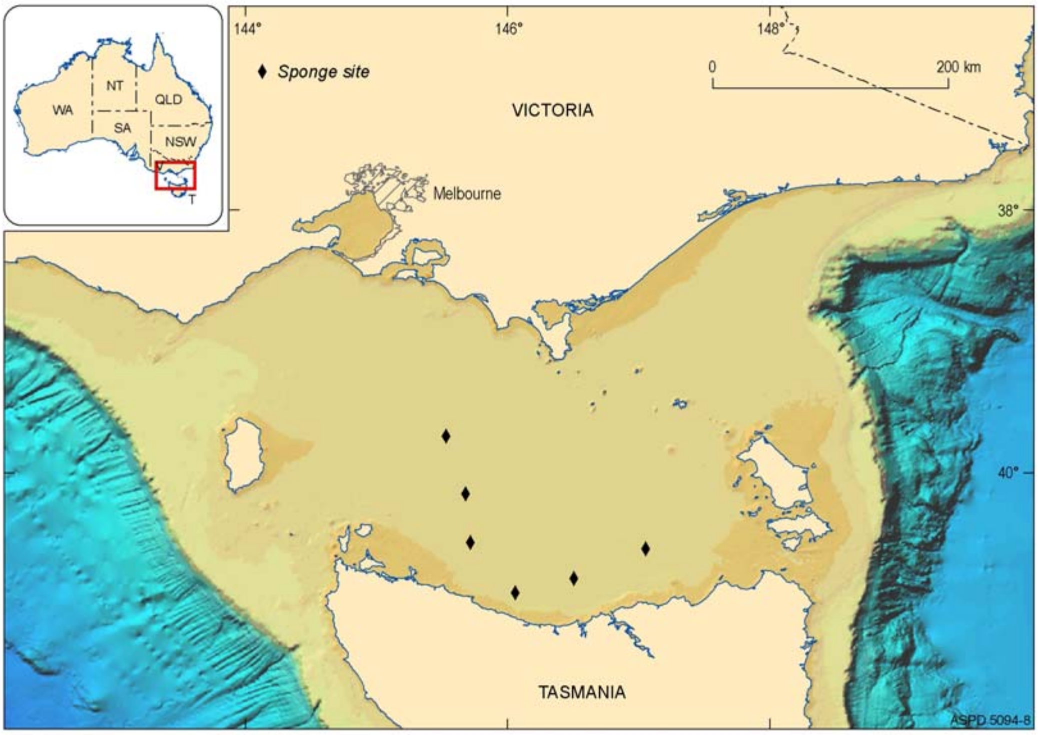


Figure 3.2 *Map of sponge sites.*

3.2 MULTIVARIATE ANALYSES

3.2.1 Grab Ordination

A multi-dimensional scaling (MDS) ordination of the grab samples (n=90 after eliminating deep-water and depauperate samples ie those containing less than 5 individuals) produced little obvious grouping (Fig. 3.3). However, two environmental variables (longitude and depth) were significantly correlated with the points (Table 3.4). Percent mud and sand were also reasonably well correlated with the ordination, although they were not significant (using pairwise deletion of missing data) after a Bonferroni correction for multiple comparisons. Slightly different results were obtained for pairwise and casewise deletion of missing data. For example, mean grain size was significant when casewise deletion was used but not when pairwise deletion was used. The difference between the two datasets lies mainly in the use of interpolated data for some variables (e.g., mud, rock, grain size) when actual data was missing. Thus the faunal communities appear to be better correlated with actual mean grain size than data generated from sediment models.

The relationship between the regression vectors (using pairwise deletion) and grab ordination points can be seen on a biplot (Fig. 3.4d). The depth vector is aligned with the X-axis and the longitude, mud and sand vectors are predominantly aligned with the Y-axis. The correlations between these variables and the ordination X and Y scores are scattered (Fig. 3.5), although there are general trends. Water depth clearly increases from left to right across the ordination, and, in general, the percentage of mud increases towards the top of the ordination, as the percentage of sand declines. However, samples with 100% sand are scattered across the ordination. The relationship between longitude and the Y-axis is less clear.

The patterns above are confirmed when the ordination points are labelled with substrate, regional, and depth categories (Fig.3.4a-c). Many of the samples with >20% mud occur towards the top of the ordination and sand-dominated samples occur predominantly across the centre and bottom (Fig. 3.4a). Samples dominated by rock or gravel clasts are interspersed. Samples from western Bass Strait occur across the centre of the ordination, with samples from central and eastern regions towards the upper left. When the ordination is repeated in three dimensions (Stress=0.15, not figured) samples from eastern and central regions separate on the Z-axis. The separation between these regions is not absolute, with some samples from each region dispersed throughout the ordination space. Grab samples collected at water depths of less than 130 m occur towards the right of the ordination. Most of these samples were collected from western Bass Strait, as few deep-water grab samples were collected in the east.

Some environmental variables are significantly correlated across the entire survey (Table 3.5). The two methods of calculating grain size are highly correlated (R=0.997). Percent sand and mud are inversely correlated (R=-0.899) which is to be expected from proportional data. Percent sand and gravel are correlated with both grain size techniques. Percent sand is negatively correlated with longitude and depth (R= -0.439 and -0.565 respectively) and percent mud positively correlated (R= 0.345 and -0.569 respectively). Carbonate concentration is negatively correlated with longitude (R=-0.393), with the east Victorian shelf being dominated by siliceous sediments.

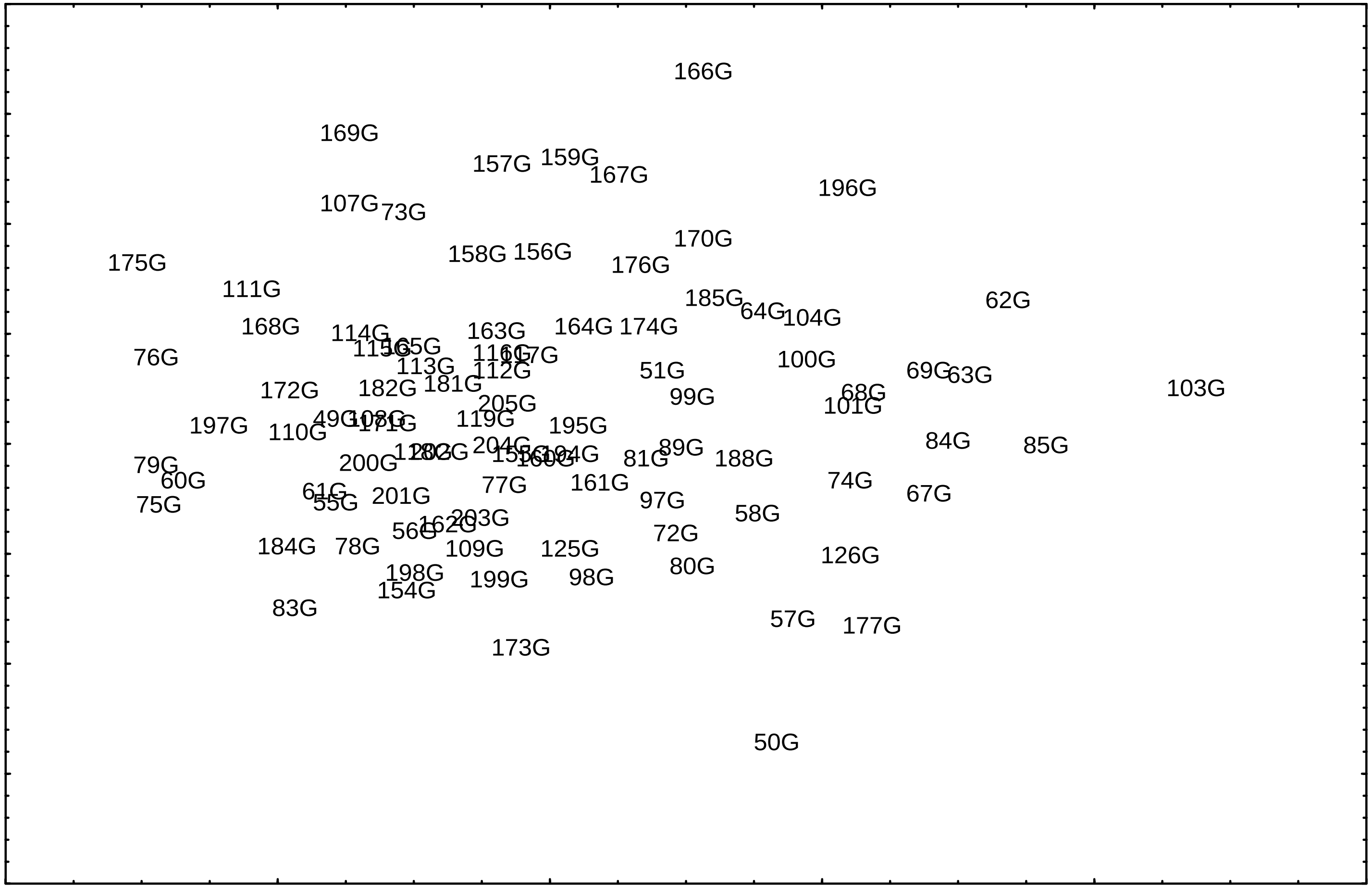


Figure 3.3 *MDS ordination of grab sample faunal abundance (Log$_e$(X+1) transformed) with points labelled with station no. Stress=0.19.*

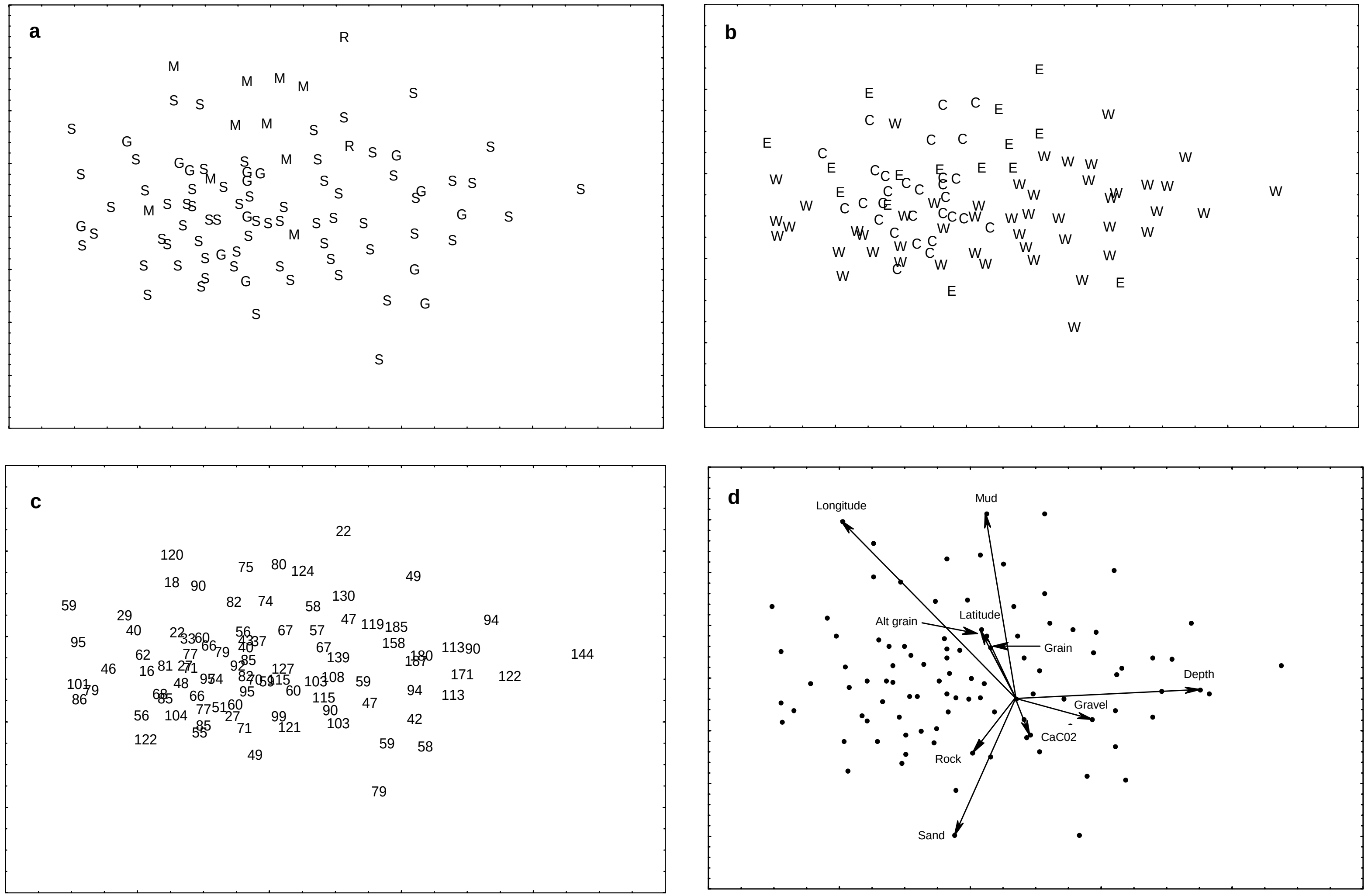


Figure 3.4 *MDS ordination of grab sample faunal abundance (see Fig. 3.2) with points labelled with a) substratum type (R=>50% rock, G=>20% gravel, M=>20% mud, S=Sand), b) region (E=east, C=central and W=west), c) depth (m), and d) PCC vectors showing the relationship of environmental variables.*

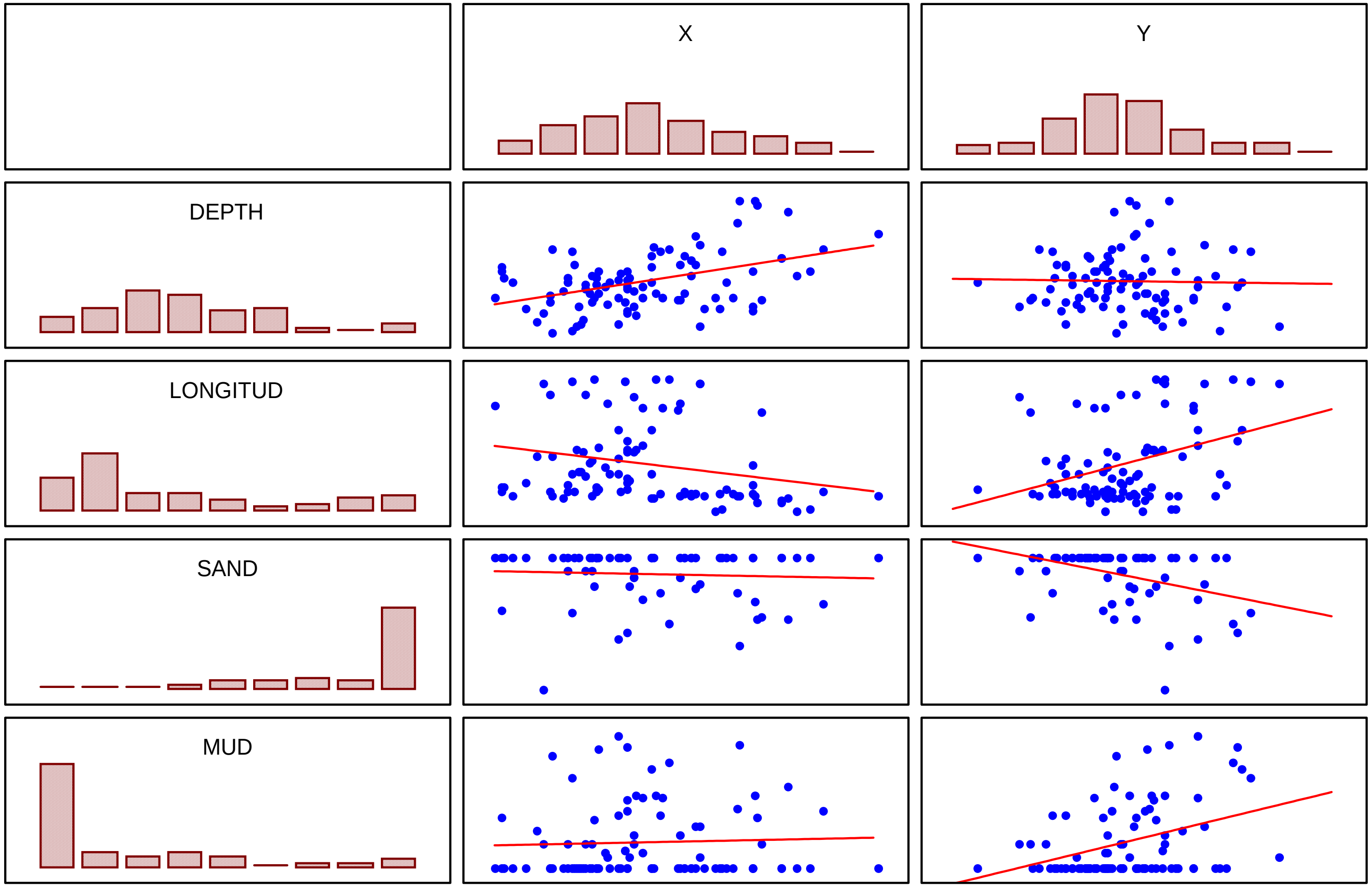


Figure 3.5 *Correlation matrix between the grab sample MDS X and Y coordinates and selected environmental variables. The percent sand and mud variables were arcsin(√) transformed to reduce their skewed distribution.*

3.2.2 Dredge and Sled Ordination

The MDS ordination of dredge and epibenthic sled samples (n=92 after eliminating deep-water and depauperate samples) produced a cluster of samples that graded into one another, rather than discrete groupings (Figs. 3.6, 3.7). Stress was relatively high (0.25) although some patterns are discerned. Samples from the west of Bass Strait are concentrated toward the upper right of the ordination, with samples from central and eastern regions occurring toward the lower left (Fig. 3.7b). Samples from the east and central regions of Bass Strait separate to some extent on the Z-axis of three-dimensional ordinations (stress=0.18, not figured), although there is significant overlap. Samples containing >20% mud occur on the left hand side of the two dimensional ordination, while samples containing >20% gravel occur in the centre, and samples containing >80% sand occur across a broad swathe in the centre and right (Fig. 3.7a). 19 rock samples comprised mostly of rock fragments occur throughout the ordination. When the points are superimposed with water depth there is little recognisable pattern (Fig. 3.7c).

Longitude, percent mud and sand, water depth, and carbonate content correlate best (R=0.71-0.37) with the environmental variables, although correlations with water depth and carbonate content are not significant after a Bonferroni correction (Table 3.4). Water depth and carbonate content correlate relatively poorly (R=0.10-0.17) when casewise deletion was used (casewise deletion is a way of removing the station entirely when not all environmental data is present). The biplot (Fig. 3.7d) indicates that longitude, percent mud and sand are aligned with the Y-axis. Despite considerable scatter between percent mud, percent sand and water depth (Fig. 3.8), the number of samples with >80% sand increases towards the right of the ordination as the number of samples with >20% mud declines.

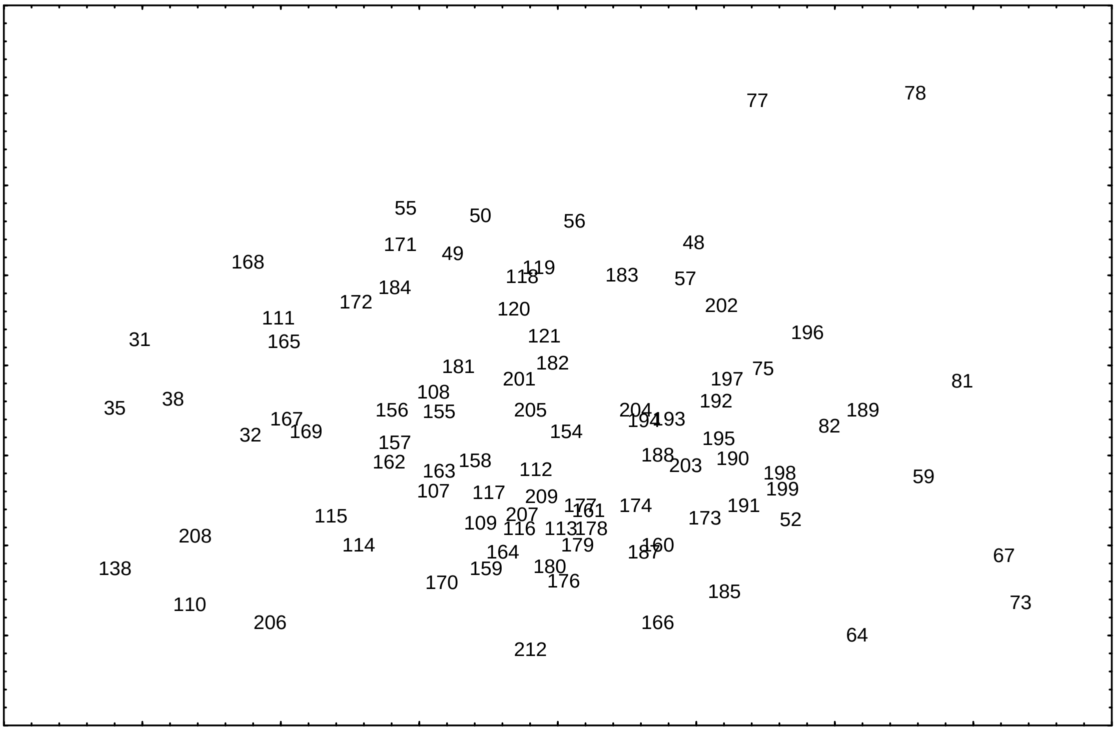


Figure 3.6 *MDS ordination of dredge/sled samples (binary transformation) with points labelled with station no. Stress=0.25.*

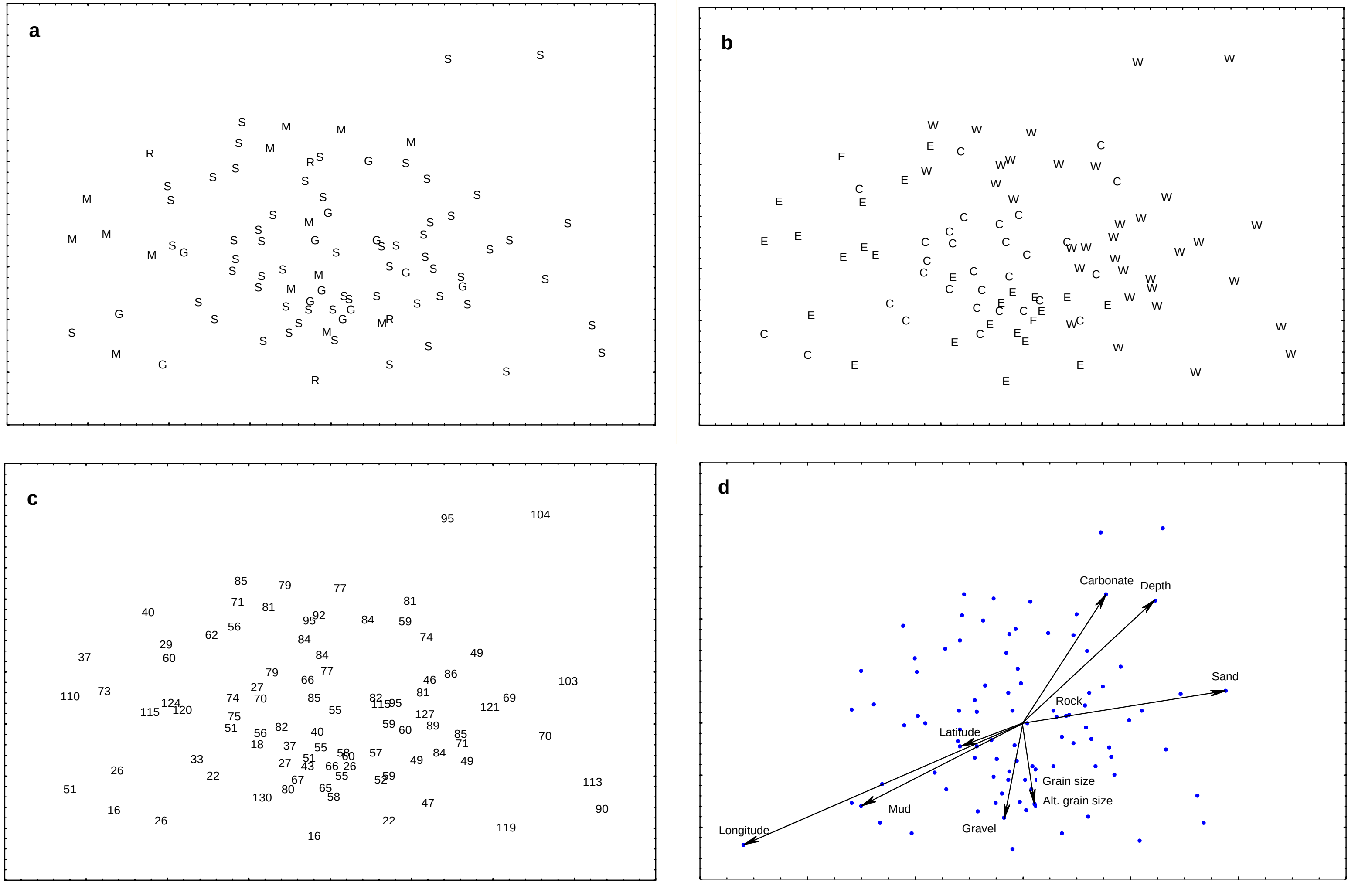


Figure 3.7 *MDS ordination of dredge/sled samples (see Fig. 3.4) with points labelled with a) substratum type (R=>50% rock, G=>20% gravel, M=>20% mud, S=Sand), b) region (E=east, C=central and W=west), c) depth (m), and d) PCC vectors showing the relationship of environmental variables.*

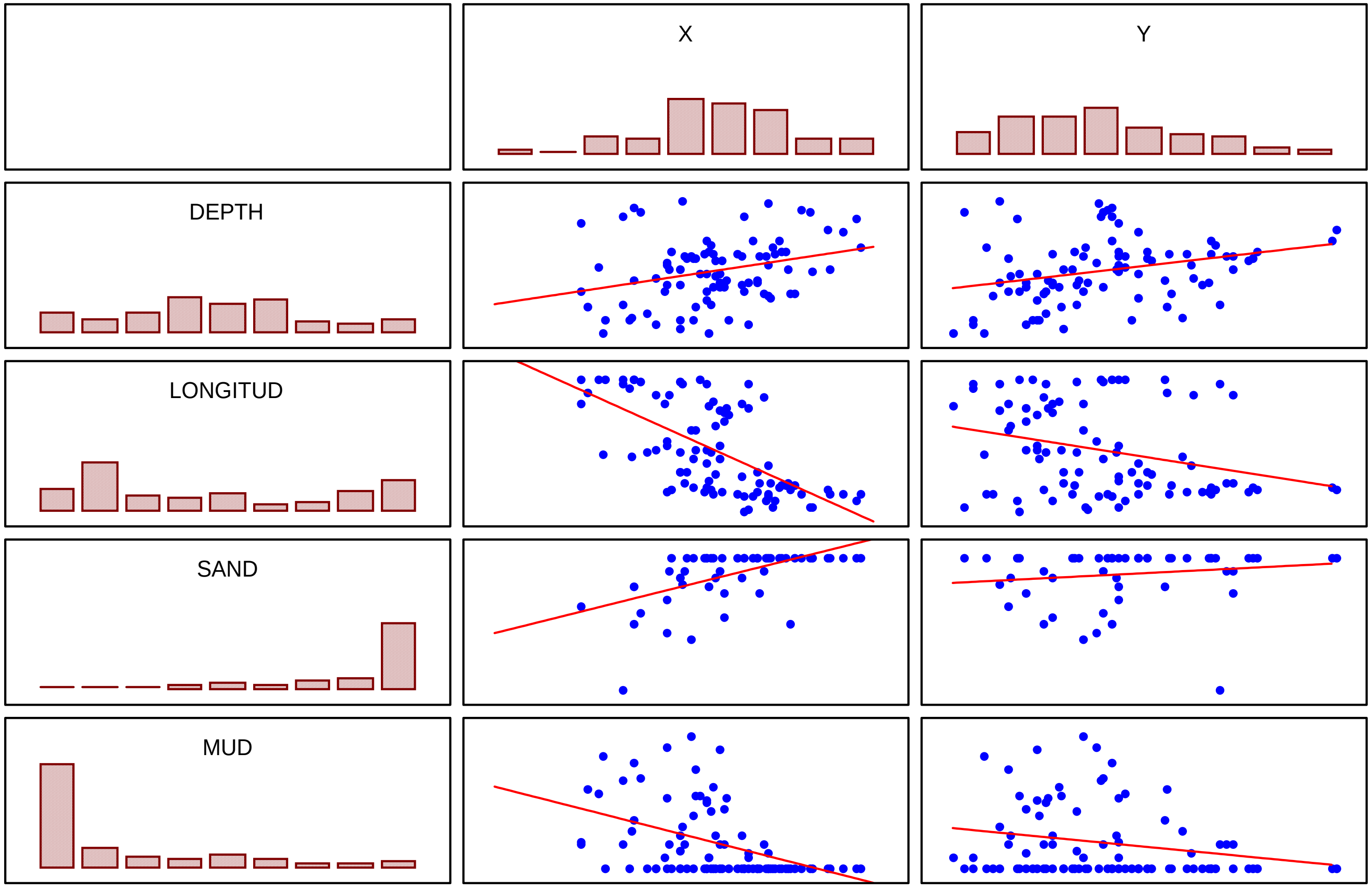


Figure 3.8 *Correlation matrix between the dredge/sled sample MDS X and Y coordinates and selected environmental variables. The percent sand and mud variables were arcsin(√) transformed to reduce their skewed distribution.*

3.2.3 Trawl Ordination

The ordination points are scattered on the two dimensional MDS of trawl samples (n=32 after eliminating depauperate samples; Fig. 3.9). Again stress was relatively high. Samples from central Bass Strait mostly occur towards the upper right of the ordination, with samples from eastern Bass Strait occurring across the left and lower sections (Fig. 3.10b). Only one trawl sample was from Western Bass Strait because of the unsuitability of this collection method for the predominantly rocky seafloor. Samples containing >20% mud and >20% gravel are concentrated towards the right of the ordination, with samples containing >80% sand scattered throughout (Fig. 3.10a). On a three dimensional ordination (Stress=0.18, not figured) the mud- and sand-rich samples separate on the Z-axis, although gravel-rich samples remain scattered throughout. There were few trends in the sample locations when the variables were superimposed with water depth (Fig. 3.10d).

Of the environmental variables, percent sand and latitude correlate best (R=0.55-0.57) with the ordination, although no variables were significant after a Bonferroni correction. The latitudinal gradient was possibly due to the lack of trawl samples from northern central Bass Strait. Other variables with relatively high correlation coefficients included carbonate concentration, water depth, and longitude with pairwise deletion, and percent mud with casewise deletion. On the biplot (Fig. 3.9d), sediment and water depth vectors are aligned with the X-axis, and latitude and longitude with the Y-axis. Except for percent sand, most of the variables exhibited scatter in a correlation matrix (Fig. 3.11).

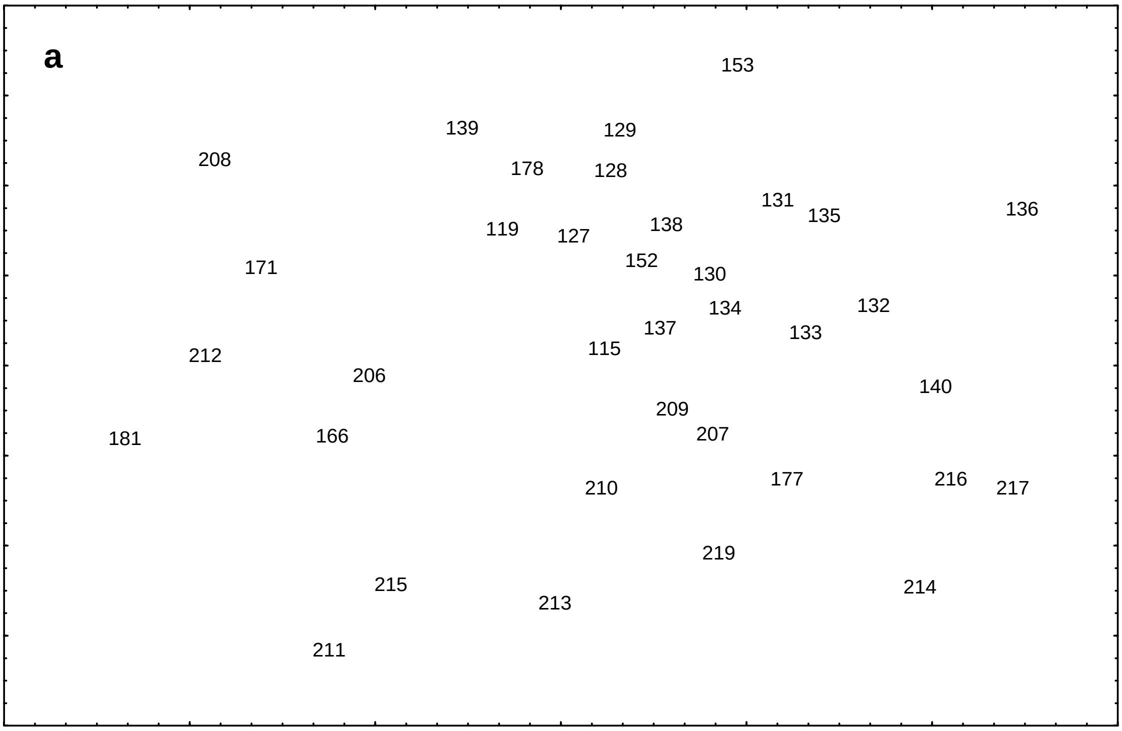


Figure 3.9 *MDS ordination of trawl samples (binary transformation) with points labelled with station no. Stress=0.24.*

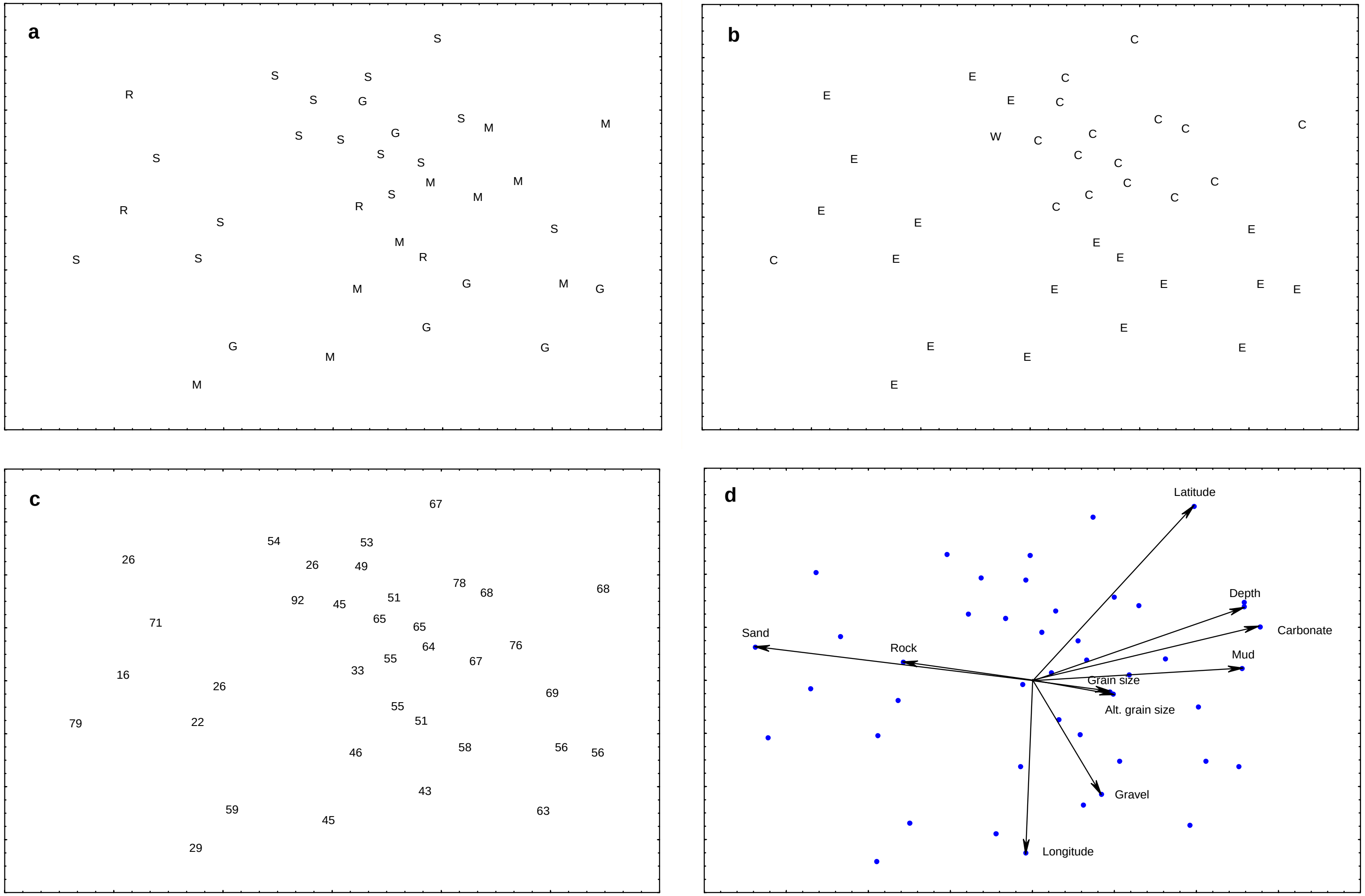


Figure 3.10 *MDS ordination of trawl samples with points labelled with a) substratum type (R=>50% rock, G=>20% gravel, M=>20% mud, S=Sand), b) region (E=east, C=central and W=west), c) depth (m), and d) PCC vectors showing the relationship of environmental variables.*

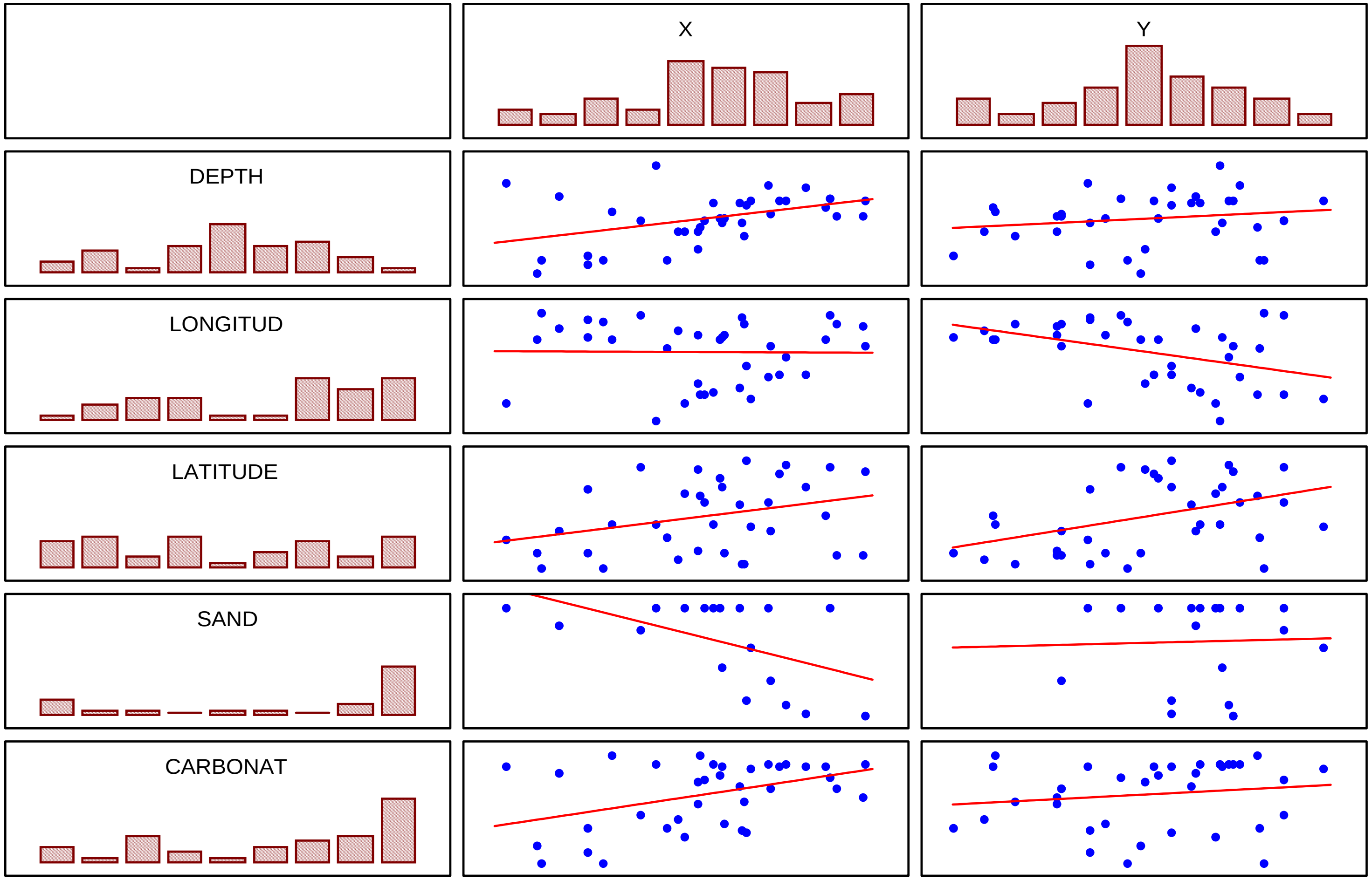


Figure 3.11 *Correlation matrix between the trawl sample MDS X and Y coordinates and selected environmental variables. The percent sand, mud and carbonate variables were arcsin(√) transformed to reduce their skewed distribution.*

3.2.4 Cluster Analyses

Cluster analyses were performed on all three datasets (Figs. 3.12 to 3.14). Only 3 pairs of grab samples,1 pair of dredge samples and 2 pairs of trawl samples were more than 60% similar (as calculated by the Bray-Curtis equation), even for spatially proximal samples. This reflected the diverse and patchy nature of the faunal assemblages. At the lowest level, there was some clustering of geographically close samples (within a 100 km radius), typically with similar water depths and substratum characteristics, although these samples tended to have a similarity of less than 40%. The primary clusters had a very low overall similarity, typically less than 10%, and were not exclusively formed from samples with a common region, water depth, or substrate.

In summary, samples do cluster together at scales of hundreds of kilometres but not at a regional (i.e., east, central, and west Bass Strait) or habitat (i.e., sand, mud, rock) level.

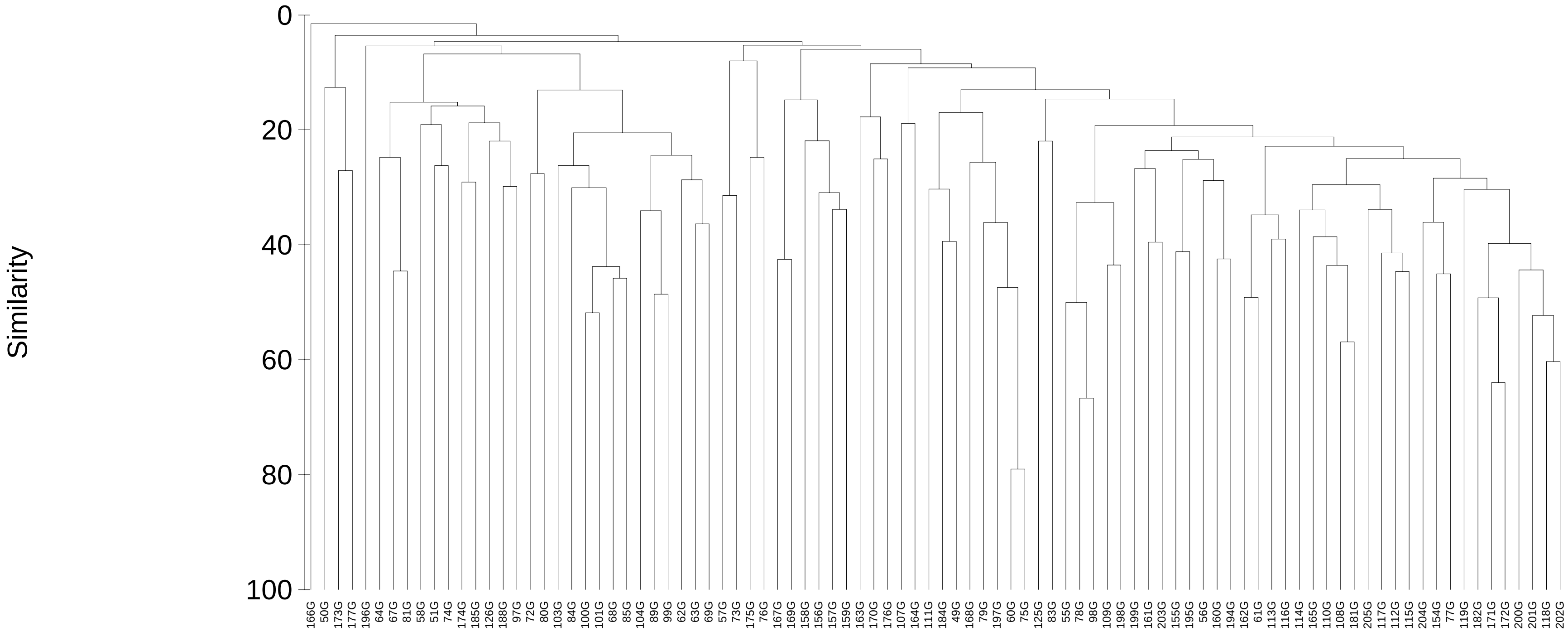


Figure 3.12 *Dendrogram of grab samples, labelled by sample number. Data was* $\log_e(x+1)$ *transformed.*

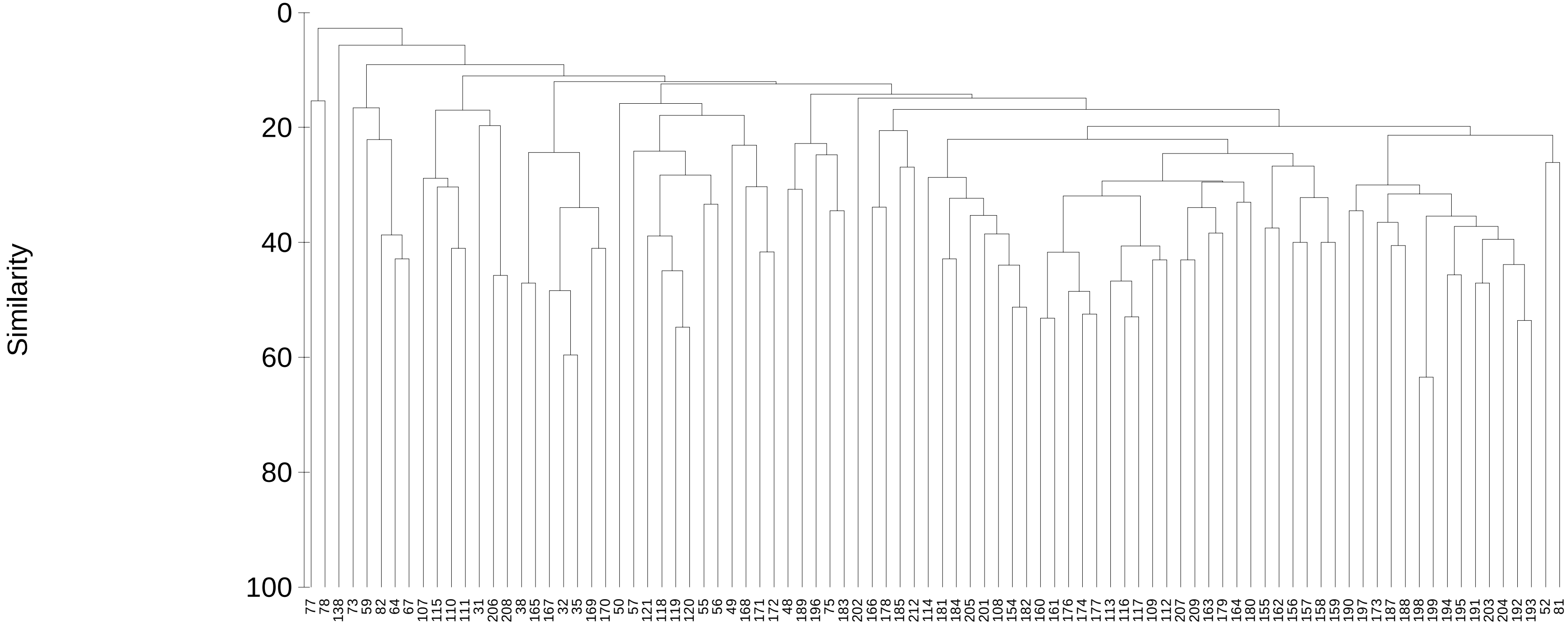


Figure 3.13 *Dendrogram of dredge/sled samples, labelled by sample number. Data was binary transformed.*

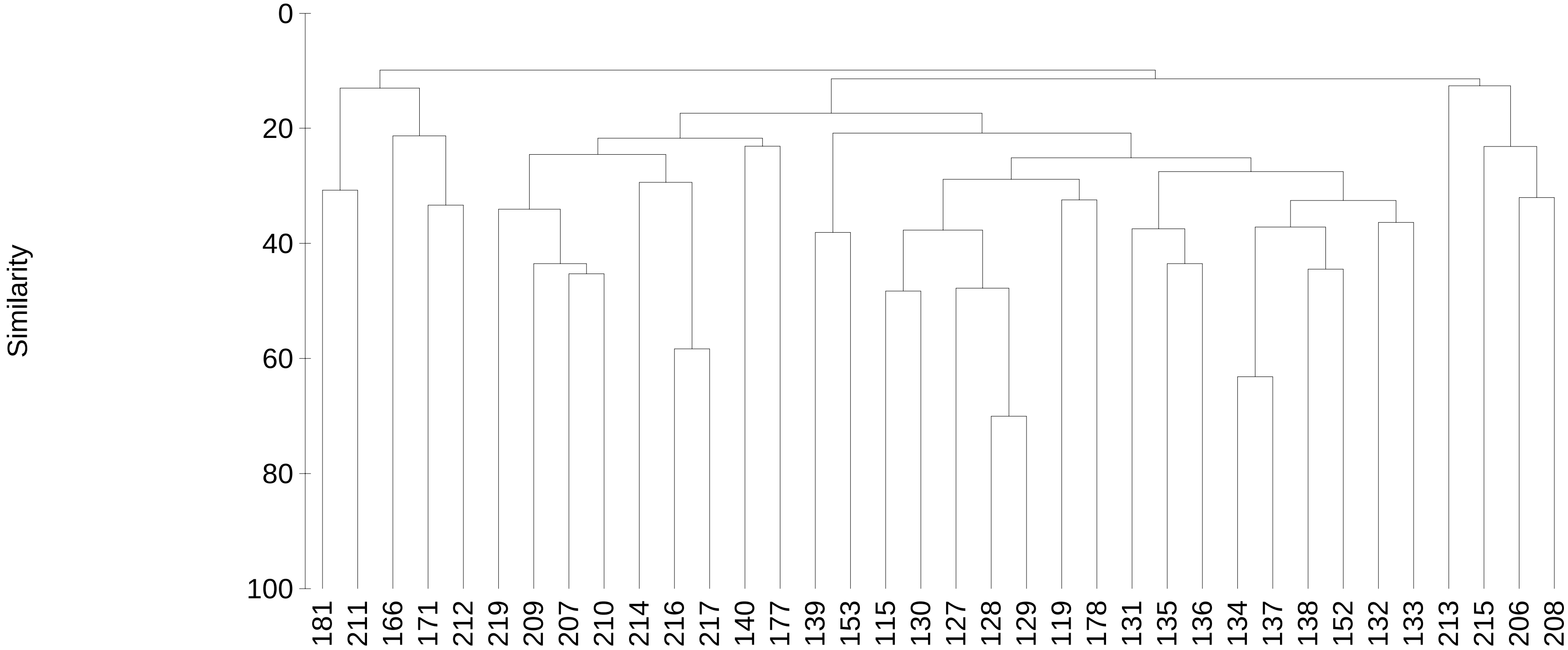


Figure 3.14 *Dendrogram of trawl samples, labelled by sample number. Data was binary transformed.*

3.2.5 BIOENV

The BIOENV analysis was carried out to provide an alternative method of matching faunal assemblages with environmental variables. A similarity matrix produced from faunal data was rank-correlated with others generated from various combinations of environmental data. Water depth and longitude are the two variables that were repeatedly most significant throughout the analysis (Table 3.6). Secondary variables included percent mud, grain size, and carbonate concentration, although this may reflect the correlation of these variables with longitude and to a lesser extent water depth (Table 3.5). Latitude was also significant for trawl samples. Overall, R-values were very low suggesting that no combinations of environmental variables were good predictors of the overall faunal assemblage.

Table 3.4: Results of a multiple regression of untransformed environmental variables against MDS X and Y coordinates for dredge, grab and trawl samples collected in the BSS. Missing environmental data was removed by using both pairwise and casewise deletion. * indicates that the regression was significant after a Bonferroni correction for multiple comparisons.

	PAIRWISE DELETION		CASEWISE DELETION	
VARIABLE	R	P	R	P
Grab samples				
LONGITUDE	0.45	0.002*	0.46	0.001*
WATER DEPTH	0.44	0.002*	0.43	0.003*
%MUD	0.39	0.009	0.55	0.000*
%SAND	0.37	0.014	0.39	0.009
%GRAVEL	0.25	0.152	0.28	0.102
%CARBONATE	0.18	0.408	0.22	0.243
%ROCK	0.18	0.406	0.26	0.139
LATITUDE	0.12	0.675	0.16	0.462
ALT. GRAIN SIZE	0.10	0.750	0.30	0.073
GRAIN SIZE	0.08	0.826	0.47	0.001*
Dredge/sled samples				
LONGITUDE	0.71	0.000*	0.72	0.000*
%SAND	0.47	0.002*	0.48	0.002*
%MUD	0.43	0.009*	0.46	0.003*
WATER DEPTH	0.42	0.009	0.17	0.518
%CARBONATE	0.37	0.033	0.10	0.784
%GRAVEL	0.23	0.270	0.24	0.359
GRAIN SIZE	0.20	0.383	0.37	0.031
ALT. GRAIN SIZE	0.20	0.397	0.39	0.021
LATITUDE	0.18	0.474	0.14	0.641
%ROCK	0.11	0.760	0.19	0.424
Trawl samples				
%SAND	0.57	0.053	0.56	0.048
LATITUDE	0.55	0.069	0.56	0.062
%CARBONATE	0.48	0.137	0.10	0.922
WATER DEPTH	0.47	0.156	0.17	0.813
LONGITUDE	0.44	0.208	0.29	0.510
%MUD	0.43	0.219	0.51	0.100

%GRAVEL	0.32	0.446	0.33	0.419
%ROCK	0.27	0.575	0.20	0.738
GRAIN SIZE	0.17	0.805	0.21	0.715
ALT. GRAIN SIZE	0.16	0.820	0.19	0.751

Table 3.5: Pearson correlation coefficients between untransformed environmental variables for all stations in the BSS. Shaded cells indicate that the correlation was significant at α=0.05 after a Bonferroni correction for multiple comparisons. Missing data was pairwise deleted.

	DEPTH	LONGITUDE	LATITUDE	GRAIN SIZE	% GRAVEL	% SAND	% MUD	% ROCK	% CARBONATE
LONGITUDE	0.300								
LATITUDE	-0.162	-0.229							
GRAIN SIZE	-0.113	-0.032	0.035						
%GRAVEL	-0.060	-0.091	0.021	0.476					
%SAND	-0.565	-0.439	-0.013	0.394	-0.226				
%MUD	0.569	0.345	0.066	-0.142	-0.041	-0.899			
%ROCK	-0.101	-0.252	-0.199	0.118	-0.152	0.261	-0.176		
%CARBONATE	-0.043	-0.393	0.257	-0.022	-0.001	0.096	0.016	0.000	
ALT. GRAIN SIZE	-0.108	-0.030	0.036	0.997	0.365	0.419	-0.140	0.121	-0.017

Table 3.6: BIOENV Spearman correlation between the faunal similarity matrices for each collection method and a set of environmental variables. The similarity coefficient was normalised Euclidean distance. Only the six best matches for up to three variables are shown.

R	VARIABLES
GRAB SAMPLES	
0.244	Water depth, longitude
0.234	Water depth, longitude, carbonate
0.234	Depth, longitude, %rock
0.218	Depth, longitude, mud
0.207	Depth, mud, carbonate
0.200	Depth, rock, carbonate
DREDGE/SLED SAMPLES	
0.154	Depth, longitude, mud
0.154	Depth, mud, alt. grain size
0.152	Depth, mud
0.150	Depth, grain size, mud
0.149	Mud, alt. grain size
0.142	Depth, latitude, mud
TRAWL SAMPLES	
0.254	Depth, longitude, latitude
0.247	Depth, latitude
0.228	Depth, longitude
0.219	Depth, longitude, carbonate
0.215	Longitude, latitude, carbonate
0.213	Depth, longitude, carbonate

3.3 RV *TANGAROA* SEDIMENT GRAIN SIZE

3.3.1 Sieve Data

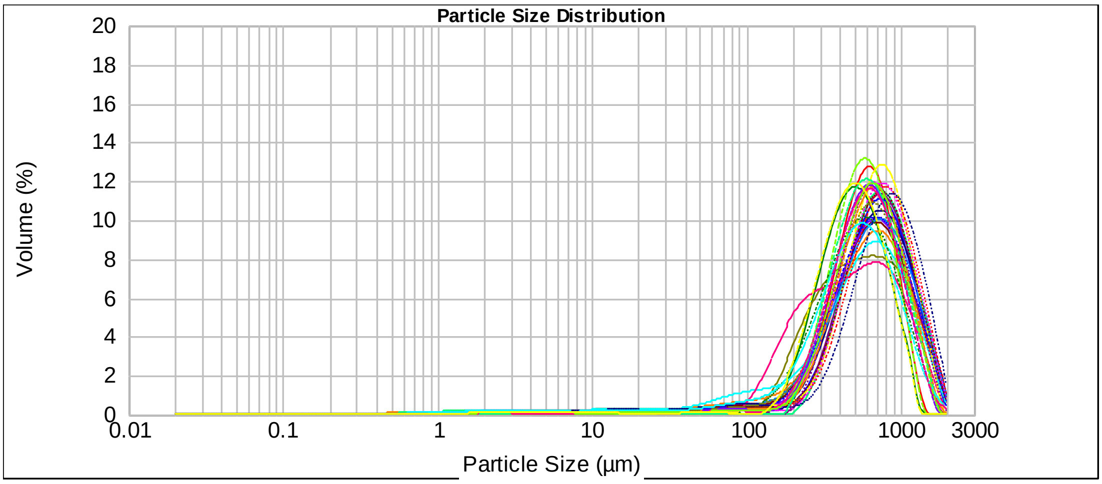
Measured values of percent gravel, sand and mud for RV *Tangaroa* samples analysed at GA are provided in Table 3.7. The sample results can be divided into two sets. The first is a set of samples from water depths >1100 m. These samples (Q631 to Q636 inclusive) comprise predominantly sandy muds, characterised by mud content of 49% or greater and a lack of gravel. The remaining samples are gravelly sands, sands, and sandy gravels. In the latter samples, gravel concentrations are variable, ranging from 0% to 88.5% and comprise granule-sized, or medium to large pebble-sized clasts. With one exception, sample Q617 (BSS 159) from central Bass Strait, mud concentrations are very low, less than 2.3%, throughout.

Table 3.7: Values of percent gravel, sand and mud for RV *Tangaroa* samples analysed at GA.

STATION	GRAVEL %	SAND %	MUD %
Q612	88.5	10.2	1.3
Q617	0.8	59.2	40.0
Q618	23.5	75.8	0.8
Q619	24.5	74.4	1.1
Q620	15.1	84.8	0.1
Q621	6.8	92.2	1.1
Q622	6.6	91.1	2.3
Q631	0.0	37.6	62.4
Q632	0.0	50.6	49.4
Q633	0.0	13.6	86.4
Q634	0.0	23.3	76.7
Q635	0.0	12.8	87.2
Q636	0.0	35.2	64.8
Q643	17.8	82.2	0.0
Q647	24.0	74.7	1.3
Q648	29.7	68.3	2.0
Q653	3.8	96.1	0.1
Q655	3.0	96.9	0.1
Q656	5.6	93.9	0.6
Q657	59.3	40.6	0.1
Q658	16.0	83.9	0.0
Q659	1.2	98.4	0.4
Q660	0.0	99.9	0.1
Q662	0.0	99.3	0.7
Q664	11.4	88.6	0.1
Q666	18.4	81.5	0.1
Q667	27.0	72.7	0.2
Q670	19.2	78.9	1.9
Q671	11.2	88.4	0.4
Q675	6.0	93.8	0.2
Q678	19.7	79.8	0.5
Q680	17.3	82.7	0.0
Q681	7.2	92.5	0.3
Q684	25.7	74.0	0.3

3.3.2 Laser Grain Size Distributions

Grain size distributions for the bulk of samples are essentially unimodal (Fig. 3.15). These samples are subdivided into samples with primary modes in coarse to very coarse sand (Fig. 3.15a) and those



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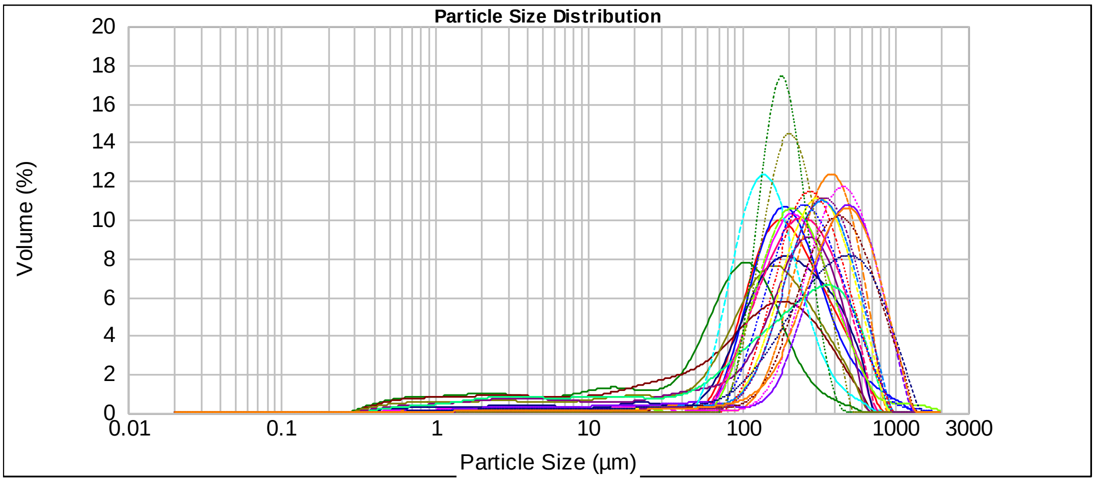
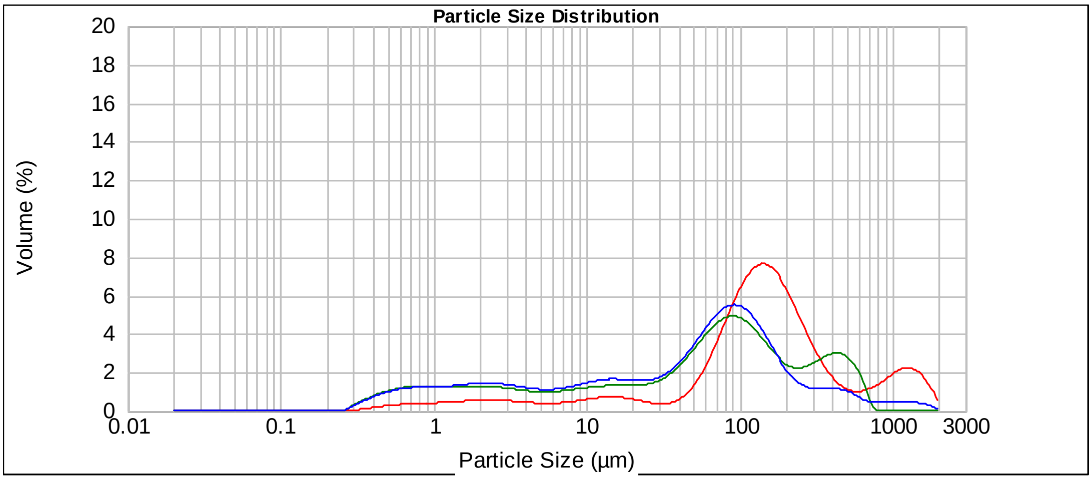


B



C

Figure 3.15 *Laser grain size distributions for selected Bass Strait sediments (RV Tangaroa Cruise): (a) samples with primary modes in coarse to very coarse sand; (b) samples with primary modes in fine to medium sand, (c) samples which are bimodal in sand.*

(Refer to Key on the following page)

Key to Figure 3.15

(a)

Q612 (BSS 154)
Q618 (BSS 160)
Q619 (BSS 161)
Q620 (BSS 162)
Q622 (BSS 164)
Q626 (BSS 168)
Q643 (BSS 172)
Q644 (BSS 173)
Q645 (BSS 174)
Q646 (BSS 175)
Q647 (BSS 176)
Q648 (BSS 177)
Q649 (BSS 178)
Q657 (BSS-Q 657)
Q658 (BSS-Q 658)
Q664 (BSS 188)
Q665 (BSS 189)
Q666 (BSS 190)
Q667 (BSS 191)
Q668 (BSS 192)
Q669 (BSS 193)
Q670 (BSS 194)
Q672 (BSS 196)
Q674 (BSS 198)
Q675 (BSS 199)
Q676 (BSS 200)
Q677 (BSS 201)
Q678 (BSS 202)
Q679 (BSS 203)
Q680 (BSS 204)
Q681 (BSS 205)

(b)

Q613 (BSS 155)
Q617 (BSS 159)
Q621 (BSS 163)
Q623 (BSS 165)
Q625 (BSS 167)
Q627 (BSS 169)
Q628 (BSS 170)
Q638 (BSS-Q 638)
Q642 (BSS 171)
Q650 (BSS 179)
Q651 (BSS 180)
Q652 (BSS 181)
Q653 (BSS 182)
Q654 (BSS-Q 654)
Q655 (BSS-Q 655)
Q656 (BSS-Q 656)
Q659 (BSS-Q 659)
Q660 (BSS 184)
Q662 (BSS 186)
Q663 (BSS 187)
Q671 (BSS 195)
Q673 (BSS 197)
Q682 (BSS-Q 682)
Q683 (BSS-Q 683)
Q684 (BSS-Q 684)

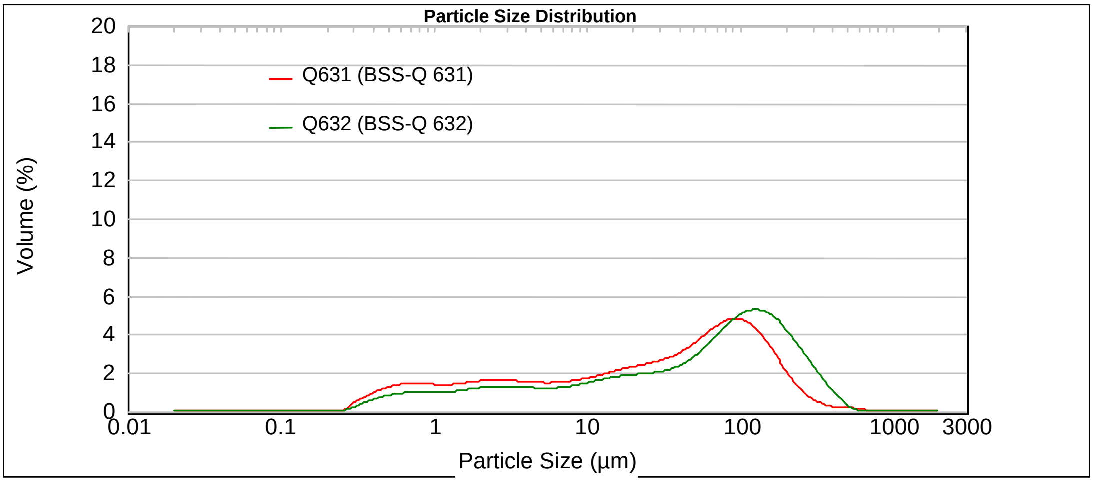
(c)

Q614 (BSS 156)
Q615 (BSS 157)
Q616 (BSS 158)

with primary modes in very fine to medium sand (Fig. 3.15b). Primary modes in coarse sands (Fig. 3.15a) range from 509 to 876 µm. Volume-weighted mean values are similar to modal values and range from 515 to 805 µm. Secondary modes, where present, show very low volumes and occur in the very fine sand fraction or, less commonly, in the silt fraction. A very low volume (<2%), fine tail is typical. Standard deviations of 247 to 437 µm indicate the samples are relatively poorly sorted.

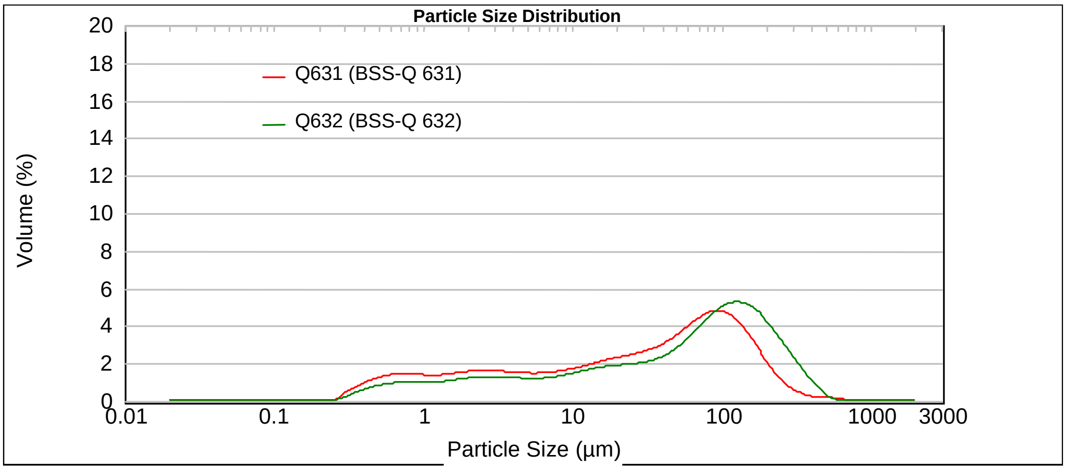
Fine-grained sands (Fig. 3.15b) have primary modes of 106 to 499 µm. Secondary modes are common and occur in the silt fraction. Volume-weighted means are again close to modal values and range from 93 to 484 µm. The degree of sorting is generally poor to moderate, with a fine tail common and a coarse to very coarse tail present in some samples. Standard deviations of 65 to 288 µm indicate samples are moderately sorted. Three fine-grained sands, all from central Bass Strait, show a secondary mode in the sand fraction (Fig. 3.15c). The occurrence of this secondary mode does not appear to be an artefact of the analytical procedure, as the modes can be correlated with components in the sediment (see discussion of composition below). The laser data indicates that these samples contain a slightly higher proportion of fine material, although the overall volume is still very low. Grain size data obtained previously for these samples showed mud concentrations of between 17% and 52% (Wilson and Poore, 1987).

A second, smaller group of samples shows multi-modal grain size distributions (Fig. 3.16a, b, Table 3.8). These samples are fine-grained, with volume-weighted means ranging from 15 to 92 µm. The modes occur within the silt and clay fractions, although several samples also contain modes in sand. These samples were all collected from eastern Bass Strait, adjacent to the Bass Canyon, in water depths of >1000 m (Figs. 1.1; 2.2). Interestingly, sample Q638, which comes from the same area, has a grain size distribution more typical of the coarse sands found in shallow water (Fig. 3.16c). This suggests that the sediment at this location has been transported from the shelf. However, since the composition of the sample was not examined, this origin was not confirmed.



A

(Figure 3.16 continued on following page)



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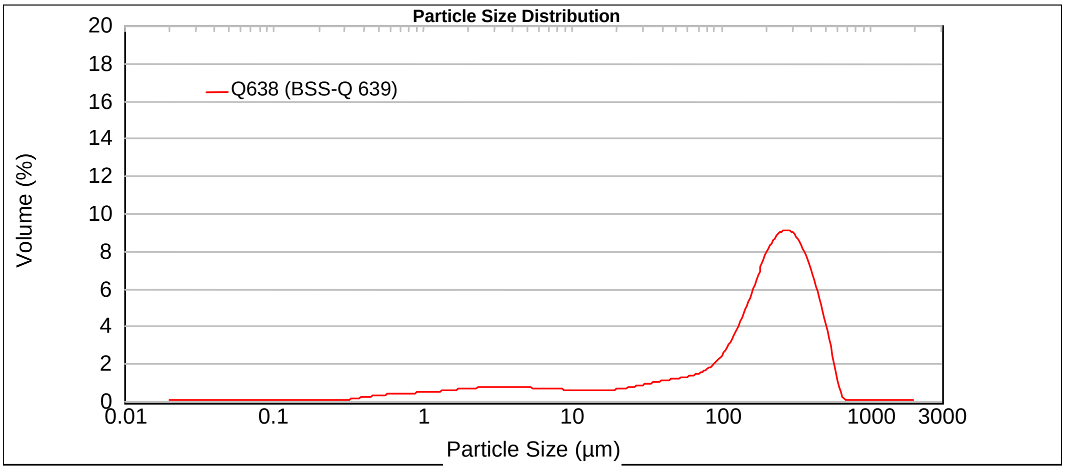


C

Figure 3.16 *Laser grain size distributions for selected Bass Strait sediments (RV Tangaroa Cruise): (a, b) fine-grained sands with multimodal distribution; (c) sample Q638: coarse sand.*

Table 3.8: Locations and water depths of fine-grained sands showing grain size distributions with multiple modes.

RV *TANGAROA* SAMPLE NO.	BSS SAMPLE NO.	LATITUDE (°E)	LONGITUDE (°S)	WATER DEPTH (M)
Q631	631Q	38°47.1	148°32.9	1120
Q632	632Q	38°35.1	148°36.8	1200
Q633	633Q	38°27.8	148°53.6	2350
Q634	634Q	38°42.3	148°48.0	2510
Q635	635Q	38°55.6	148°46.4	1730
Q636	636Q	38°49.0	149°00.9	2450
Q637	637Q	38°24.5	149°09.5	1575
Q639	639Q	38°54.5	149°24.1	2280

The full set of RV *Tangaroa* laser grain-size data is provided in Appendix D (refer to CD-ROM).

3.4 RV *TANGAROA* CARBONATE CONTENT DATA

Carbonate content in whole sample analyses varies between 50% and 92.5% (Table 3.9, Fig. 3.17), and is similar to concentrations found in earlier analyses of BSS samples (Wilson and Poore, 1987). Percent carbonate content was determined for separate gravel, sand and mud fractions where sample sizes were sufficiently large to analyse.

The dataset for individual fractions is too small to analyse in detail; however, it does indicate the level of variation between different fractions. Generally, carbonate content in the mud fractions is high, greater than 60%. Only one of the samples, Q651 located adjacent to the Victorian coast, contained less than 50% carbonate in the mud fraction. Discussion of the composition of the carbonate and non-carbonate components of sand and gravel fractions are presented in the following section.

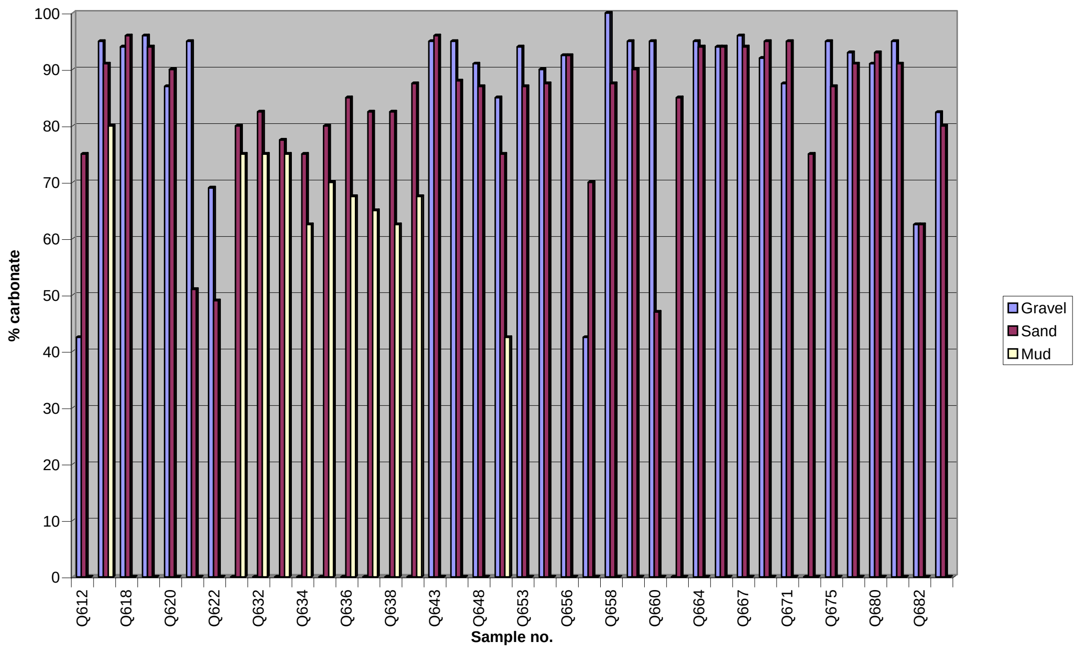


Figure 3.17 *Carbonate content of gravel, sand, and mud fractions obtained for samples collected on the RV Tangaroa.*

Table 3.9: Carbonate content for bulk samples, and gravel, sand, and mud fractions of RV *Tangaroa* samples, analysed at GA. *vis indicates visual analysis of gravel fractions.

STATION	CACO3 % GRAVEL*	CACO3 % SAND	CACO3 % MUD	CACO3% BULK
Q612	42.5	75	Nil Sample	67.5
Q617	vis 95	91	80	81
Q618	94	96	Nil Sample	92.5
Q619	96	94	Nil Sample	92
Q620	87	90	Nil Sample	90
Q621	vis 95	51	Nil Sample	50
Q622	69	49	Nil Sample	55
Q631	Nil Sample	80	75	72.5
Q632	Nil Sample	82.5	75	77.5

Q633	Nil Sample	77.5	75	70
Q634	Nil Sample	75	62.5	65
Q635	Nil Sample	80	70	67.5
Q636	Nil Sample	85	67.5	67.5
Q637	Nil Sample	82.5	65	65
Q638	Nil Sample	82.5	62.5	77.5
Q639	Nil Sample	87.5	67.5	70
Q643	95	96	Nil Sample	92
Q647	95	88	Nil Sample	91
Q648	91	87	Nil Sample	82.5
Q651	85	75	42.5	77
Q653	94	87	Nil Sample	73
Q655	90	87.5	Nil Sample	92
Q656	92.5	92.5	Nil Sample	90
Q657	42.5	70	Nil Sample	64
Q658	100	87.5	Nil Sample	92
Q659	vis 95	90	Nil Sample	91
Q660	vis 95	47	Nil Sample	49
Q662	Nil Sample	85	Nil Sample	88
Q664	vis 95	94	Nil Sample	92
Q666	94	94	Nil Sample	90
Q667	96	94	Nil Sample	94
Q670	92	95	Nil Sample	94
Q671	87.5	95	Nil Sample	94
Q673	Nil Sample	75	Nil Sample	81
Q675	vis 95	87	Nil Sample	86
Q678	93	91	Nil Sample	90
Q680	91	93	Nil Sample	90
Q681	vis 95	91	Nil Sample	87.5
Q682	62.5	62.5	Nil Sample	62
Q684	82.4	80	Nil Sample	81

3.5 RV *TANGAROA* SEDIMENT COMPOSITION AND FOSSIL PRESERVATION

A summary of sample composition results for the 29 samples examined is shown in Table 3.10. A more detailed breakdown of composition data for gravel and sand fractions, together with preservation data for each faunal group is provided in Appendix E (refer to CD-ROM). Based on composition and grain size characteristics, three groups of sediments can be distinguished: bioclastic and lithoclastic sands and gravel; bioclastic fine sands; and quartz sands. Composition and preservation trends are discussed below in terms of these three sediment groups.

3.5.1 Bryozoan and Lithoclastic Sand and Gravel

These sediments comprise bioclastic (dominantly bryozoan) sands and gravel with a variable lithoclastic content. Sediments dominated by lithoclasts (Q618, Q681; Fig. 3.18, 3.19f) form a minor subgroup, although over half the samples examined contain between 15% and 45% lithoclasts (Fig. 3.18, 3.19d, e; Table 3.10). Sediment types include gravelly bryozoan sands, bryozoan sands with minor gravel, lithoclastic sandy gravels and lithoclastic sands. Gravel content in sands is generally high and ranges from 6-29%. The sand fractions vary from coarse to very coarse (Fig. 3.19b) or medium to fine (Fig. 3.19e). Mud content is very low to absent (0-2.3%). All the sediments are characterised by primary modes and means for the <2 mm fraction in the range of medium to very coarse sand (Fig. 3.15).

Gravel fractions of these sediments are dominated by bioclasts and intraclasts (Fig. 3.18a). The non-biogenic component is typically quartz and/or lithics, with glauconitic infill present in one sample (Q681). The composition of the lithic grains varies, but common in many samples are limestone pebbles, which are heavily encrusted and bioeroded (Fig. 3.19g). Sand fractions are variably dominated by bioclasts, lithics or, less commonly, quartz (Fig. 3.18b). Quartz is often present in small quantities (Fig. 3.18, 3.19), as is mica in a few samples. Both quartz and lithic grains in sand and gravel fractions are typically sub rounded to rounded and may be stained, highly polished or etched.

The bioclastic component of gravel fractions is dominated by bryozoans (Figs. 3.19a, c, d; 3.20a). Other, less abundant, components of the gravel fraction include: echinoids, benthic forams, gastropods, serpulids, arthropods, brachiopods (locally abundant), other bioclasts (predominantly fragments), and rare corals (Fig. 3.20b). Bryozoans also dominate the biogenic content of most sand fractions (Figs. 3.19b, e, f; 3.20b). Other bioclasts (dominantly fragments) are the second most abundant component and dominate in sample Q684 (Fig. 3.20b). Bivalves, echinoids, gastropods and benthic forams, and less abundant ostracods, arthropods, brachiopods, serpulids and porifera are also present (Fig. 3.20b; Table 3.10). Very fine biogenic remains, such as sponge spicules, and juvenile bivalves or ostracods are noticeably rare (Fig. 3.19e) or absent (Fig. 3.19b).

Preservation of biogenic material in gravel fractions is poor, with samples dominated by relict and intermediate material (Fig. 3.21a). Modern content is less than 20 and more typically below 5%. Relict material is often stained, highly polished, or highly abraded. While many samples have an abraded appearance (eg Fig. 3.19a), material of intermediate preservation may show a high degree of fragmentation, rather than abrasion. Sample Q675 is atypical, with a relatively fine-grained gravel fraction, modern in appearance (Fig. 3.19b). Sand fractions generally show similar preservation to gravel fractions, although in some samples there is a greater proportion of intermediate material and less relict eg Q648, Q675, Q674 (Fig. 3.21b).

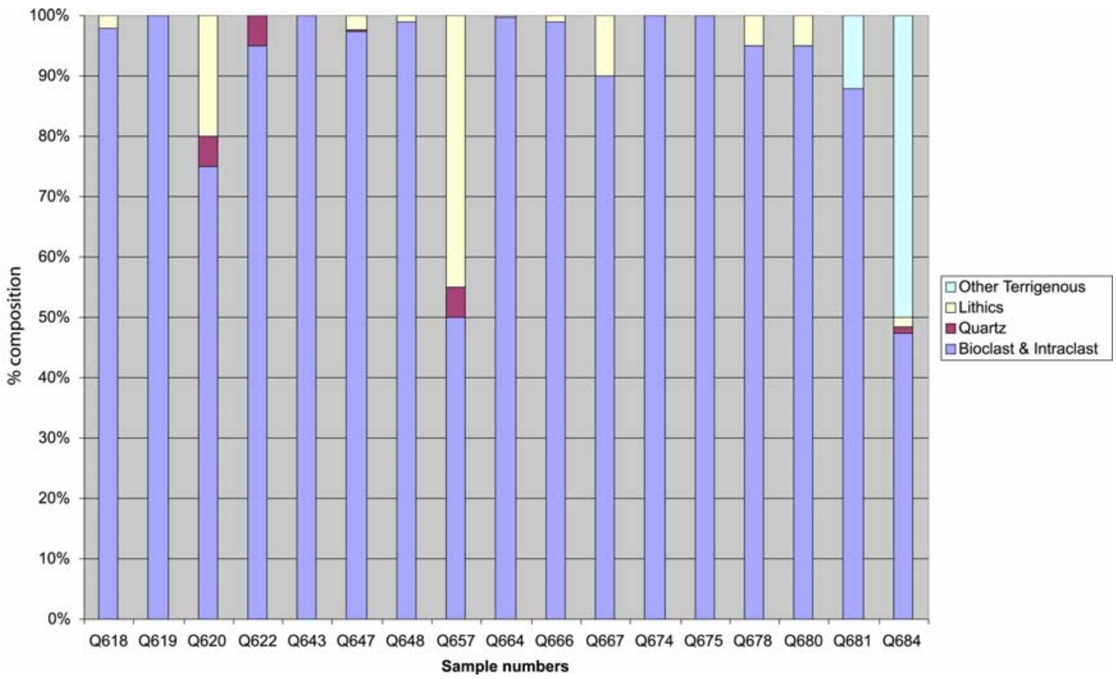
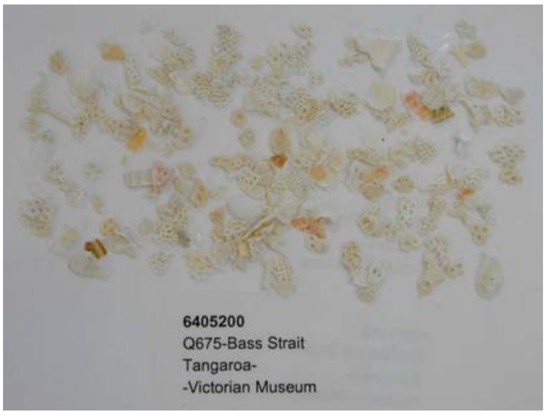


Figure 3.18 *Biogenic versus terrigenous content of (a) gravel fraction and (b) sand fraction in Bryozoan and Lithoclastic Sand and Gravel sediments.*

A



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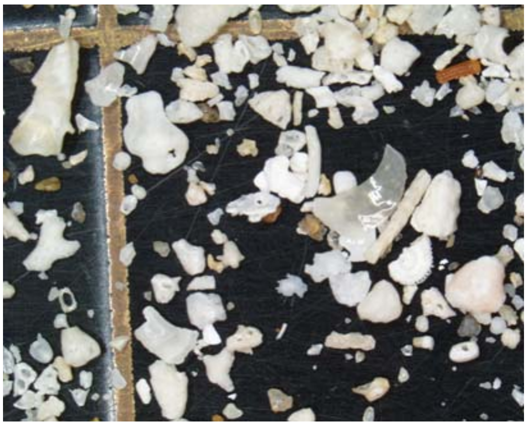
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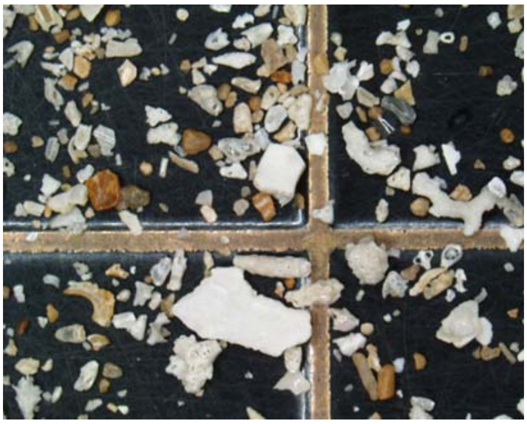
E

(Figure 3.19 continued next page)



F

G

Figure 3.19 *Photographs of sediment composition and preservation in Bryozoan and Lithoclastic Gravel and Sand samples. (a) Q678 gravel fraction; (b) Q675 gravel fraction; (c) Q 666 gravel fraction; (d) Q675 sand fraction; (e) Q666 sand fraction; (f) Q678 sand fraction; (g) Q657 bioeroded and encrusted pebbles from gravel fraction.*

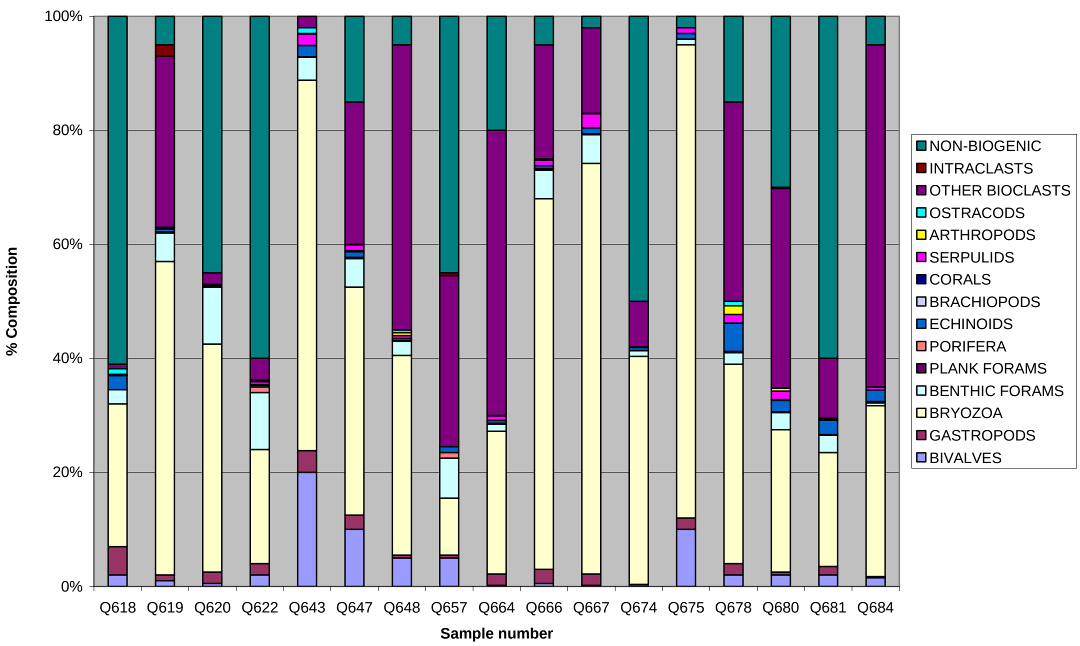
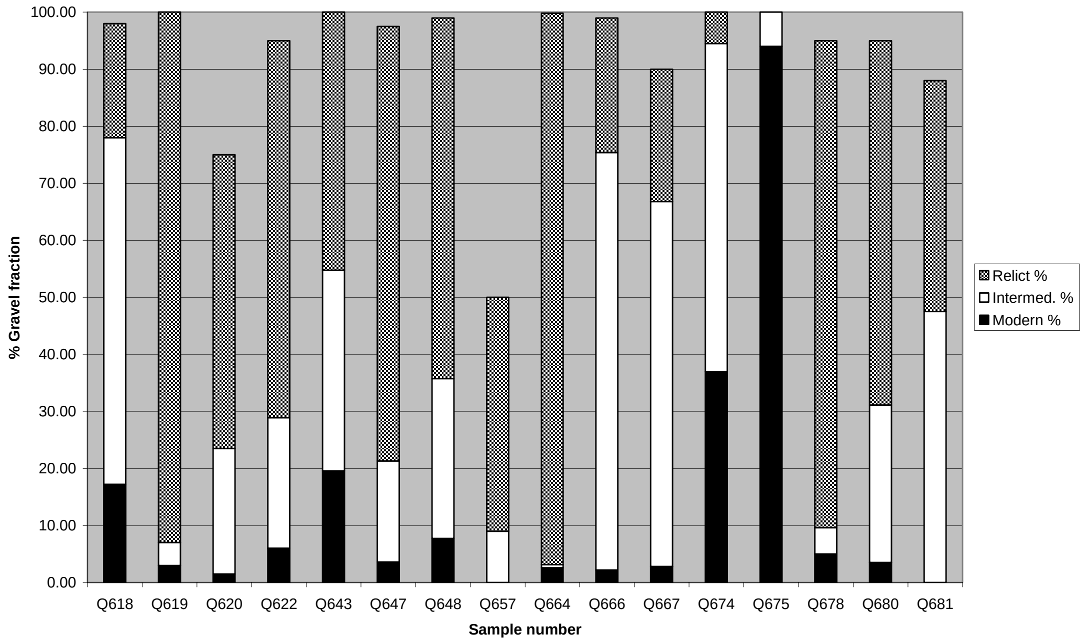
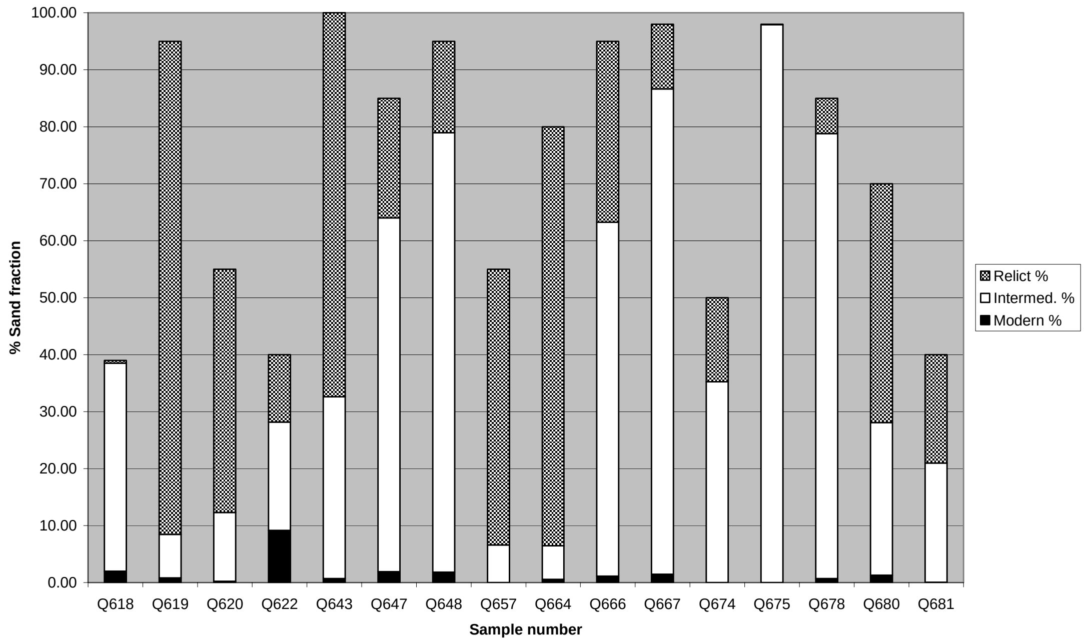


Figure 3.20 *Detailed break-up of biogenic content of (a) gravel fractions and (b) sand fractions in Bryozoan and Lithoclastic Sand and Gravel sediments.*



A



B

Figure 3.21 *Preservation of biogenic content in (a) gravel fraction and (b) sand fraction of sediments in the Bryozoan and Lithoclastic Sand and Gravel sediments.*

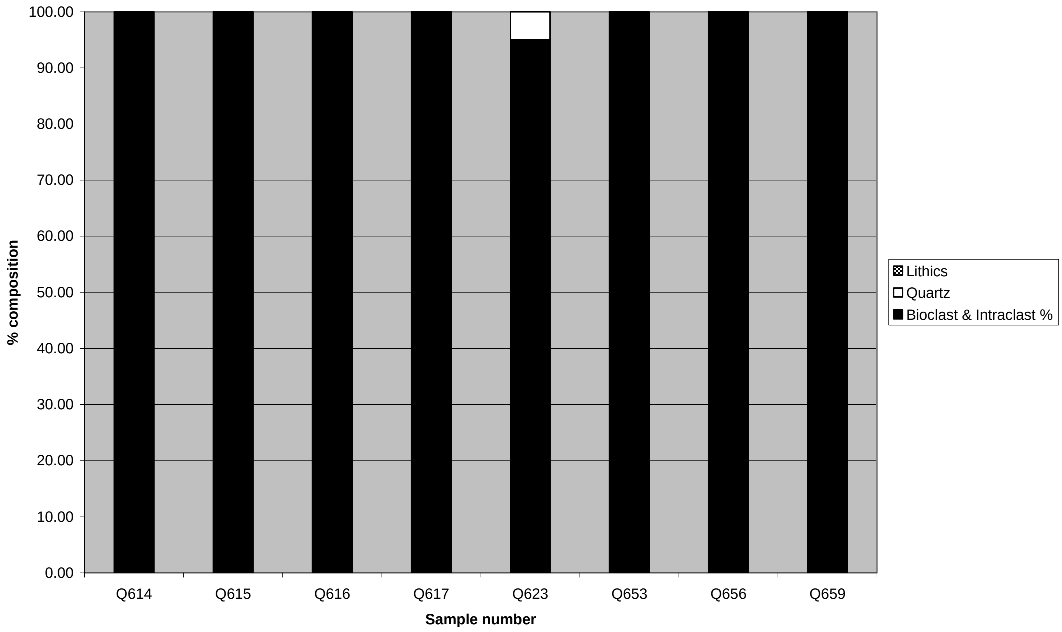
3.5.2 Bioclastic and Lithoclastic Fine Sand

These sediments comprise bioclastic (fragment-dominated) sands and muds. One sample is dominated by lithoclasts (Q653; Table 3.10; Fig. 3.22); otherwise the lithics content is generally low (20% to <5%; Fig. 3.22; Table 3.10). Sediment types include bioclastic sands, bioclastic sandy muds, lithoclastic sands with minor gravel, muddy bioclastic sands and bryozoan sands with minor gravel. Gravel content is low (<10%) and, in contrast to the bryozoan and lithoclastic sands, comprises more delicate bioclasts (*cf* Figs. 3.19a, d; 3.23a, c). The sand fractions vary from medium (Fig. 3.23d), fine to medium (Fig. 3.23e) to fine to very fine (3.23b). Primary modes and means for the <2 mm fraction occur in the range of very fine to medium sand (Fig. 3.15).

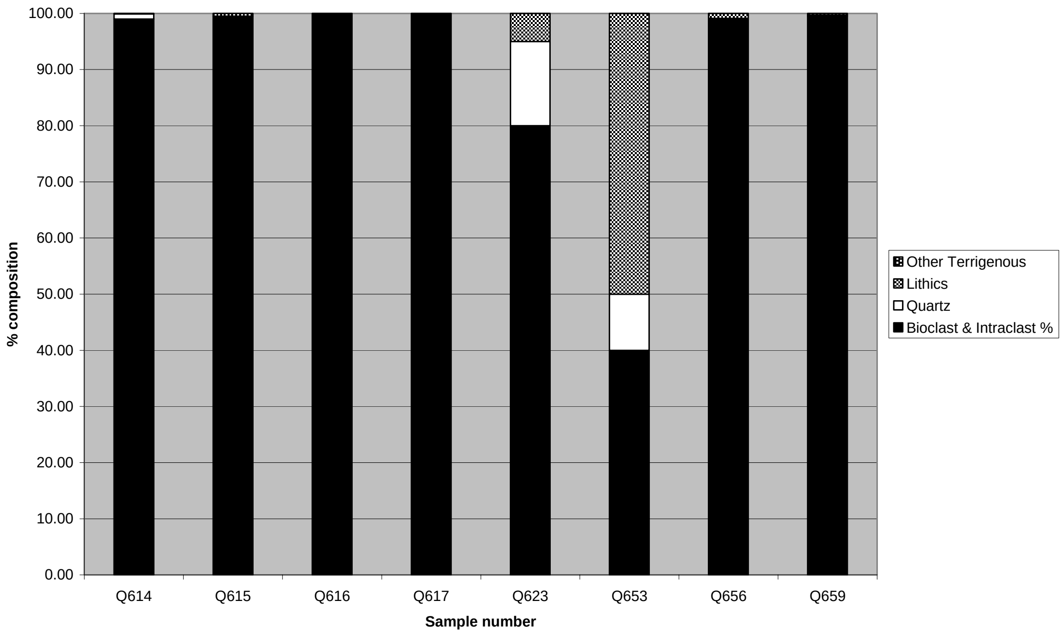
Gravel fractions are dominated by bioclasts and intraclasts (Fig. 3.22a) with minor quartz in one sample. Sand fractions are similarly dominated by bioclasts and intraclasts, with minor quartz and lithics content, except in samples Q623 and Q653, where quartz and lithics comprise around 20% and 60% respectively (Fig. 3.22b). Quartz and lithoclastic grains are sub-rounded to rounded. The composition of lithoclasts is variable, but largely siliciclastic.

Bivalves and bryozoans dominate the biogenic component of the gravel fractions (Figs. 3.23a, c; 3.24a). Echinoids, gastropods, and brachiopods occur locally in abundance. Other minor components include: gastropods, serpulids, and other bioclasts (largely fragments). Fragments, classified as other bioclasts, dominate the biogenic component of sand fractions, with the exception of sample Q656 (Figs. 3.23b, d, f; 3.24b). Bryozoans are the second most abundant group in the sand fraction, and are the dominant constituent in Q656 (Fig. 3.23d). Bivalves form the third most abundant group. Other bioclasts, present in moderate abundance include: sponge spicules, echinoderms (most commonly regular echinoids, crinoids, and ophiuroids), benthic forams, serpulids, ostracods, and gastropods and pteropods. Rare planktonic forams, corals, and brachiopods are present in a number of samples (Fig. 3.24b; Table 3.10). In contrast to the bryozoan sands and gravel, fine biogenic remains, such as sponge spicules, juvenile bivalves, and ostracods, are abundant (Fig. 3.24d, f).

Preservation of biogenic content in gravel fractions is good, with a relatively high modern content (around 10%-75%) and low relict content (Fig. 3.25a). Sand fractions are generally intermediate in preservation, reflecting the high proportion of fragments (Figs. 3. 23b, d; 3.24b; 3.25b). A small modern component is usually present. The relict component is generally low to absent, except in sample Q653, which is dominated by highly polished or abraded relict material (Figs. 3.23d; 3.25b). Quartz and lithic grains from the latter sample also show evidence of polishing.



a)



b)

Figure 3.22 *Biogenic versus terrigenous content of (a) gravel fraction and (b) sand fraction in Bioclastic and Lithoclastic Fine Sand sediments.*

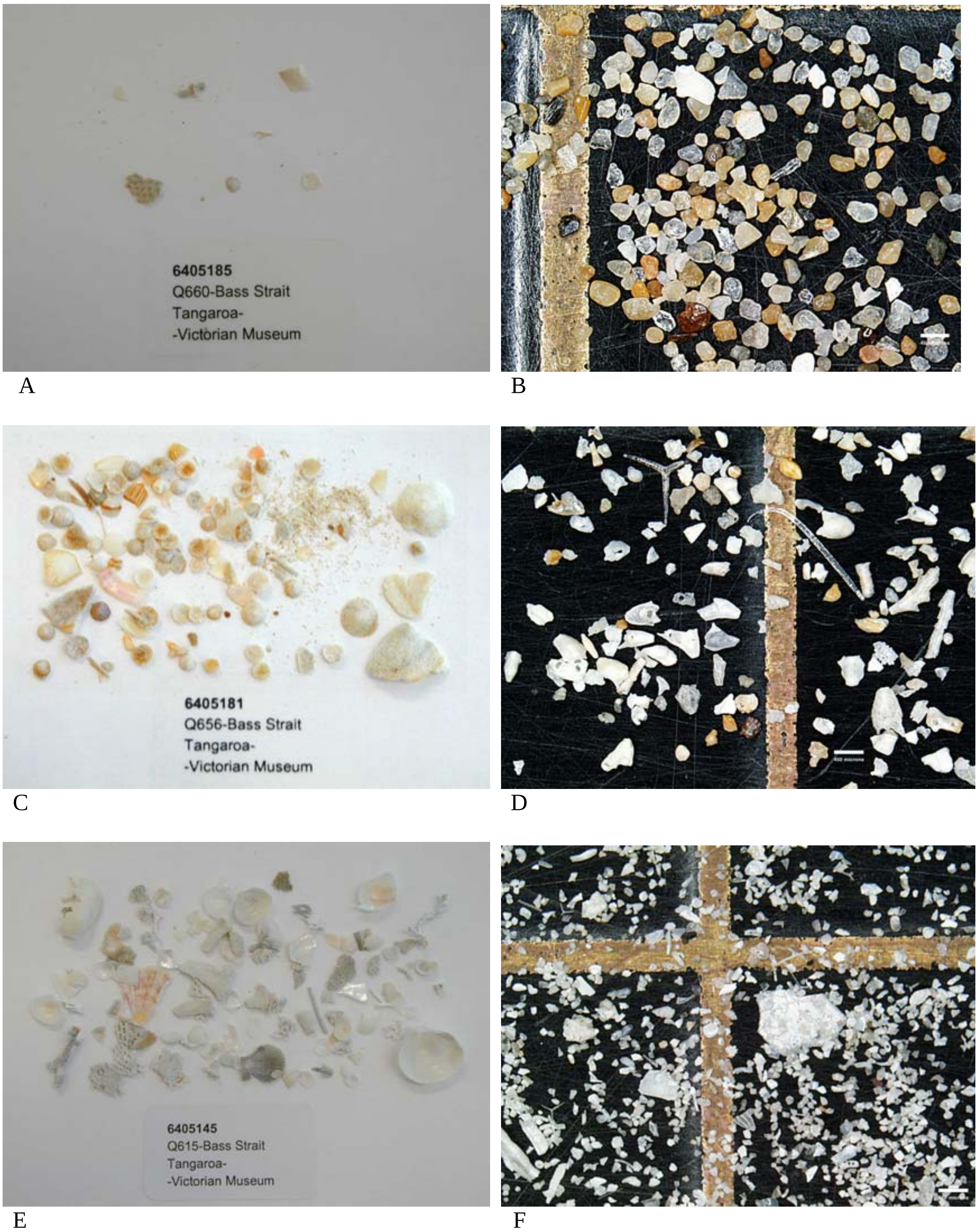
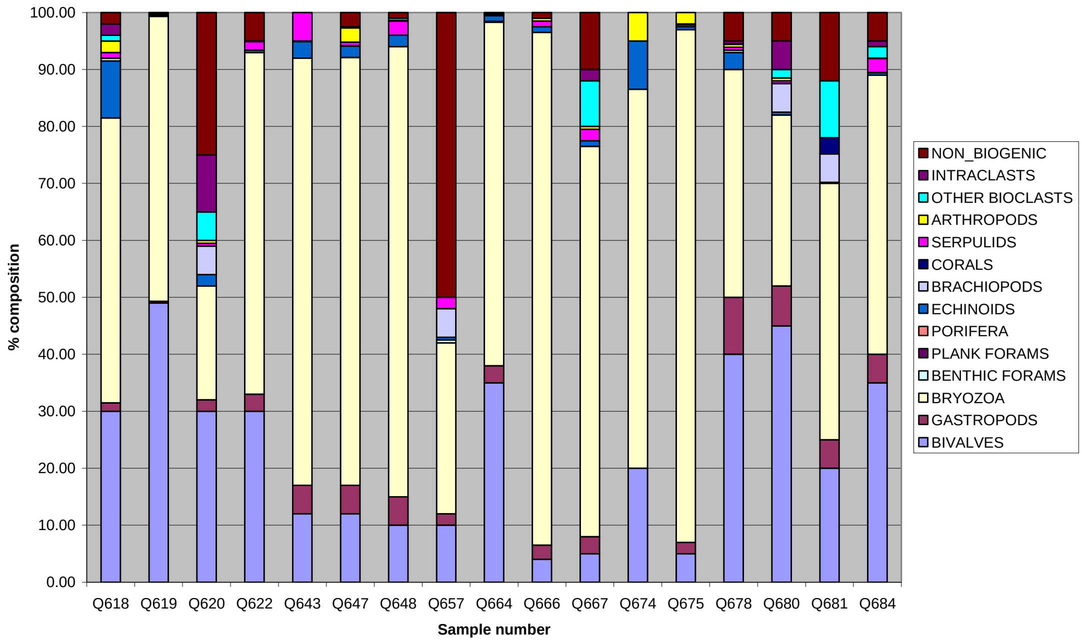
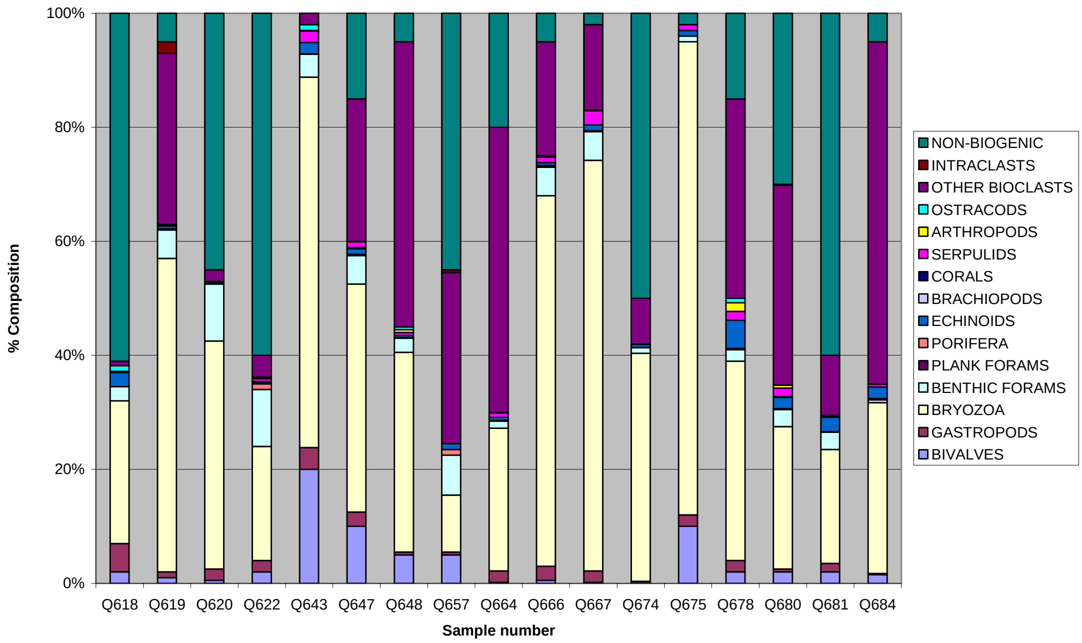


Figure 3.23 *Photographs of sediment composition and preservation in fine sand samples. (a) Q660 gravel fraction; (b) Q660 sand fraction; (c) Q656 gravel fraction; (d) Q656 sand fraction; (e) Q615 gravel fraction; (f) Q615 sand fraction.*

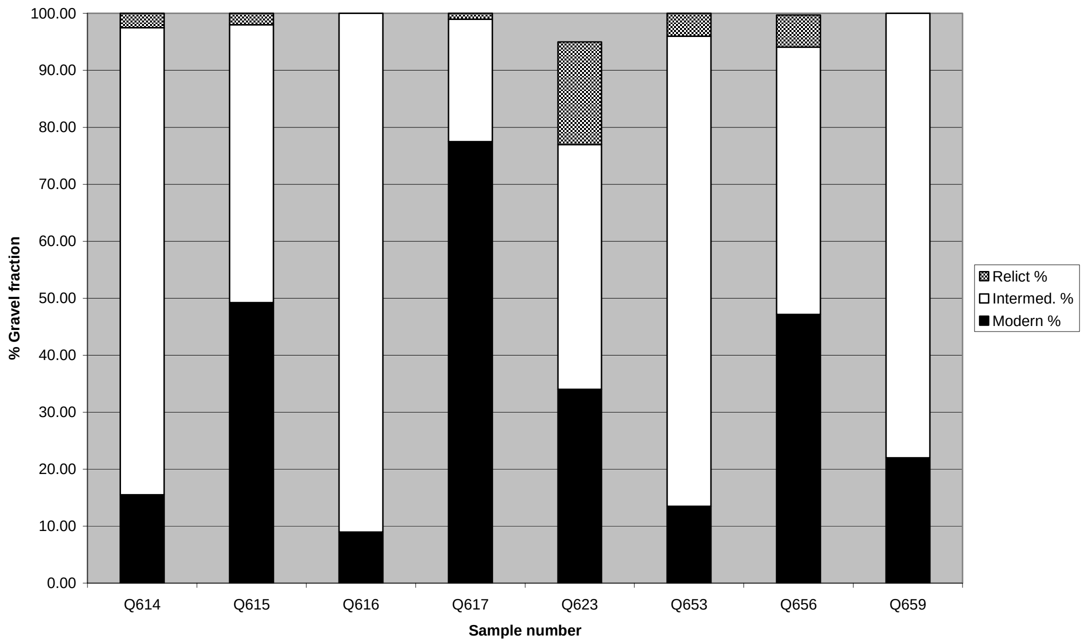


a)

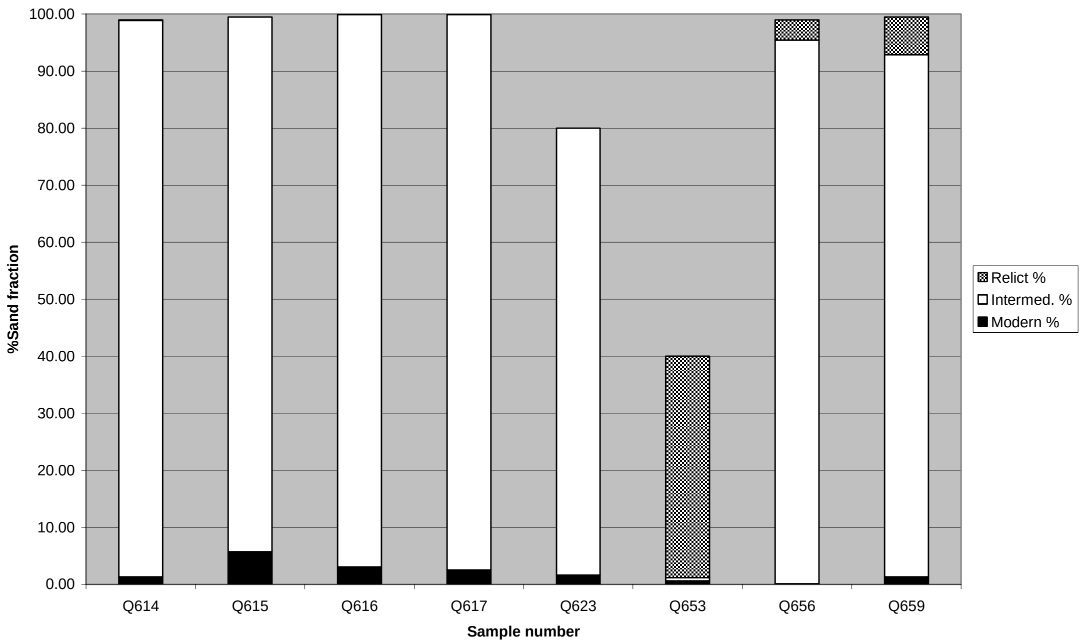


b)

Figure 3.24 *Detailed break-up of biogenic content of (a) gravel fractions and (b) sand fractions in Bioclastic and Lithoclastic Fine Sand sediments.*



A



B

Figure 3.25 *Preservation of biogenic content in (a) gravel fraction and (b) sand fraction of sediments in the Bioclastic and Lithoclastic Fine Sand sediments.*

Table 3.10: Summary of composition of RV *Tangaroa* samples (gravel and sand fractions combined).

RV TANGAROA SAMPLE NO.	BSS SAMPLE NO:	WATER DEPTH (M)	LATITUDE (DEG S)	LONGITUDE (DEG E)	BIVALVES %	GASTROPODS %	BRYOZOANS %	BENTHIC FORAMS %	PLANK FORAMS %	PORIFERA %	ECHINOIDS %	BRACHIOPODS %	CORALS %	SERPULIDS %	ARTHROPODS %	OSTRACODS %	OTHER BIOCLASTS %	INTRACLASTS	TOTAL BIOCLAST & INTRACLAST %	GLAUCONITE %	QUARTZ %	LITHICS %	OTHER TERRIGENOUS %	TOTAL
Q614	156	74	-39.76	145.56	2.06	0.1	9.40	0.45	0.18	0.91	0.78	0.00	0.00	0.14	0.00	0.91	84.17	0.00	99.09	0.00	0.81	0.00	0.09	100.00
Q615	157	75	-40.18	145.74	6.31	0.1	13.50	9.10	0.05	0.91	0.20	0.00	0.00	0.09	0.00	0.91	68.27	0.09	99.54	0.00	0.00	0.46	0.00	100.00
Q616	158	82	-39.83	146.31	4.45	0.2	24.56	0.36	0.29	1.46	0.73	0.00	0.00	0.32	0.01	0.36	67.11	0.07	99.93	0.00	0.04	0.04	0.00	100.00
Q617	159	80	-39.75	146.30	4.38	0.3	5.70	1.93	2.41	4.83	2.90	0.00	0.00	0.02	0.21	4.83	72.38	0.00	99.90	0.00	0.00	0.00	0.10	100.00
Q618	160	59	-39.71	147.33	6.19	4.5	28.74	2.13	0.00	0.00	3.62	0.07	0.00	0.32	0.30	0.85	0.83	0.30	47.82	0.00	0.85	51.33	0.00	100.00
Q619	161	60	-39.78	147.32	9.71	0.9	54.09	4.09	0.00	0.16	0.43	0.02	0.00	0.18	0.02	0.08	24.59	1.66	95.91	0.00	0.00	4.09	0.00	100.00
Q620	162	51	-40.15	147.53	5.07	2.0	36.90	8.45	0.00	0.08	0.39	0.77	0.00	0.16	0.08	0.17	2.46	1.55	58.10	0.00	2.46	39.44	0.00	100.00
Q621	163	56	-40.73	148.54	4.46	0.6	6.46	2.83	0.00	0.09	0.09	0.00	0.00	0.08	0.01	0.47	47.16	0.01	62.28	0.00	33.01	4.72	0.00	100.00
Q622	164	67	-40.73	148.63	3.55	2.1	22.22	9.45	0.00	0.94	0.31	0.05	0.05	0.56	0.19	0.09	3.60	0.00	43.05	0.00	33.34	23.62	0.00	100.00
Q623	165	60	-40.23	148.66	1.21	0.6	5.27	2.95	0.05	0.49	0.94	0.00	0.00	0.00	0.00	0.05	68.73	0.00	80.27	0.00	14.82	4.91	0.00	100.00
Q626	168	40	-39.52	148.42	26.09	1.1	6.48	0.37	0.09	0.00	0.92	0.00	0.00	0.07	0.04	0.37	0.05	0.02	35.57	0.00	59.79	4.64	0.00	100.00
Q643	172	62	-39.06	147.92	18.78	4.0	66.53	3.39	0.08	0.00	2.14	0.01	0.00	2.46	0.09	0.85	1.69	0.00	100.00	0.00	0.00	0.00	0.00	100.00
Q647	176	58	-38.90	147.22	10.45	3.1	47.90	3.87	0.00	0.15	1.23	0.18	0.00	0.91	0.56	0.08	19.42	0.00	87.81	0.00	1.57	10.61	0.00	100.00
Q648	177	58	-38.90	147.11	6.38	1.7	47.14	1.81	0.00	0.07	0.84	0.00	0.00	1.05	0.39	0.36	36.32	0.00	96.10	0.00	1.45	2.45	0.00	100.00
Q653	182	77	-38.74	144.15	1.43	0.1	2.15	1.95	0.01	0.49	0.97	0.09	0.00	0.00	0.00	0.00	34.20	0.00	41.41	0.00	9.77	48.83	0.00	100.00
Q656	Q656	92	-39.11	143.49	0.83	0.2	89.56	1.84	0.11	0.47	0.13	0.02	0.03	0.02	0.00	0.05	5.78	0.00	99.06	0.00	0.11	0.83	0.00	100.00
Q657	Q657	83	-39.01	143.39	8.24	1.5	22.97	2.79	0.00	0.35	0.68	3.24	0.00	1.30	0.00	0.00	10.55	0.18	51.76	0.00	8.52	39.73	0.00	100.00
Q659	Q659	82	-39.02	143.26	1.18	0.5	30.43	2.46	0.49	1.97	2.12	0.15	0.00	0.11	0.00	0.99	59.11	0.00	99.51	0.00	0.20	0.30	0.00	100.00
Q660	184	56	-39.82	143.40	0.12	0.0	1.04	0.50	0.00	0.30	0.20	0.00	0.00	0.10	0.00	0.00	4.80	0.00	7.06	0.00	69.96	22.99	0.00	100.00
Q664	188	59	-38.64	142.58	4.39	2.1	29.25	1.13	0.01	0.10	0.56	0.01	0.00	0.72	0.00	0.09	44.00	0.01	82.38	0.00	0.00	17.62	0.00	100.00
Q666	190	89	-38.83	142.59	1.05	2.5	68.90	4.22	0.08	0.17	0.58	0.00	0.00	1.00	0.08	0.17	16.88	0.00	95.62	0.00	0.00	4.38	0.00	100.00
Q667	191	84	-39.11	142.93	1.39	2.2	71.13	3.76	0.08	0.08	1.00	0.38	0.00	2.38	0.12	0.08	12.89	0.49	96.02	0.00	0.00	3.98	0.00	100.00
Q674	198	85	-40.45	143.69	0.42	0.0	40.16	0.99	0.05	0.00	0.55	0.00	0.00	0.10	0.03	0.00	7.95	0.00	50.31	0.00	4.97	44.73	0.00	100.00

RV TANGAROA SAMPLE NO.	BSS SAMPLE NO:	WATER DEPTH (M)	LATITUDE (DEG S)	LONGITUDE (DEG E)	BIVALVES %	GASTROPODS %	BRYOZOANS %	BENTHIC FORAMS %	PLANK FORAMS %	PORIFERA %	ECHINOIDS %	BRACHIOPODS %	CORALS %	SERPULIDS %	ARTHROPODS %	OSTRACODS %	OTHER BIOCLASTS %	INTRACLASTS	TOTAL BIOCLAST & INTRACLAST %	GLAUCONITE %	QUARTZ %	LITHICS %	OTHER TERRIGENOUS %	TOTAL
Q675	199	71	-40.33	143.81	9.79	2.0	83.30	0.96	0.00	0.00	0.98	0.01	0.00	0.97	0.09	0.00	0.00	0.00	98.09	0.00	1.44	0.48	0.00	100.00
Q676	200	48	-40.00	144.35	14.83	0.0	2.26	0.22	0.00	0.01	0.00	0.04	0.00	0.02	0.00	0.00	0.23	0.00	17.61	0.00	77.72	4.67	0.00	100.00
Q678	202	74	-39.00	144.57	9.16	3.5	35.94	1.62	0.00	0.16	4.62	0.08	0.00	1.31	1.31	0.65	28.43	0.09	86.88	0.00	1.62	11.49	0.00	100.00
Q680	204	82	-39.27	144.09	9.01	1.6	25.82	2.51	0.08	0.02	1.76	0.90	0.04	1.32	0.50	0.04	29.54	0.98	74.08	0.00	0.02	25.91	0.00	100.00
Q681	205	85	-39.23	143.93	3.48	1.8	22.05	2.75	0.09	0.05	2.31	0.41	0.23	0.18	0.09	0.05	10.46	0.00	43.94	0.99	0.92	54.16	0.00	100.00
Q684	Q684	85	-39.00	143.51	9.16	1.3	34.35	0.39	0.04	0.15	1.63	0.01	0.00	0.96	0.03	0.02	46.73	0.23	95.00	0.00	1.23	3.77	0.00	100.00

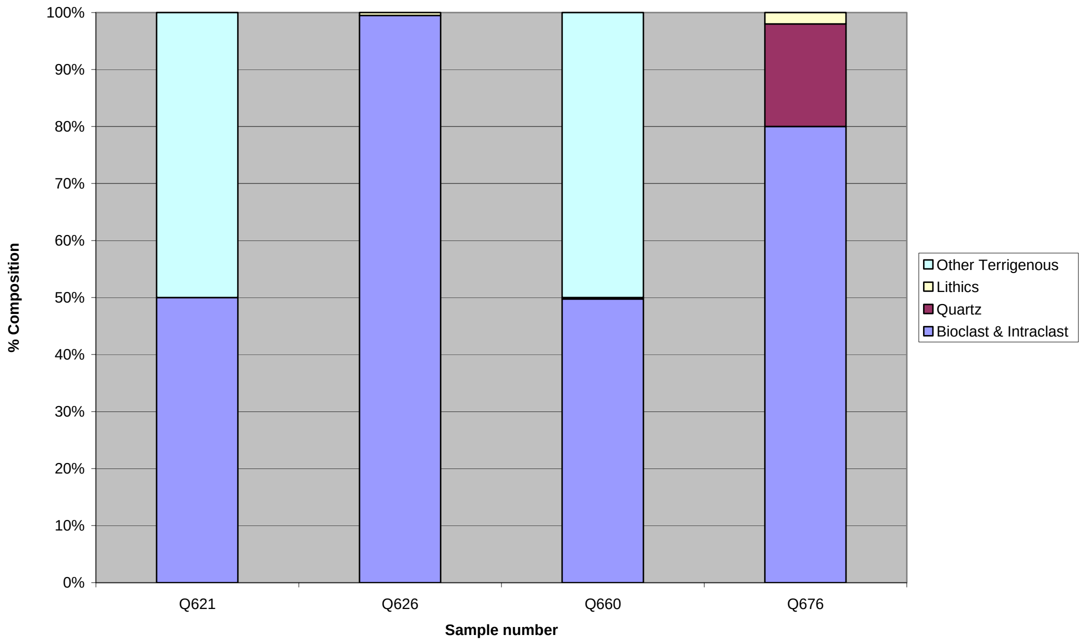
3.5.3 Quartz Sand

Only four samples fall into this category (Fig. 3.26). They comprise a bivalve quartz sand, a quartz sand and two bioclastic quartz sands. Gravel content was measured as 0% in most of the samples (Table 3.7; Wilson and Poore, 1987), although examination of larger sediment quantities revealed gravel fractions ranging from 0.06% to 10.8% of the total gravel and sand fraction (Appendix E – refer to CD-ROM). The bivalve quartz and quartz sands are coarse-grained, with means and modes of the <2 mm fraction in the coarse sand range. The bioclastic quartz sand samples are finer-grained, with means and modes of the <2 mm fraction in the fine sand range (Fig. 3.15).

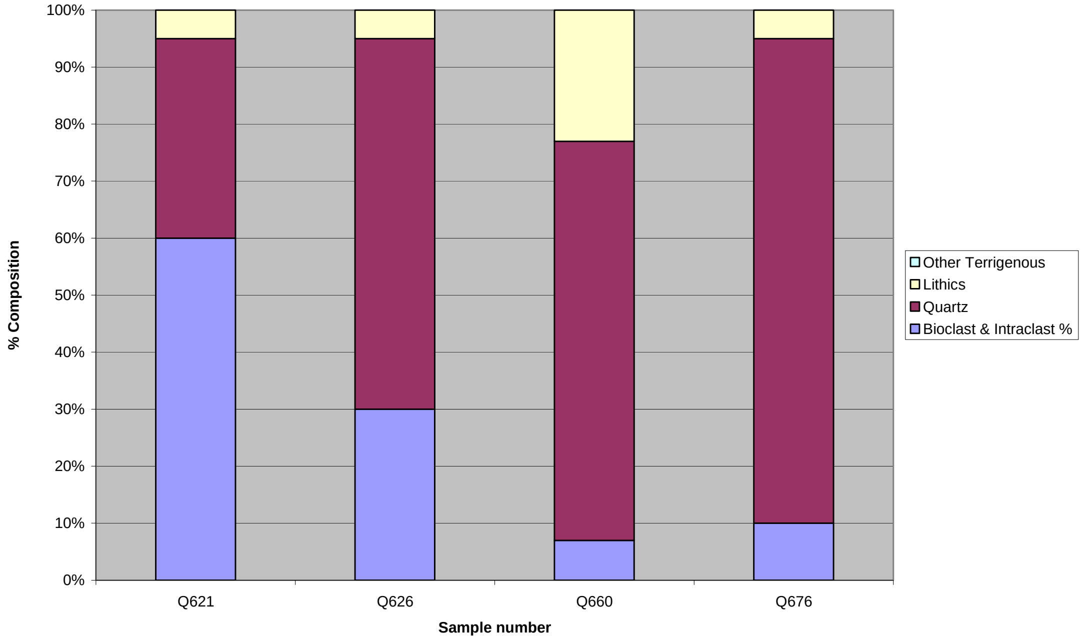
Gravel fractions are dominated by bioclastic material; sample Q676 contains around 20% quartz and minor lithics, while minor quartz is present in sample Q660 (Fig. 3.26a). The quartz content of these samples occurs predominantly in the sand fraction (Fig. 3.26b). Note that in sample Q621 the estimated quartz content based on sample composition is less than the measured value of 50% CaCO3 (Table 3.9).

The biogenic content of gravel fractions in samples is dominated by bivalves, or bivalves and bryozoans, in sample Q660 (Fig. 3.27a). Other bioclasts present in minor abundances include bryozoans, serpulids, sponges, gastropods, arthropods, other bioclasts (fragments) and intraclasts (Table 3.10; Fig. 3.27a). Biogenic content of sand fractions of the coarser-grained samples is also dominated by bivalves. Bryozoans are moderately abundant. Other biota, present in minor abundance include gastropods, benthic and planktonic forams, sponges, echinoids and other bioclasts (largely fragments) (Fig. 3.27b). In the fine-grained bioclastic quartz sands the biogenic fraction is dominated by other bioclasts (fragments) (Fig. 3.27b). Biota present in minor abundances include bivalves, serpulids, ostracods, gastropods, benthic forams, sponges, echinoids and intraclasts (Fig. 3.27b).

Preservation of biogenic material in gravel fractions of the coarse quartz sands is dominantly modern (Fig. 3.28a). In sample Q626 there is a continuum of preservation from modern to relict in the bivalves (Fig. 3.28a). Sand fractions of these samples vary from largely relict in sample Q676 to intermediate with a reasonable modern component in sample Q626 (Fig. 3.28b). In the biogenic quartz sands, biogenic material in the gravel fractions is mostly intermediate with minor modern and relict components, reflecting the high degree of fragmentation (Fig. 3.28). Sand fractions are dominated by relict and intermediate grains, with little modern material (Fig. 3.28b).

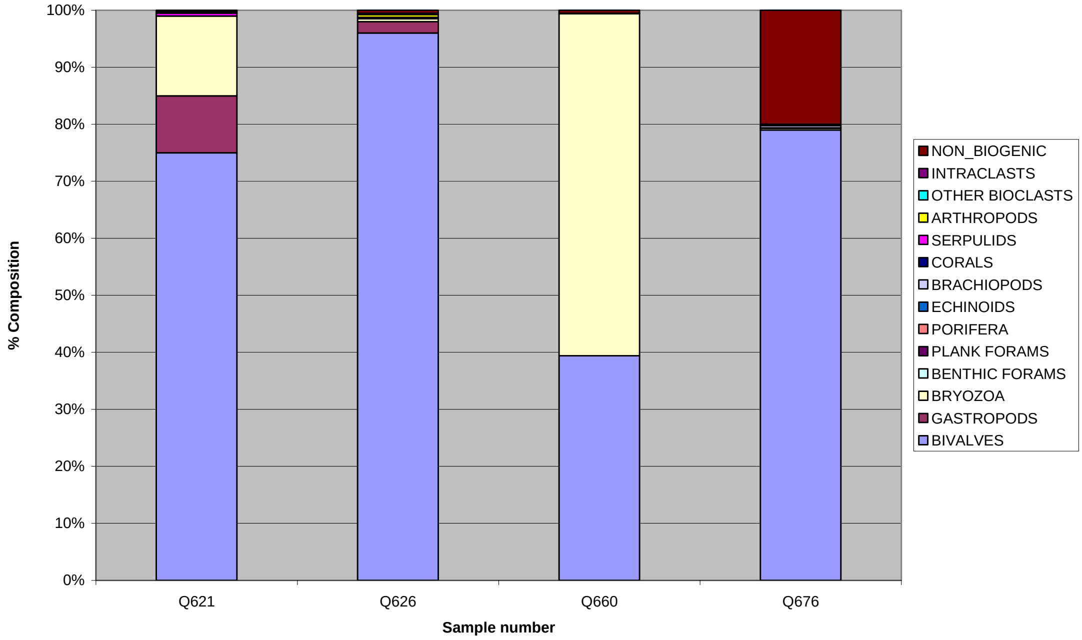


a)

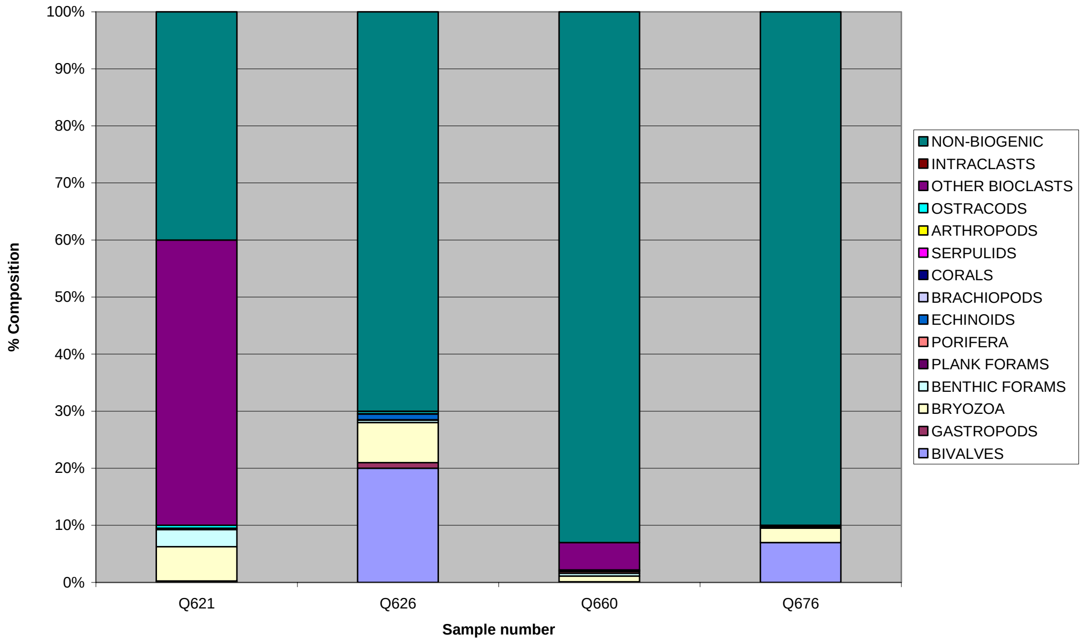


b)

Figure 3.26 *Biogenic versus terrigenous content of (a) gravel fraction and (b) sand fraction in Quartz Sand sediments.*

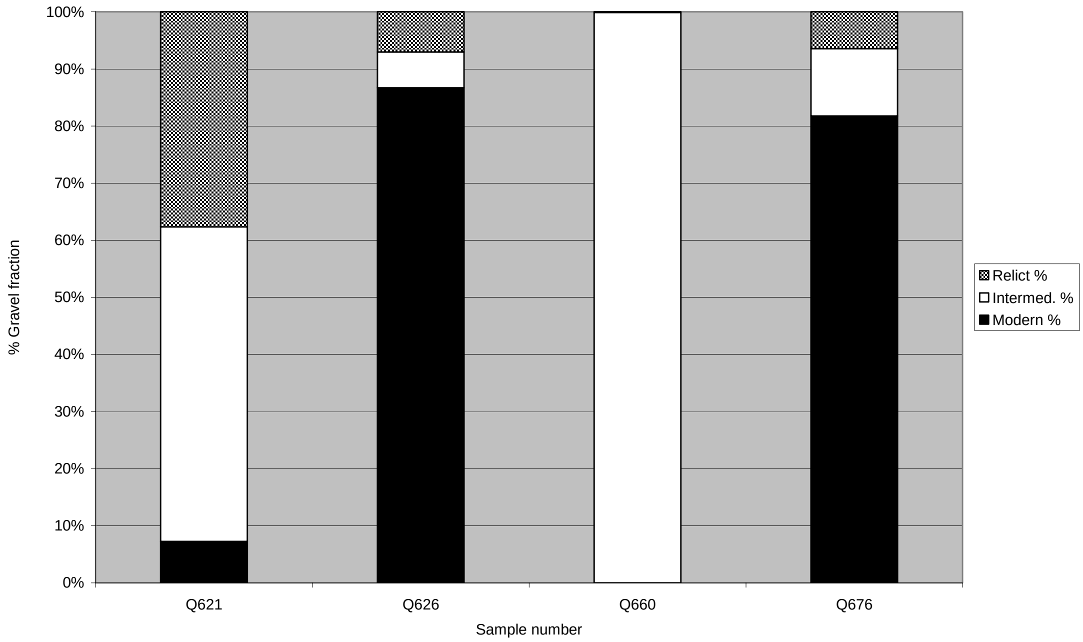


a)

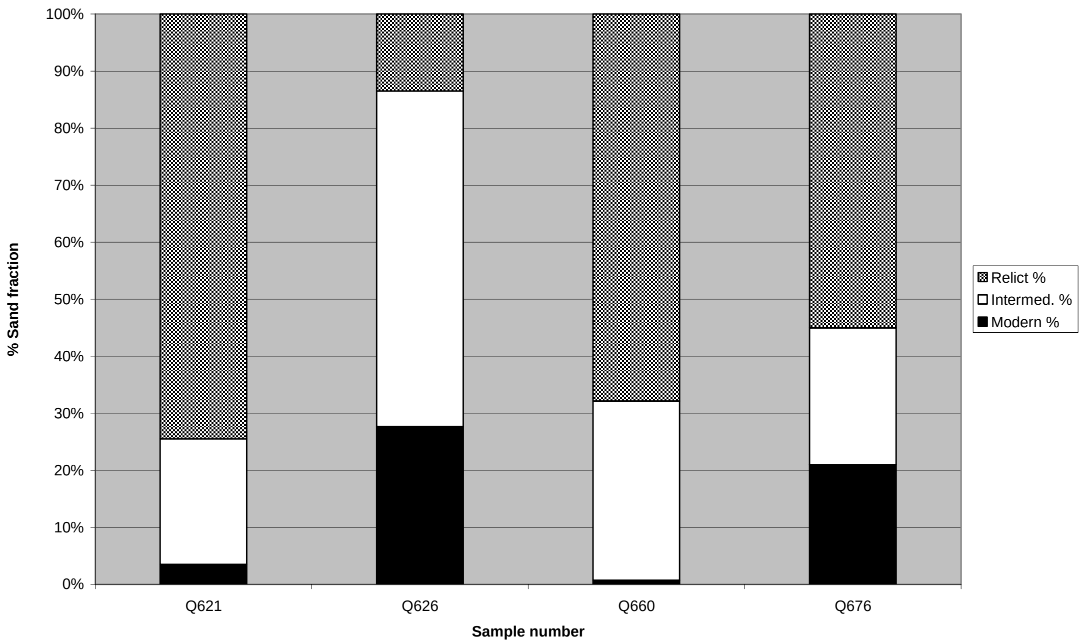


b)

Figure 3.27 *Detailed break-up of biogenic content of (a) gravel fractions and (b) sand fractions in Quartz Sand sediments.*



A



B

Figure 3.28 *Preservation in (a) gravel fraction and (b) sand fraction of sediments in the Quartz Sand sediments.*

3.6 COMPARISONS OF FOSSIL AND MODERN BIOTA DISTRIBUTIONS

Direct comparisons between living and fossil biota in this study are difficult. Much of the living biota is characterised by soft-bodied taxa or groups (eg Table 3.2) that do not preserve well in the sediment. There is little overlap with the main groups that contribute to the sediment (Table 3.10). Because of limitations to the study, living biota of the two major sediment-producing groups, bryozoans and bivalves, were not classified. The distribution of fossil bryozoan types is provided in the following section. The only group for which fossil data can be compared directly with the occurrence of living biota is brachiopods. The distribution of samples containing live and fossil material is compared in Fig. 3.29.

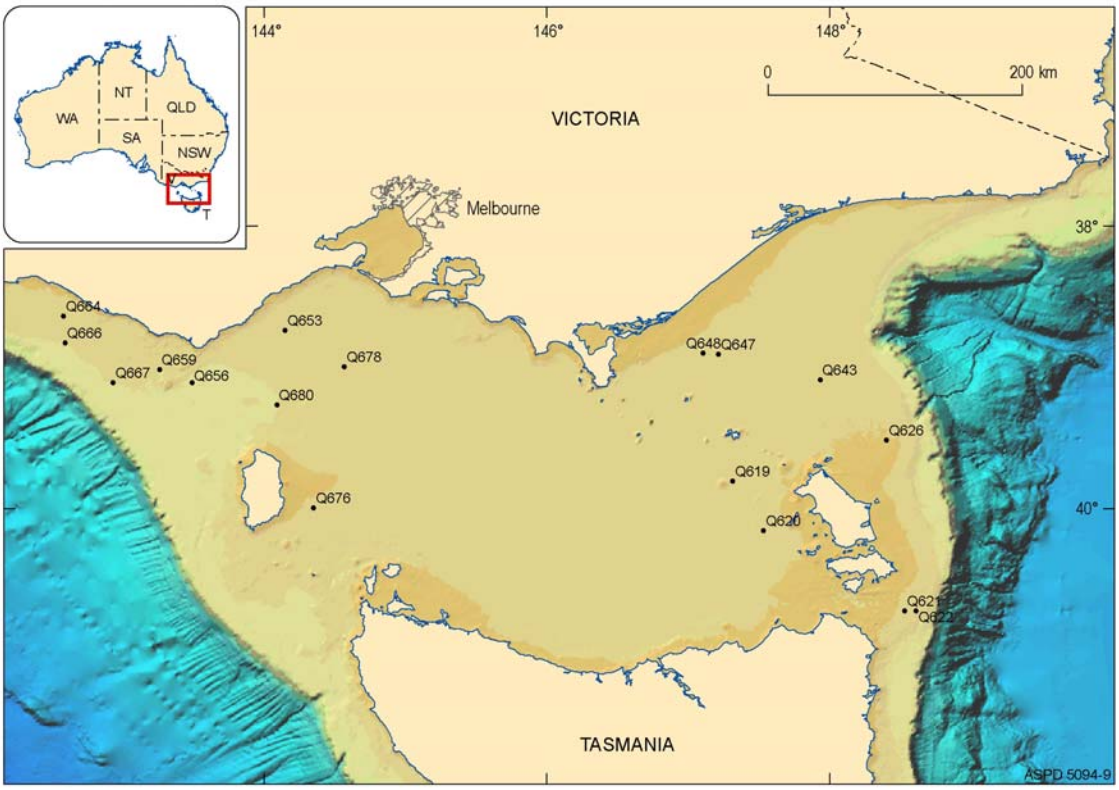


Figure 3.29 *Distribution of samples containing relict and modern sediments.*

3.6.1 Bryozoan Types and Distribution

The distribution of bryozoan types is shown in Table 3.11. Abundances are indicative only; types are listed as either major (abundant) or minor (low abundance). The classification scheme and associated codes used were outlined in Table 2.3. The most common bryozoans present in gravel fractions are encrusting forms (both unilaminar and multilaminar), and erect rigid robust branching types. Fenestrate and free-living forms are locally abundant, but show no clear association with sediment types. Erect rigid delicate branching types are present in low abundances. Erect rigid radiate and erect flexible types (both articulated branching and articulated zooidal) are present in a few samples. Erect flexible and encrusting types dominate the sand fraction of all samples. Erect rigid robust branching types are abundant in small number of samples. Other minor contributors in sand fractions are free living, erect rigid radiate, delicate branching and fenestrate types.

Table 3.11: Types of bryozoans present in the gravel and sand fractions of RV *Tangaroa* samples. See Table 2.3 for classification scheme, codes used and examples of types.

	GRAVEL FRACTION		SAND FRACTION	
RV *TANGAROA* SAMPLE NO.	MAIN TYPES	MINOR TYPES	MAIN TYPES	MINOR TYPES
Q614	ENml	ERro, ERra, ERfe, ERde?	EFaz	ENul, ENml
Q615	ENml, ERro	EFab, ENul, ERfe,	EFab	EFaz, ENml, Erde, ERra
Q616	ENml, ENul	ERfe, ERde, FL	EFaz	EFab, ENul
Q617	ERro, ENml	ENul, ERfe	ENml	ENul, EFab, EFaz
Q618	ERro, ENml	ENul, FL, ERfe	EFab, ERra	EFaz, ENml, ERfe, ERra
Q619	ENul, ENml	FL, ERde	ERro, EFab, ENml	EFaz, ERra, ERde, FL
Q620	ENml, ENul, FL	ERro, ERde	ERro, EFab	ERra, ERde, EFaz
Q621	ENul, ENml	ENml, ERro, FL	EFaz	EFab, ENml, FL
Q622	ERde, ERro	ENml, ERNul, ERfe	EFab, ERde	EFaz, ERro, ENml, ENul
Q623	ENul		EFaz	EFab
Q626	ENul		EFab	EFaz, ENml
Q643	ENml, ERfe, ERro	ENul, ERde, ERra, EFab	ENml, ERro, EFab, EFaz	ERra, ERde, ENul, FL
Q647	ENml, ERro	ENul, ERfe, FL, ERde, EFab	ENml, ERro, EFab, EFaz	ERde, FL, ERfe, ERra
Q648	ENml, ENul, ERro	ERra, ERde, ERfe, EFab, FL	EFab, EFaz, ENul, ERro	ENml
Q653	FL		EFab	EFaz, ENul, ERde?
Q656	FL	EFaz, EFab, ENul, ENml	EFaz	ERra?, FL, EFab, ERde?
Q657	ENul, ENml, ERro	EFab, ERfe, ERde, FL	EFaz, EFab	ERra?, ERro, ENml
Q659	FL		EFaz	EFab, ENml
Q660		ERro, ERde, ERfe, FL		EFab, EFaz, ERra, ENul
Q664	ERro, ENml	ERfe, EFab, EFaz, ENul	EFab	EFaz, ERro, ENul, ENml
Q666	ENml, ERro	ENul, EFab, ERfe, FL	ENml, EFab, EFaz	ERro
Q667	ERro	ERde, ERfe, Eraz, Erab, ENml	EFab, EFaz, ERro, ENml	ERfe, ERde
Q674	ENul	ERfe, ERde, ENml	ENml, ERFab, EFaz	ERfe, ERde, Enul
Q675	Erfe, ENul	ERro, ERde, ENml	EFaz, EFab, ENul	ERfe, ERde, ENml, ERro
Q676		ENml, ENul, ERfe, ERro		EFab, EFaz, ENul
Q678		ENml, ENul, FL	EFaz	EFab, ENml
Q680	ERro, FL	ERde, ERfe, ENml, ENul	EFab, EFaz	ERde, ERro, Enul, ENml
Q681	FL	ERfe, ERro, ERde, ENml	EFab, EFaz	ENml
Q684	ERfe, FL	ERro, ERra, EFab	EFaz	FL, ERfe, ERro, EFab, ENml

3.7 BANKS STRAIT SEDIMENT CHARACTERISTICS

Six sediment samples from GA Survey 226 (Fig. 2.4) were analysed for bulk grain size (weight percent gravel, sand and mud) and carbonate content (Table 3.12). Full sediment descriptions and photographs of bulk sediment are included in Appendix F - refer to CD-ROM).

Table 3.12: Locations, bulk grain size data and carbonate content for sediment samples from Banks Strait (GA Survey 226).

SAMPLE NO.	LATITUDE (DEG S)	LONGITUDE (DEG E)	WATER DEPTH (M)	GRAVEL %	SAND %	MUD %	CACO3 %
226/34GR02	40°49.60’	148°39.48’	92	2	87	11	69
226/35GR03	40°39.55’	147°07.10’	38	53	46	1	60
226/36GR04	40°45.03’	147°49.05’	33.5	1	95	3	38
226/37GR05	40°40.72’	147°35.53’	43.5	21	78	1	64
226/38GR06	40°40.60’	147°21.02’	53.5	0.5	97.5	2	38
226/39GR07	40°40.69’	147°08.62’	66.5	3	78	19	60

Laser grain size distributions were determined for the <2 mm fractions for five of the six samples (Fig. 3.30). Sample 226/35GR03 was too coarse for analysis. Full laser data are included in Appendix D (refer to CD-ROM). Grain size distributions for the <2 mm fractions of these samples are essentially unimodal (Fig. 3.30). Primary modes and volume weighted means range from fine to coarse sand. Secondary modes, where present, show very low volumes and occur in the silt fraction. A very low volume (<2%), fine tail is typical. Standard deviations of 100 to 396 μm indicate the samples are moderately to poorly sorted.

Based on grain size data (Table 3.12; Fig. 3.30) and composition (Appendix E – refer to CD-ROM), the sediments can be classified according to the facies recognised above (Section 3.5). Two samples (226/34GR02 and 226/37GR05) represent bryozoan sands while sample 226/35GR03 is a bryozoan gravel. These sediments are dominated by bryozoans of intermediate to relict preservation. The siliciclastic component is predominantly quartz, with a small, variable lithic component. Much of the quartz is rounded and iron-stained. Gravel content ranges from 2% to 53%. The grain size distribution of the <2 mm fraction occurs in the medium to coarse range. A mud content of 11% in sample 226/34GR02 is higher than usual for sediments of this facies.

One sample (226/39GR07) represents the fine bioclastic sands. This sample is dominated by fragments of intermediate preservation. Bryozoans and bivalves are abundant in the gravel and sand fractions. There is also a significant quartz and lithic component (40%). The gravel component is small (3%) and consists of fine, delicate bioclasts (see gravel fraction photograph in Appendix F – refer to CD-ROM). The <2 mm fraction of the sediment falls within fine sand range (Fig. 3.30).

Two samples comprise quartz sands (226/36GR04 and 226/38GR06). These are dominated by quartz (carbonate content 38%) in the sand fractions. Both are fine-grained, with the <2 mm fraction occurring in the fine sand range (Fig. 3.30). The biogenic content in the gravel fraction of sample 226/36GR04 is dominated by bivalves, modern to intermediate in preservation. In sample 226/38GR06 the biota in the gravel fraction is dominated by bryozoans but includes abundant bivalves. Sand fractions in both samples are dominated by fragments.

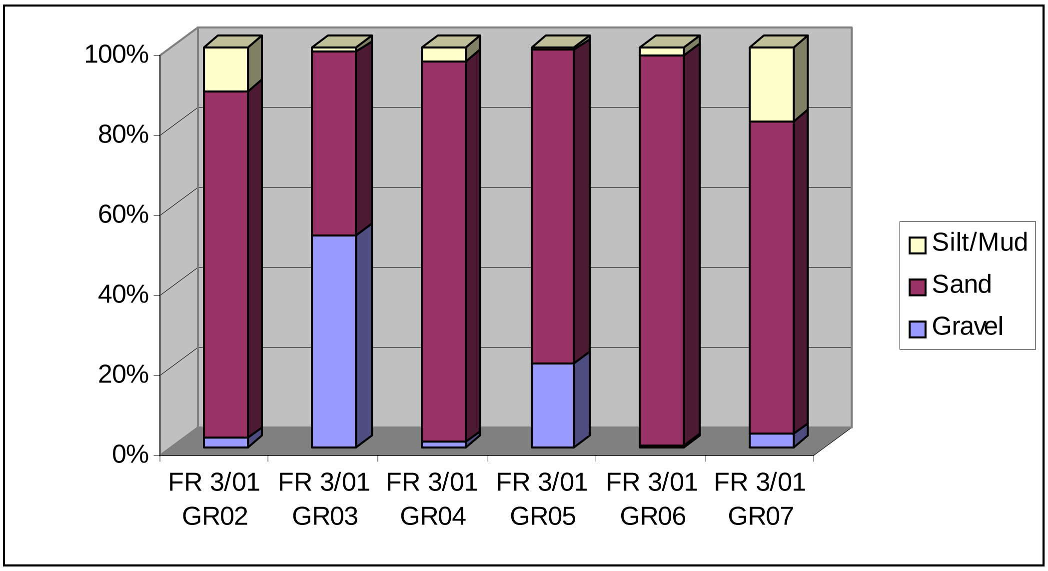


Figure 3.30 *Graph of laser grain size data for selected samples collected on Survey 226. Note: sample 226/35GR03 was too coarse (grain size >2 mm) for analysis by laser.*

3.8 COMPARISON OF SEDIMENT SAMPLING TECHNIQUES

The six sediment samples analysed from Survey 266 were collected in a transect extending from the outer continental shelf, through Banks Strait into Bass Strait (Fig 2.4). The composition and texture of these 6 sediment samples (Table 3.12) were compared with samples collected from the same locations by Jones and Davies (1983; Table 3.13) to compare the different sampling techniques.

Table 3.13: Grain size distributions and carbonate content of samples from Jones and Davies (1983) samples listed with their corresponding Survey 226 sample.

* denotes results omitted from Jones and Davies (1983).

+ denotes where silt and clay fractions, as quoted in Jones and Davies (1983), have been summed.

JONES AND DAVIES (1983)	GRAVEL %	SAND %	MUD %+	CACO3 %	CORRESPONDING GA SAMPLE
1950	*	*	*	*	226/34GR02
1930	*	*	*	*	226/35GR03
1940	11.23	87.06	1.71	*	226/36GR04
1941	12.56	86.53	0.91	*	226/36GR04
1965	39.79	59.62	0.59	61	226/37GR05
1970	1.34	97.44	1.22	40	226/38GR06
1973	6.79	71.45	13.48	65	226/39GR07

Figures 3.31-3.35 show the comparisons between the Geoscience Australia Sedimentology Laboratory grain size distributions for the S266 grab samples against the Jones and Davies (1983) samples. Overall there was little difference between the two sets of samples. The main difference was that the samples collected using a Smith-McIntyre grab (Survey 226) contained a larger proportion of mud and a smaller proportion of gravel than the pipe dredge samples collected during the Jones and Davies (1983) study. Although it appears that there is a difference in the grain size distributions using the two sampling techniques, there are insufficient samples to indicate whether this difference is statistically significant.

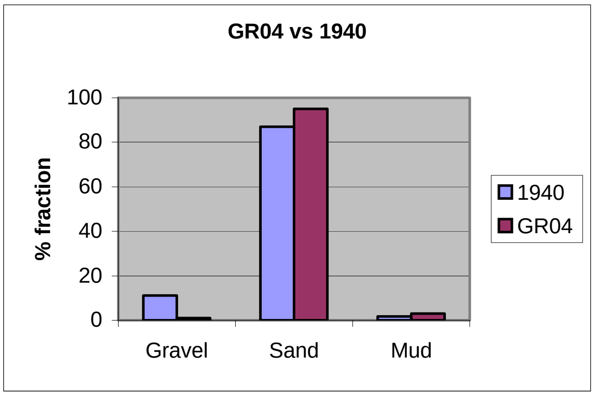


Figure 3.31 *Grain size distribution data from sample 226/36GR04 compared with sample 1940 (Jones and Davies, 1983)***.**

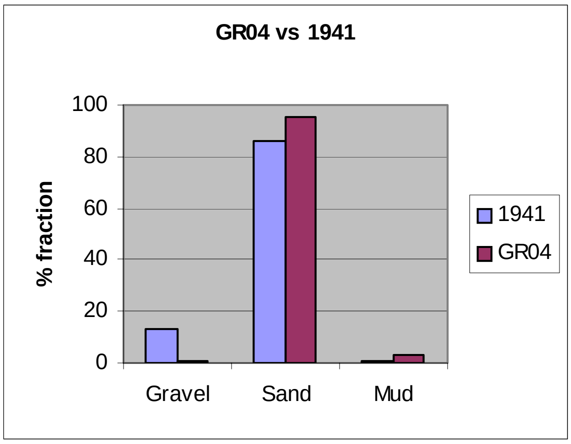


Figure 3.32 *Grain size distribution data from sample 226/36GR04 compared with sample 1941 (Jones and Davies 1983).*

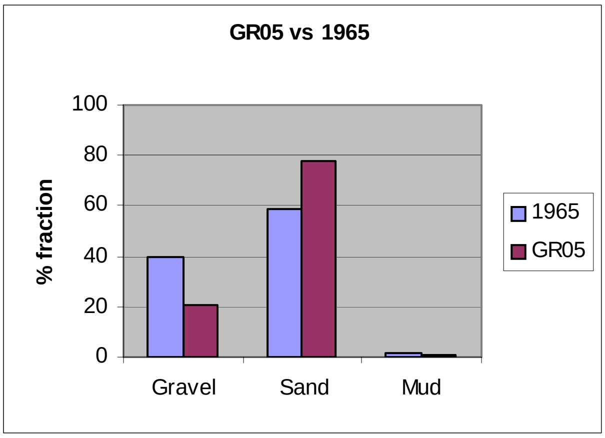


Figure 3.33 *Grain size distribution data from sample 226/37GR05 compared with sample 1965 (Jones and Davies, 1983).*

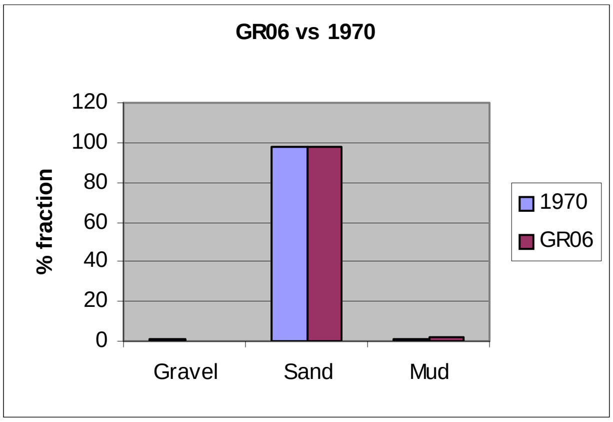


Figure 3.34 *Grain size distribution data from sample 226/38GR06 compared with sample 1970 (Jones and Davies, 1983).*

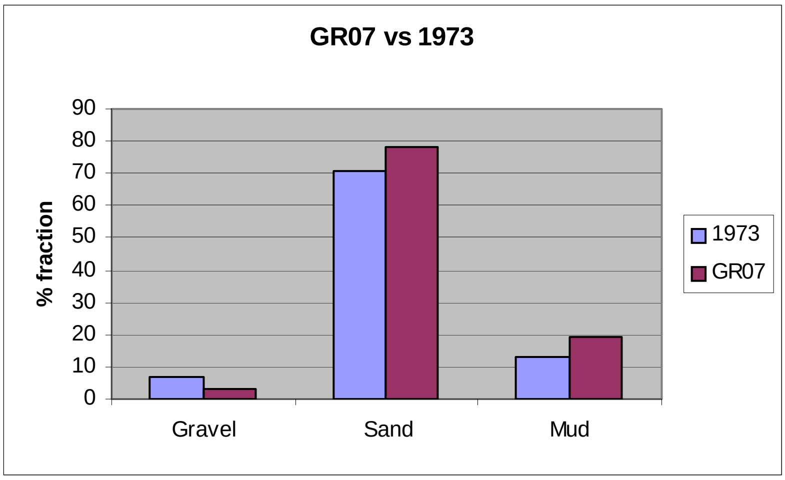


Figure 3.35 *Grain size distribution data from sample 226/39GR07 compared with sample 1973 (Jones and Davies, 1983).*

3.9 NEW ZEALAND STAR BANK SURVEY

The cruise narrative for Australia Hydrographic Office Survey HI339 (GA Survey 233) of New Zealand Star Bank is contained in Appendix C (refer to CD-ROM). The main results of the sampling and surveying program are presented below.

3.9.1 Sampling Stations

A total of eight sediment samples was collected (Table 3.14). Rough sea conditions and strong tidal currents made it difficult to ensure that the grab hit the sea bed perpendicular to the surface, and the returns from the Shipek grab were generally poor. As a result, 6 stations were sampled twice to ensure sufficient sample was obtained. Despite this, only two samples were sufficiently large for laboratory processing. All samples were described visually on board ship (Table 3.14).

Table 3.14: New Zealand Star Bank sample stations with sediment descriptions.
* 'Small sample': indicates samples that were of insufficient size for laboratory analysis.

SAMPLE NO.	LATITUDE (DEG S)	LONGITUDE (DEG E)	WATER DEPTH (M)	SHIPBOARD DESCRIPTION
233/1GR01	47º45.800'	149º42.096'	75	Dune area. Small sample*. Coarse to very coarse sand with minor shell hash. Polychaete tube castings, mollusc.
233/1GR02	37º45.890'	149º41.910'	75	Dune Area. Small sample*. Coarse to very coarse sand with some shell.
233/2GR03	37º44.712'	149º41.226'	65	Dune Area. Small sample*. Coarse to very coarse sand with shell hash.
233/2GR04	37º44.736'	149º41.084'	65	Dune area. Gravelly coarse shelly sand. Sponges present. Shell hash mostly fragments of molluscs and bryozoans. Sample was of sufficient size for further lab analysis (see Table 3.15)
233/3GR05	37º43.987'	149º41.906'	70	Smooth sea floor. Coarse to very coarse sand with shelly gravel. Sample was of sufficient size for further lab analysis (see Table 3.15)
233/4GR06	37º44.963'	149º43.115'	35	Middle of the northern reef. Single fragment of sponge, no sediment.
233/4GR07	37º45.061'	149º42.931'	42	Rugged sea bed. Middle of the northern reef. Very small sample*. Coarse sand and shell hash.
233/5GR08	37º44.734'	149º44.209'	71	Smooth bed east of the northern reef. Small sample*. Coarse sand with shell hash.
233/5GR09	37º44.760'	149º44.130'	74	Smooth bed east of the northern reef. Small sample*. Coarse sand with shell hash.
233/6GR10	37º45.618'	149º44.469'	73	Smooth bed north of southern reef. Small sample*. Coarse sand with shell hash. Coarse fraction includes sponge fragments.
233/6GR11	37º45.667'	149º44.330'	73	Smooth bed north of the southern reef. Small

				sample*. Very coarse sand with shell hash.
233/7GR12	37º46.366'	149º44.148'	39	Reef at south of survey area. Very small sample*. Very coarse sand with shell hash and possible echinoid fragments.
233/8GR13	37º46.794'	149º42.861'	38	Reef southwest of survey area. Small sample*. Coarse shelly sand with bryozoans.

3.9.2 Processed Sediment Samples

Results from the two sediment samples processed in the Sedimentology Laboratory are shown in Table 3.15. Grain size distributions determined in the laboratory support visual estimates, with both samples characterised as bryozoan sands with minor gravel. Preservation of the bioclastic component is poor, with a high relict content.

Table 3.15: Grain size distribution and carbonate content (calculated for gravel and sand fractions) for New Zealand Star Bank samples.

SAMPLE NO.	% GRAVEL	% SAND	% MUD	CACO3% (GRAVEL FRACTION)	CACO3% (SAND FRACTION)
233/2GR04	14.61	84.97	0.42	66	36
233/3GR05	11.36	87.85	0.79	58	40

3.9.3 Multibeam Bathymetry

The multibeam sonar survey revealed a complex terrain ranging in depth from -128 m to –21 m (Fig 3.36). Based on morphology, the New Zealand Star Bank area can be divided into three main types of sea floor:

- Granitic Outcrop. These are characteristically large topographic highs with a complex surface. These outcrops are assumed to be granite due to Devonian granite outcropping in the region and on nearby Gabo Island (Bax and Williams, 2001).
- Undulating/dipping bedrock. Regions of what appear to be outcropping, dipping strata are present. These features could alternatively be dunes or beach rock though morphological evidence (elongate and parallel) suggests sequences of strata, probably sedimentary in origin.
- Flat sediment. This represents sediment without complex topography. The complex topography shown in the traverse is due to high frequency noise within the bathymetry dataset. This high frequency noise is caused by underestimation of the corrections for roll artefacts by the motion sensor on board HMAS Melville.

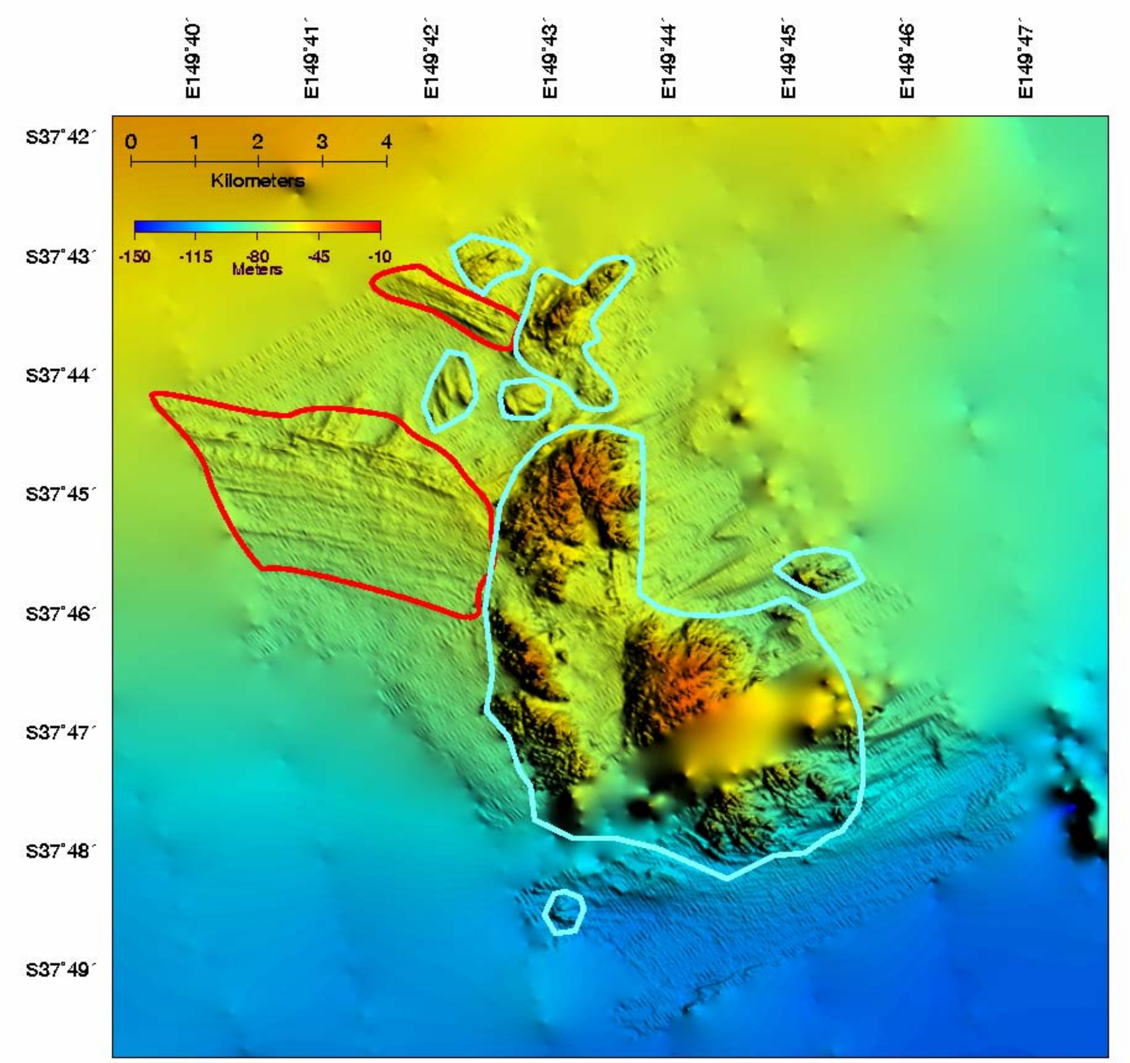


Figure 3.36 *Bathymetry image from the multibeam survey of New Zealand Star Bank. A preliminary interpretation of the seabed geology is shown with Granitic Outcrops indicated by light blue, dipping bedrock (or possibly dunes) indicated by red. All other areas are assumed to be sand covered.*

3.10 VIDEO FOOTAGE

3.10.1 New Zealand Star Bank Sea Bed Video Camera Stations

The sea bed over the New Zealand Star Bank is characterised by a highly diverse fauna on the reefs, including: sponges, bryozoans, soft corals, sea whips, crinoids, echinoids, fish, as well as many other, less abundant, fauna (Table 3.16). The surface of the reef was rugged, creating a wide range of niches and microhabitats to sustain the diverse faunas. Numerous seals were seen while surveying, indicating that the reef might be a feeding ground for local colonies, such as on Gabo Island. The footage demonstrates a high degree of variability of biota within a small spatial area, as well as between closely-spaced sites. Some stills from the video footage, which reflect the variety of sea floor and biological diversity, are shown in Fig. 3.37-3.45.

Figure 3.37: *Shows a rough sand and gravel seabed from camera station*

Figure 3.38: *Shows a sand and gravel seabed with some sponges from camera station 2*

Figure 3.39: *Shows a sand and gravel seabed from camera station 3*

Figure 3.40: *Shows a rocky reef with abundant biological cover including sponges from camera station 4*

Figure 3.41: *Shows a sand and gravel seabed with some sponges from camera station 5*

Figure 3.42: *Shows a rough sand and gravel seabed from camera station 6*

Figure 3.43: *Shows a mixed rocky and sand seabed with limited biological cover from camera station 7*

Figure 3.44: *Shows a rocky reef with abundant biological cover including sponges from camera station 8*

Figure 3.45: *Shows a sand and gravel seabed from camera station 9*

Table 3.16: Sea bed video data logged over New Zealand Star Bank.

Video No.	Video No.	Latitude (deg S)	Longitude (deg E)	Water Depth (m)	Shipboard Description
233/1CAM01	233/1CAM01	37º45.858’	149º42.152’	75	Sandy shelly gravel. Rare sponges.
233/2CAM02	233/2CAM02	37º44.783’	149º40.824’	68	Isolated sponge gardens. Abundant cover. Smooth sandy gravel.
233/3CAM03	233/3CAM03	37º44.030’	149º41.767’	71	Gastropod shells. Occasional sponge gardens. Sandy shelly gravel.
233/4CAM04	233/4CAM04	37º45.105’	149º42.828’	42	Abundant marine life. Crinoids, urchins, sponges. Rocky outcrop covered with diverse biota. Rugged surface.
233/5CAM05	233/5CAM05	37º44.825’	149º43.826’	71	Hermit crab, occasional sponge gardens, octopus. Assorted shells (mainly high spire gastropods). Gravel sea bed (beach-rock?)
233/6CAM06	233/6CAM06	37º45.715’	149º44.164’	73	Clumps of Sponges. Abundant fishes. Shell hash. Rocky outcrop.
233/7CAM07	233/7CAM07	37º46.440’	149º43.855’	35	Occasional urchins, sponges, sea whips. Bedrock outcrops.
233/8CAM08	233/8CAM08	37º46.765’	149º42.733’	38	Abundant damsel fish, crinoids, urchins, sponges, ascidians. Diverse biota on sandy sediments and rocky outcrops.
233/9CAM09	233/9CAM09	37º48.943’	149º43.306’	126	Largely barren, flat seabed. Occasional burrows. Coarse shelly sand substrate.

3.10.2 Integration and Display of Video Data in ArcView GIS

The ArcView GIS provides a convenient way of displaying tables of logged data, geo-referenced, over a bathymetric map. The video data collected during survey S266 was logged according to the scheme described in Section 2.8 of this report. The use of a standard method to log data facilitated the transfer of information seen in the video to the computer screen in the form of a layer in a GIS. The GIS visually represents what was seen in the video as coloured symbols that were geographically referenced using the GPS feed from the ship. Whilst there were only 9 camera station during the survey the information from the video demonstrated the complexity of biological cover in the survey area.

In Figure 3.46-3.48 there appears to be very little observable relationship between the topography and the information derived from the video. This may be due to a number of factors.

1) The GPS feed on the video was relative to the ships position and not the camera itself. As the survey area experienced strong currents (observable by the drag on the camera cable) to actual position of the camera station may be in error.
2) It is possible to observe different habitat types within 1 video sample station.

3) The video is likely to see more relief that the multibeam sonar. The multibeam sonar data was gridded at 5 metres making it impossible to view features any smaller that about 10m in the NS/EW direction
4) Noise in the multibeam data also affected the resolution of the final bathymetry grid.
5) A lack of sample sites makes it impossible to do any statistical tests to assist habitat definition.

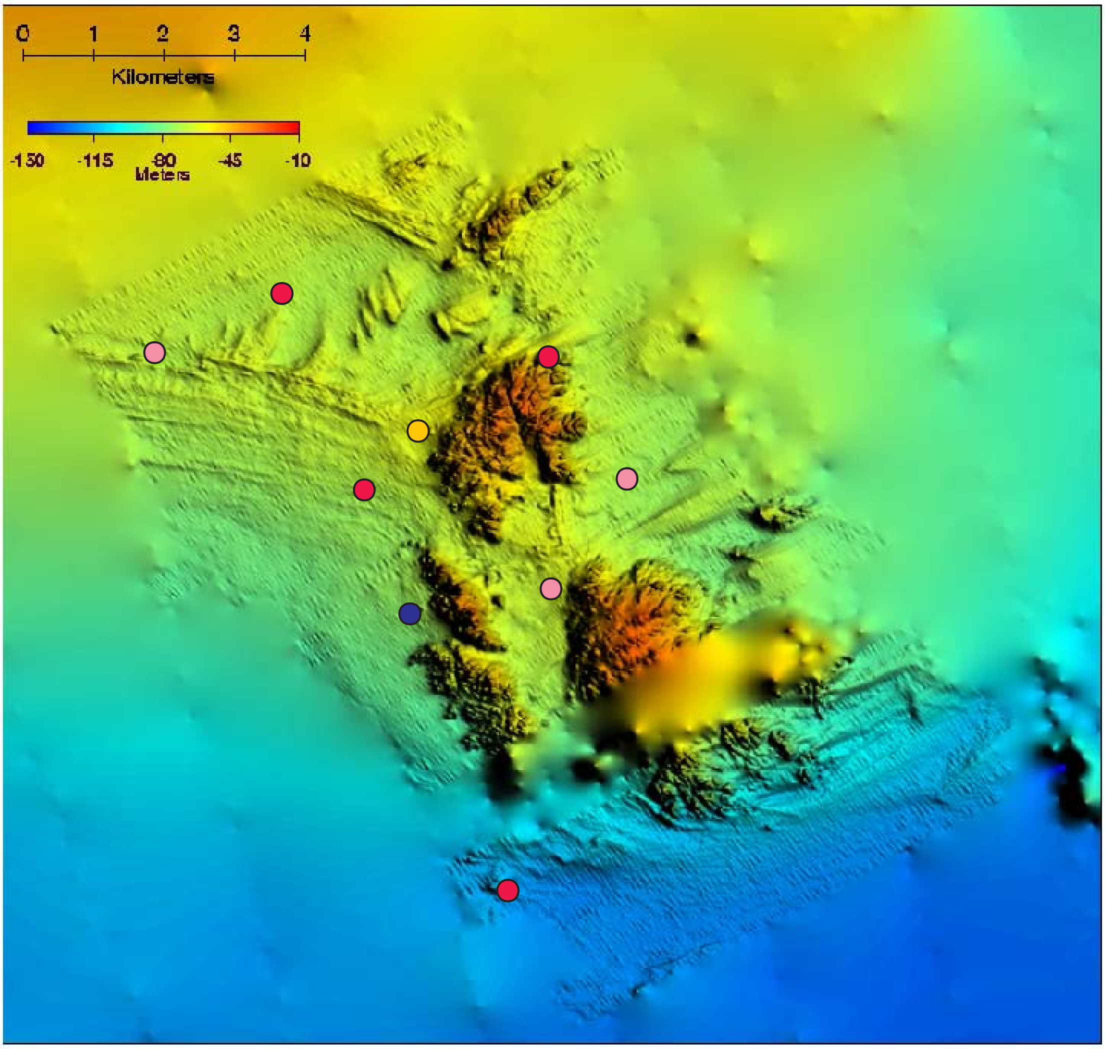


Figure 3.46 *Bathymetric image showing the pattern of biological coverage. The coloured circles demonstrate the different types of coverage styles. Magenta = Clumps, Red = Sparse, Blue = Thick, Yellow = total cover.*

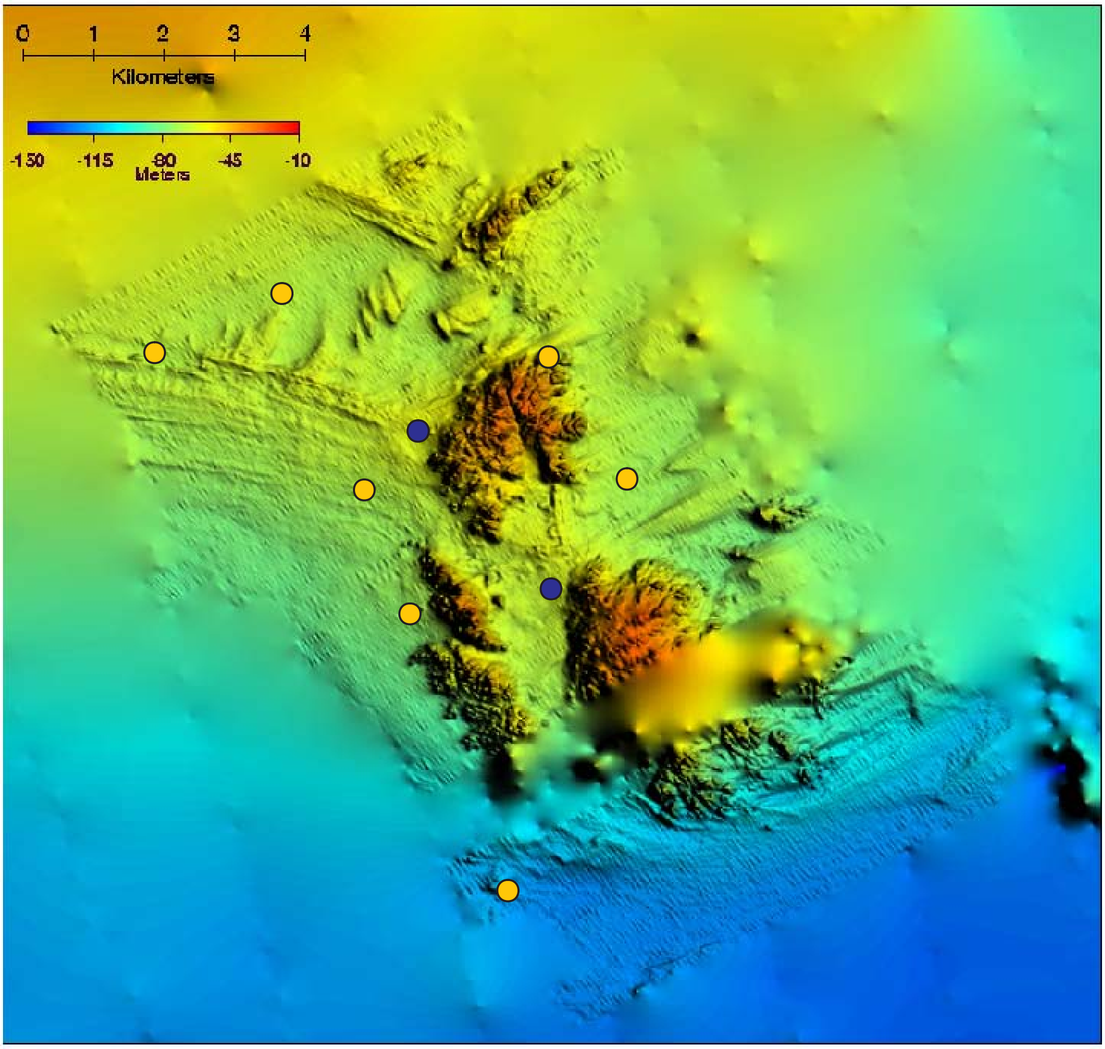


Figure 3.47 *Bathymetric image showing the distribution of sponges. The coloured circles demonstrate the different types of coverage styles. Yellow = Rock, Blue = Sediment.*

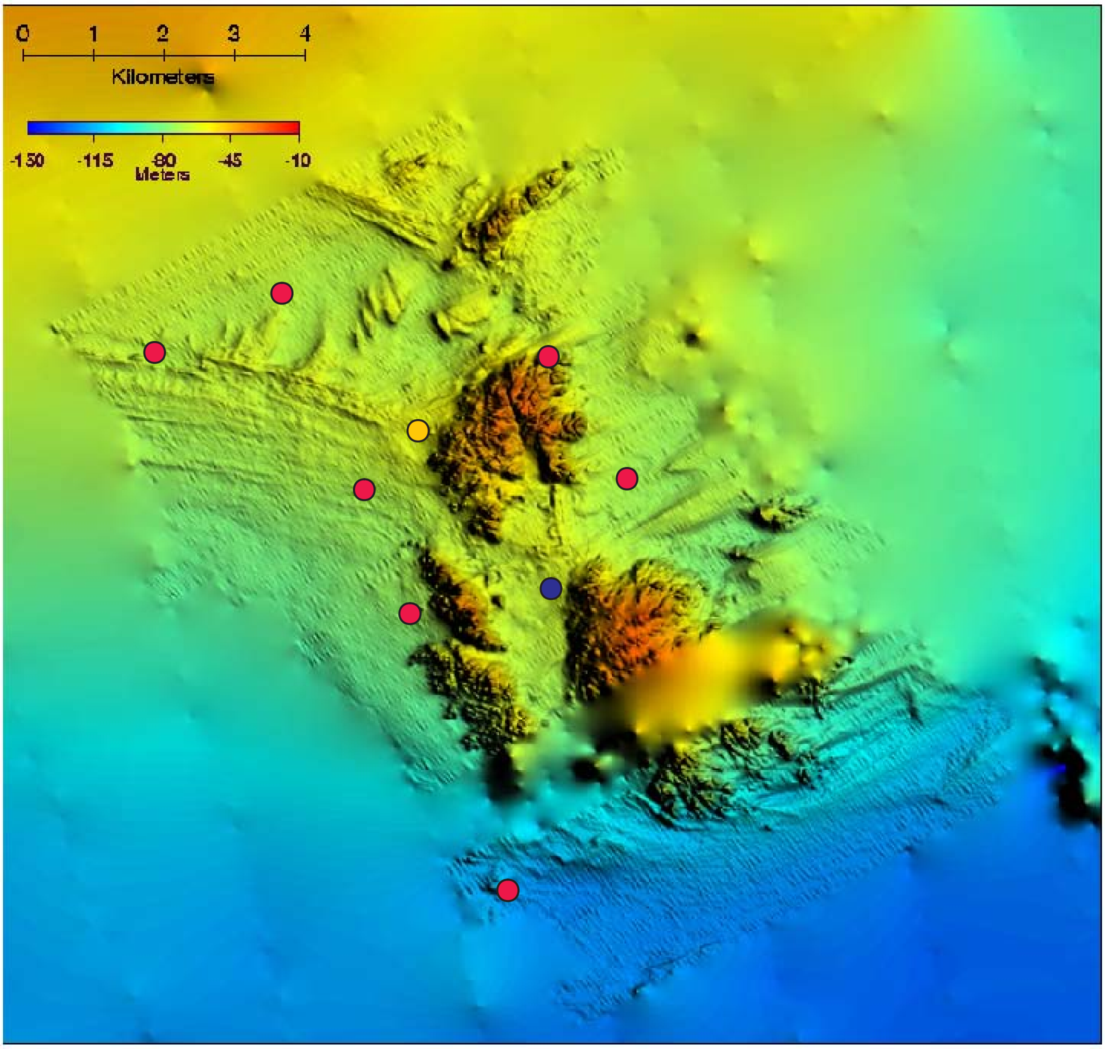


Figure 3.48 *Bathymetric image showing the pattern of sediment coverage as recoded from the underwater video camera. Yellow = Rocky, Red = Thick, Blue = Thin.*

4. Discussion

4.1 INTEGRATION OF BIOTA AND ENVIRONMENTAL PARAMETERS

4.1.1 Study Biases and Limitations

The large number of species and samples used in this study reduced the potential for multivariate statistics to detect clear patterns in the distribution of assemblages. Moreover, the original random sample design of the BSS was supplemented by additional collection of samples on the western and eastern edges of Bass Strait leading to an over-representation of samples in those areas (Wilson and Poore 1987).

Other study biases included the semi-quantitative nature of the dredge, sled and trawl samples and the incomplete coverage of all taxonomic groups. The semi-quantitative sampling was overcome by transforming species abundance data into presence-absence data for the dredge, sled and trawl samples. The distribution patterns generated from these samples largely agreed with distribution patterns generated from the quantitative analysis of fauna in the grab samples. It was desirable to include trawl and sled data in the analyses, as these collection methods capture large animals such as seastars, urchins, crabs and gastropods that are typically absent from grab samples.

Taxonomic groups included in the analysis ranged from large, long-lived animals to smaller, short-lived forms. Excluded groups were: 1) habitat-forming sessile invertebrates such as sponges, bryozoans, hydroids and ascidians; 2) important infaunal groups such as bivalves, and 3) other speciose groups such as amphipods, cumaceans, and many polychaete families. These groups may generate different patterns than those created from the current dataset. While it would be desirable to include habitat-forming groups, it is difficult to reconcile abundance data of solitary (typically measured as number of individuals) and colonial animals (typically measured in biomass). Colonial animals are frequently omitted from marine community analyses.

The geological data on which interpolations were based have been collected over many years from a variety of sources. The method of sample collection varied and hence may have affected the data. Samples collected by Jones and Davies (1983) were taken by pipe dredge, so the sediment may be collected over an area rather than from a specific site. An additional problem with dredges is that they may not retain the fine fraction. Concerns about this led to resampling of some of these sites by grab (Exon *et al*., 2001), and while some differences were observed between sediments in this study these do not appear to be significant (Section 4.2.2, below). Data from which percent rock was determined are sketchy and suffer from similar limitations of sampling techniques, particularly since much of this data is interpolated from written descriptions. Sample size affected the grain size distributions obtained from sieving. These sub samples often contained little or no gravel, while the larger samples analysed for composition all contained a small gravel fraction. Discrepancies between grain size and carbonate content data were noted between published data from the BSS (Wilson and Poore, 1987) and samples analysed at GA (e.g. Section 3.5.3).

4.1.2 Overall Patterns

Despite the study limitations, some interesting patterns emerged from the analyses. The study found that Bass Strait supports a particularly diverse benthic fauna. Overall, the similarity between samples is very low. Even neighbouring samples rarely have a Bray-Curtis similarity coefficient of less than 50%, and a large degree of small-scale variation exists. There was sufficient similarity between some samples to form recognisable clusters. But overall the primary clusters did not have a recognisable regional, water depth or sediment profile.

Several environmental variables were significantly correlated with the ordination patterns. Longitude and water depth were important gradients, followed by the percent sand and mud, although to some extent these variables were correlated with longitude and to a lesser extent water depth. Generally, gradients based on latitude, mean grain size, percent rock and gravel, and carbonate content were not significant in the analyses.

There has been speculation that larger sediment particles (i.e., gravel) have influenced the evolution of the diverse Bass Strait fauna (e.g., Richardson 1997). However, this study did not find any substantive evidence to support this conclusion. In fact, finer particles (sand and mud) appeared more highly correlated to faunal patterns.

The analyses suggest that numerous environmental variables influence the composition of benthic assemblages in Bass Strait. No one factor dominated the analysis. In the dredge and sled samples. The most significant correlation between benthic assemblages is with longitude. However, even in these data, only 50 % of the variation is explained (R=0.7). The best-matching sediment variables, the percent sand and mud, explained less than 25 % of the variation. From these data, we infer that the biotic pattern for Bass Strait is not strongly related to sediment composition, a finding best demonstrated by the scatter significant associated with samples containing 100 % sand across the ordination space for all three collection methods. Sediment composition is therefore only one of a number of interacting environmental gradients.

Different suites of species probably interact with different environmental variables. The infauna would be influenced by sediment characteristics more than the epifauna living on the surface. The larger epifauna possibly depend on large sediment grains for initial settlement and many sessile animals rely on strong water flow for food supply. The sessile fauna would then provide additional microhabitats for another suite of epizoic species.

Overall, it is not possible to classify the biological assemblages into a scheme that can be mapped over the study area. This is because samples do not form discrete groups on the ordination and, although samples do cluster on the dendrograms at spatial scales of ~100 km, there is not a strong pattern at larger spatial scales. The analyses indicate that environmental gradients rather than discrete bioregions or habitats better explain the biotic patterns observed in the sea bed of Bass Strait.

The study emphasises that assemblages (or communities) can have different distribution patterns to species. Previous studies have described a considerable turnover of species across Bass Strait, almost 50% for algae, echinoderms and decapods (e.g., Bolton, 1996, O'Hara and Poore, 2000). However, this biogeographical gradient is not necessarily apparent from multivariate analyses of assemblage distributions (e.g., Coleman *et al.,* 1999; O'Hara 2001; this study). Possibly, those species with distribution limits in Bass Strait are either locally rare, or restricted to habitats that have not been studied in this region using multivariate methods (e.g., seagrass beds or rocky shores). A positive relationship between abundance and range has been described for many taxonomic groups in other habitats (Gaston, 1996)

4.2 SEDIMENT CHARACTERISTICS IN BASS STRAIT

4.2.1 Sediment Facies and Distribution

Based on detailed examination of texture (grain size), carbonate content and composition of selected samples, four sediment facies are identified:

- Bryozoan and lithoclastic sand and gravel;
- Bioclastic and lithoclastic fine sand;

- Quartz sand; and
- Carbonate sandy mud and muddy sand.

While the number of samples examined in detail in this study is small, the sediment facies and their distributions can usefully be compared with facies described by previous workers in Bass Strait (Jones and Davies, 1983; Blom and Alsop, 1988) and the Otway shelf (Boreen et al., 1993). The bryozoan and lithoclastic sand and gravel facies can be correlated with the bryozoan sands and gravels of Jones and Davies (1983). This facies is the most abundant and widespread in the samples examined, dominating the western and eastern margins of Bass Strait. As noted by Jones and Davies (1983) the facies is characterised by a high relict content.

The abundance of rounded, highly abraded limestone lithoclasts in many samples examined here is in contrast to the findings of Jones and Davies (1983). The latter found granitic rock fragments in samples from east of Flinders Island, but these showed evidence of little transport. A similar lithoclastic facies, the bivalve lithoclast gravel, has been described by Boreen et al. (1993) from the Otway margin. The lithoclasts are similar to those described here, being of granule to cobble size, abraded, polished and extensively bored. The source of the clasts is Miocene limestone, which underlays the thin veneer of sediments on the Otway and west Tasmanian margins (Davies and Marshall, 1973; Jones and Davies, 1983).

Sediments of this facies are indicative of high-energy environments. The extent of winnowing of the sediments is indicated not only by the paucity of mud, but by the absence of fine sand particles, such as sponge spicules and juvenile ostracods, in the biogenic fraction. The coarsest of these sediments, such as the gravels of Banks Strait, probably represent lag deposits; others may be dune sediments. Similar facies have been described from the Otway margin (Boreen et al., 1993), including a cross-bedded bryozoan sand facies which occurs in starved dunes.

The bioclastic and lithoclastic fine sand facies has no direct equivalent in the facies of Jones and Davies (1983), but is similar to the fine-grained bioclastic sand facies of Boreen et al. (1993). This facies represents finer-grained sediments deposited in lower-energy environments, such as central Bass Strait or in the lee of areas with high tidal current activity, such as east of Flinders Island.

The quartz sand facies is similar to the slightly quartzose fine shelly sands of Jones and Davies (1983) and to the poorly sorted mollusc sand facies of Boreen et al. (1983). Coarser-grained sands with a higher content of quartz are probably equivalent to the quartzose sands of Jones and Davies (1983). The distribution of this facies occurs locally east of Cape Otway, and north of Flinders Island. The rounded and polished nature of the bulk of quartz grains in samples is consistent with the aeolian origin suggested by Jones and Davies (1983).

The carbonate sandy mud and muddy sand facies represents the only muddy sediments examined in detail in this study and has no equivalent to the facies of Jones and Davies (1983) or to the muddy sediments of Blom and Alsop (1988), as they were taken in deeper waters (>1100 m) not sampled by either. Samples examined are restricted to the area adjacent to Bass Canyon, the only deep water area sampled in the BSS (Fig. 2.1). The facies includes multimodal fine-grained muddy sands or muds with no gravel content. Although their composition was not examined, the high carbonate content of both sand and mud fractions (Table 3.9) and the water depth in which they were taken suggests that they are neritic.

4.2.2 Effects of Sampling Method on Grain Size Properties

There are some inherent difficulties with attempting to compare the sediment samples and sampling techniques of Jones and Davies (1983) with Exon *et al*. (2002). One critical problem is navigation; recent advances in Global Positioning System (GPS) technology allow for sub-decimetre accuracy of positing. GPS technology was not available during the Jones and Davies surveys. Positioning at that time was by dead reckoning or possibly with early satellite technology. Both techniques are much less accurate than the present day GPS. Reworking of sediments by currents and storms could also affect the accuracy of comparing the sediment sampling techniques.

This study makes the assumptions that:

- the repeat samples were taken from as close to original locations as possible, allowing for differences in navigation technology;
- there was no additional sorting or reworking of the sediments in the time between sampling due to waves, tides or storm action; and
- the addition of the clay and silt fractions in the Jones and Davies (1983) samples is equivalent to the estimate of mud content in the present study.

It is difficult to make statistical correlations between the different sampling methods due to the small number of samples analysed. A further study involving a statistical reliable number of fine-grained samples would be the most effective way to estimate the significance of differences between pipe dredge and grab samples. Another potential method of comparing the effects of the different sampling methodologies on sediment texture would be to compare mean grainsize, standard deviation, skewness and kurtosis. Although, with the present data there are inconsistencies between the Jones and Davies (1983) samples which are calculated using moments and expressed in phi, and our samples, which are calculated volumetrically and expressed in μm.

The paucity of fines in sediments collected from Bass Strait by Jones and Davies (1983) has long been thought to be a reflection of the sampling technique, rather than a true reflection of the grainsize (Exon *et al*., 2002). This study suggests that while pipe dredge samples are slightly lower in fines than those collected in grabs, the difference is not significant. The absence of fines in the sediments is a reflection of the high-energy regime in the region and is consistent with the patterns of transport of fines offshore in other southern margin shelves (Boreen *et al*., 1993). It is interesting to note that of the RV *Tangaroa* sediments analysed, the finest-grained were those collected from deep-water in the Bass Canyon area. These samples were taken by dredge, compared with the bulk of samples, which were taken using a Smith-McIntyre grab.

In areas where tides are constricted, current velocities at the bed are elevated and enhance sediment movement and resuspension. Banks Strait, between Flinders Island and Tasmania, is strongly tidally-dominated (Harris *et al*., 2000). The tide-dominated sedimentary regime in Banks Strait supports the existence of subaqueous dunes (Malikides *et al*., 1988) though the GA bathymetry grid of the area does not delineate the dunes due to the griding process and pixel size (250m for Fig. 1.1).

Geoscience Australia's 250m bathymetry grid shows current-parallel depressions within Banks Strait (Fig 1.1) that may also be due to near-bed tidal currents. Similar scoured-out depressions are described in Clarence Strait in Northern Australia (Harris *et al*., 1991). Harris *et al*. (1991) describe these depressions as regions of 'erosion and scour' that have exposed bedrock or Pleistocene deposits or leave a 'gravelly lag deposit'. In Fig. 1.1 the coarsest sediment sample (226/35GR03) is located within Banks Strait and probably represents a lag deposit that has resulted from strong tidal current activity. To the west and east of Banks Strait the sediment deposits become less gradually less coarse as a result of weaker tidal currents away from the constricted waterway.

4.3 LINKS BETWEEN SEDIMENTS, BIOTA AND HABITAT

The results of our study show that biogenic composition of sediments provides valuable information on the extent of relict material, indicate the relative contributions of different organisms to the sediment composition and texture, and allow for testing of the use of sediment composition as a surrogate for living biota. Information from the biogenic content in sediments also provides insights into the trends in grain size data.

Both composition and grain size distribution are influenced by biogenic input, including the sizes of the organisms present and typical breakdown patterns. For example different bryozoan types break down in different ways (Bone and James, 1993; Smith and Nelson, 1996). Erect flexible types breakdown into their discrete zooids, while erect rigid types fragment into rod-like particles. Multilaminar encrusting forms are prone to abrasion and tend to break into small particles, while free-living types are more likely to be preserved whole (Smith and Nelson, 1996). The hydrodynamic processes operating in sedimentary environments also affect the preservation of biogenic remains. Selective transport of differently-sized individuals and dissolution effects can influence the population. Juvenile specimens are often lost through sediment winnowing or abrasion, so the presence of well-preserved juveniles in a population is generally indicative of in-situ material.

The degree to which sediments reflect the diversity of living biota in a site can be assessed using video and grabs from the New Zealand Star Bank site. As indicated above (Section 3.9), sediments from the sites were similar in texture and composition. The sites from which these samples were collected were shown on video to contain very different biota. Rocky areas and some patches of unconsolidated sediments contained abundant and varied fauna, while other areas had much lower diversity and abundance. These differences indicate that sediments provide a record of post-depositional processes far more than they reflect living biota.

Jones and Davies (1983) and Radke (in Harris *et al*., 2001) discussed the problem of determining the age of biogenic material in sediments from this area. While recognising modern and relict end members is relatively easy, there is a wide range of intermediate preservation states. Radiation dating of corals from the Otway margin (Boreen and James, 1993) indicates that material can acquire a chalky, eroded, relict appearance in 4-5,000 years. By 10,000 years, material may be deeply corroded and iron-stained. While susceptibility to corrosion varies between taxa, other shell material is likely to show somewhat similar changes at comparable timescales.

Examination of erosion of biogenic carbonate material from cool-water environments indicates that production of carbonate mud is a significant process. This process has been documented in Bass Strait (Blom and Alsop, 1988). Experimental work by Young and Nelson (1988) has shown that the process occurs through a combination of biological and physical erosion, with bioerosion playing an important role in making the material more susceptible to physical breakdown. Elevated carbonate concentrations in mud fractions of samples, together with extensive evidence of bioerosion and encrustation on biogenic (and some lithic) material (see Fig. 3.24) examined in this study, attest to the importance of this process in Bass Strait. The presence of biogenic activity on shell fragments is not necessarily indicative of age (Farrow and Fyfe, 1988). The extensive development of encrustation reflects the importance of biogenic material as sites for encrusting organisms in shelly substrates (Nebelsick *et al*., 1997).

4.3.1 Habitat Assessment from Video Footage

The utility of video footage in habitat assessment is demonstrated by data collected from NZ Star Bank. The camera showed the seafloor at a coarser scale than sediment sampling, which allows identification and some quantification of biological diversity. This allows juxtaposition of geology

and biology, a relationship that the process of bioregionalisation is attempting to determine. The video footage demonstrated the degree of variability in biota within a small area, as well as between sites. From the preliminary assessment of associated sediment samples it appears that little of this biological variation is reflected in the sediments.
The video footage of the seabed taken of the sediment sample sites provides ground-truthing for the grab samples. The footage reveals a highly diverse fauna located on the reef. This fauna consists of sponges, bryozoans, soft corals, sea whips, crinoids, echinoids, fish, and probably other more 'cryptic' biota. The reef is characterized by a rugged surface that probably aids the creation of a wide range of niches and microhabitats to sustain the diverse range of fauna.

This study shows that there is a strong argument for collecting video (or stills) footage as part of seabed habitat mapping. Small-scale geomorphic features on the scale of <10 m (in this case) can easily be identified using video technologies. Video also reveals the juxtaposition of geology/geomorphology and biology, important in the identification and evaluation of using physical surrogates for habitats. Previous work in this region (Bax and Williams, 2001, and references contained therein) has suggested that hard grounds are increasingly being targeted by commercial fishing, as such features attract fish. Understanding the distributions of features on the seafloor and how their affect biotic diversity in an area is important for fisheries management. Hence, developing methods for mapping and appropriately classifying seafloor features will aid our understanding of the distribution of ocean resources. The integration of video into Geoscience Australia survey programs will be important for benthic habitat mapping.

With access to (or collection) of more extensive marine sediment (or video) data sets it is hoped that accurate maps of sediment and habitat distributions could be developed. This would involve using statistical techniques (such as discriminate analysis, neural networks or others) to extrapolate point data into two dimensions with the aid of multibeam bathymetry (and/or backscatter if available). There are numerous techniques used for performing supervised classification on remotely sensed imagery (multibeam sonar is considered remotely sensed data). For a preliminary overview and application of some of these techniques are described in papers by Miller *et al*. (1995), Davies *et al*. (1997), Muller *et al*. (1997), Allen (1998), Brown *et al*. (1998), Sotheran *et al*. (1997), Goff *et al*. (2000).

The survey of New Zealand Star Bank using multi-beam sonar, surface grabs and sea bed video has provided an excellent opportunity to increase our knowledge on the diversity of habitats in that area. Further work on the data relating evidence of changes in abundances and species composition over the different areas and substrates in relation to swath bathymetry and backscatter data is the subject of PhD research being carried out at the University of Tasmania.

4.4 IMPLICATIONS FOR BIOREGIONALISATION

4.4.1 The Existing IMCRA Bioregionalisation for Bass Strait

The existing IMCRA bioregionalisation for Bass Strait (Interim Marine and Coastal Regionalisation of Australia Technical Group, 1998) was largely based on physiographic and oceanographic data (Hamilton 1994), including bathymetry, slope, roughness, seasonal water temperatures, salinity, oxygen saturation, tidal currents, carbonate concentrations, and percent sand, mud, and gravel. Two different bioregionalisation schemes were produced depending on how the variables were weighted in the multivariate analysis. One emphasised water temperature, the other bathymetry, tidal velocities and substrate type.

These analyses were combined with inshore Victorian and Tasmanian studies to define bioregions for Bass Strait as part of the IMCRA process (Fig. 1.5) (IMCRA Technical Group, 1998). This final scheme confusingly includes offshore areas in some bioregions but not others, based on political rather than physical boundaries. For example, the inshore coasts of central Victoria and central north Tasmania (State controlled waters) are differentiated from the Central Bass Strait Bioregion, but the inshore and offshore areas of eastern and Western Bass Strait are combined into single bioregions (Otway and Twofold Shelf). Longitudinally, the scheme is more accurate, reflecting both the changing water temperature from west to east and different substrate types. It distinguishes the two north-south sills through King and Flinders Islands, from the muddy plain of central Bass Strait.

The biotic patterns generated for this study broadly support the use of water temperature (i.e., longitude) and substrate as gradients that drive some differences in assemblages. While at smaller scales (10-100 km), relationships between biota and sediment appear to be well-correlated (e.g. Kostylev *et al*., 2001; O'Hara, 2001), over the scale of this study such relationships are not clear-cut. This appears to apply both to the biota and to attempts to link biota to physical characteristics. It may be that this is a reflection of the methods used, such as the design of the sampling or the multivariate analysis technique. Other methods of approaching the data analysis, which emphasise grouping of physical data into regions, will be the subject of further research.

4.4.2 Patterns and Scale

Work carried out overseas relies on remote sensing methods, such as acoustic mapping to provide information on seabed character and to identify biological assemblages. In most cases, the detailed sampling needed to establish the nature and distribution of the biota has been carried out either separately or in conjunction with remote sensing studies. Both in Australia and overseas, much of the work carried out has concentrated on small-scale studies (10-100 km). This study is one of the few attempts to link detailed biota and seafloor characteristics over a larger area (100's km). The results indicate that relationships between physical parameters and benthic biota, which are determined at smaller scales, do not necessarily hold true over larger scales.

4.4.3 The Use of Proxies

Few studies have examined the utility of the fossil content as a predictor for biota, although modern assemblages are often used as proxies for interpretation of fossil assemblages (e.g., Murray, 1982). In Bass Strait, the biogenic content of sediment is a poor indicator of living biota. This is due to a number of factors. Firstly, the biota contains high abundances of soft bodied taxa, such as worms, or taxa with hard parts that are not well preserved, such as crabs and ophioroids (brittle stars). Secondly, the absence of biological data on key sediment-producing groups, in particular bryozoa, made detailed comparisons difficult. Third, poorly preserved biogenic material made recognition of modern fauna difficult. Lastly, the effects of post-depositional processes, such as sorting and winnowing, contribute to the poor record of fossil and modern biota. Given the similarities between Bass Strait sediments and those of other areas of the southern margin (Wass *et al*., 1970; James *et al*. 1992; Boreen *et al*., 1993), similar difficulties in interpreting fossils could be expected in sediments from these areas.

Bryozoans, bivalves, and brachiopods are most likely to be useful as environmental indicators, and hence as surrogates for assemblages. Links between bryozoans and environmental parameters have been documented in sedimentological studies elsewhere on Australia's southern margin (James *et al*., 1992; Bone and James, 1993; Hageman *et al*., 1995), and in New Zealand (Nelson *et al*., 1988; Smith and Nelson, 1996; Smith, 1996). In addition, their taphonomy has been studied (Smith, 1995; Smith and Nelson, 1996). An advantage is that environmental interpretation relies on morphology rather than taxonomy.

In this study, the dominant bryozoan forms found (encrusting, erect rigid robust and erect flexible) are consistent with high levels of wave and tidal energy. Fenestrate forms are less abundant than might be expected given their dominance on the Lacepede shelf (Bone and James, 1993). This is probably a reflection of the difference in availability of rocky substrates in Bass Strait. The paucity of the more delicate forms such as delicate branching is also consistent with the high-energy regime. There are no clear patterns of bryozoan distribution with respect to sediment texture. This possibly reflects the use of both modern and intermediate bryozoan material in the interpretation of distribution. Further analysis of bryozoan distribution in conjunction with studies of the influence of waves and tides on sediment composition and texture might prove useful, but should be based on modern bryozoan material.

Bivalves from the Tasmanian continental shelf were studied in detail by Jones & Davies (1983), with a wide variety of species recorded. Bivalves form a major constituent of the sediments in Bass Strait, and include a variety of species. The presence of relatively well-preserved juveniles in some samples indicates that taxa are *in-situ*; however, identification of modern material in some sediment facies is likely to be a problem. Biological data were not available in this study. Should this data become available in future, then further investigation would be warranted, particularly as bivalves make up a significant proportion of the biological component of sediment across a range of Australia's continental shelf environments (e.g., Ferland and Roy, 1997).

In contrast to the other two groups, data on living brachiopods is available. Several species occurring in sandy substrates of the southern Australian shelf have been documented (Richardson, 1987). The map of brachiopod distribution shows there is some similarity between the distribution of living material and that of fossil material in the sediments (Fig. 3.29). However, correlation of the two sample sets is difficult, as sediment samples were not available for all sites in which living material was found and only representative sub samples of sand fractions were picked. In fact, the main issue affecting their applicability as surrogates is their low abundance. To gain a reasonable indication of their presence in sediments, it would be necessary to examine the bulk sample including all size fractions.

4.5 FUTURE APPROACHES TO BIOREGIONAL STUDIES

4.5.1 Approaches to Survey Design

Future bioregional research requires a research design that is appropriate to the spatial scale of the bioregions. Bioregions are defined as geographic areas at scales of 100's-1000 km that have distinct broad-scale biophysical processes (Ferns *et al.* 2000).

Two research designs are appropriate for future bioregionalisation studies in Bass Strait. Both designs emphasise large-scale variation over small-scale habitat changes.

4.5.1.1 Geospatial approach

A geospatial approach involves dividing Bass Strait into equal area cells or polygons and then sampling consistently in each cell or polygon. Replicates (5-10) would also be taken, and then aggregated either by simple addition or averaging of the abundance of each species (e.g., using the 'centroid' approach of Underwood and Chapman, 1998) to overcome biases associated with small-scale variations.

This approach matches a geospatial-sampling regime with the goal of defining geospatial regions. However, the cost of sampling and identification may be prohibitive depending on the size of the polygons. Ideally, the polygons would be one to two orders of magnitude smaller than the average size of a bioregion. Moreover, it is not certain that any resulting meso-scale assemblage distributions will be geographically continuous. The result may still not be mappable.

4.5.1.2 Two-tiered Approach

The second approach is to partition the biogeographic data (species area of occurrence or range) from the meso-scale habitat data (variation in species abundance or areas of occupancy within their range). Using this approach, bioregions would be defined using only species range data, with meso-scale environmental changes used to map habitats as a separate layer within each bioregion. Bioregions would then reflect wide-scale species turnover as distinct from small-scale variation in abundance.

The IMCRA bioregions incorporate information about species distributions at two separate scales. Firstly, they incorporate information about species area of occurrence (their overall range), which is limited by large-scale environmental differences such as changes in seawater temperature, water depth, or major discontinuities in habitat. This is sometimes known as gamma diversity. Secondly they incorporate information about variation in species distributions within their range, which are related to meso-scale changes in habitat or environmental variables such as sediments or water movement. This is sometimes known as beta (or within-habitat) diversity.

Species range data can be compiled from existing sources, and, if existing collection effort is not geographically consistent, by additional sampling across Bass Strait for those species that are spatially restricted. The results can be plotted on a grid and analysed using multivariate or geospatial statistics to determine bioregional boundaries. O’Hara and Poore (2000) have analysed species distribution data for echinoderms and decapods for the entire southern Australian coastline using multivariate methods. However, they used cell sizes of approximately one degree latitude/longitude which is insufficient for a detailed bioregionalisation of Bass Strait so a smaller scale would need to be implemented.

Once the bioregions have been established, habitats can be mapped within each bioregion. Habitats can be defined by linking (preferably mappable) environmental changes to changes in assemblage composition. This does not need to be done for each polygon, but could be established through pilot studies at several replicate sites. Habitats established in this way can then act as surrogates of biodiversity within each bioregion.

For sediments it is important to test the applicability of bulk grain size distribution as a biodiversity surrogate. Whether the sediment is mainly sand or mud is important for infaunal animals. However, the percent gravel may act as a surrogate for potential for sessile invertebrates (e.g. sponge gardens) to form colonies.

The advantage of this two-tiered approach is that it doesn’t require a comprehensive replicated sampling regime. It also emphasises the distribution of rare (low abundance and narrowly distributed) species compared to the geospatial sampling approach that favours common species.

The disadvantage is that it does not recognise large-scale areas of a single habitat. However, although these large-scale areas may occur on land (e.g. mallee, desert, alps), habitats appear to be fragmented in the sea at a smaller spatial scale, at least within the regions examined for this study. Evidence from video footage of the seabed indicates that a high degree of variability in both habitats and biota over small spatial scales in Bass Strait.

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