Ningaloo Reef Marine Park Benthic Biodiversity Survey

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EXECUTIVE SUMMARY

Site-specific studies of geophysical characterisation or mapping of near-shore benthic habitats are few and have only recently been developed to help guide managers in the appropriate placement of Marine Protected Areas (MPAs). The primary criteria identified for establishing MPAs are that they contain a comprehensive, adequate and representative (CAR) sample of marine biodiversity (Jordan et al. 2005). Comprehensive with regards to the extent to which the full range of ecosystems and habitats are included in MPAs; adequate with regard to the degree to which the size, boundaries and location of MPAs are adequate to maintain biodiversity and ecological patterns and processes, especially in relation to the ability to manage impacting activities; and representative with regard to the extent to which MPAs reflect the range of biological diversity of communities within ecosystems and habitats (Jordan et al. 2005). Ideally the representative protection of marine biota in Australia would be based upon extensive knowledge of the distribution of biota and ecosystem components (Post 2006).

Choosing the most suitable mapping method from a suite of techniques, depends on the objective(s) of each project, particularly with respect to the scale and distribution of the sea floor features of interest, and the required resolution of the resulting maps (Diaz et al. 2004). The application of acoustic technologies to sea floor mapping has enabled effective collection of data on sea floor substrata and has led many mapping studies to equate benthic habitat with bottom sediment or substratum type (Ball et al. 2006).

Ningaloo Marine Park (NMP) is situated on the northern extremity of the Dirk Hartog Shelf of Western Australia and extends 260 km west of Cape Range peninsula from Point Murat near North West Cape south to Amherst Point, beyond Coral Bay (21°50'S to 23°35'S) encompassing most of Ningaloo Reef (Carrigy and Fairbridge 1954; LeProvost Dames and Moore 2000). The submarine shelf is gently sloping underlain by Pleistocene limestone with a veneer of marine sediments and interrupting this shelf, a fringing barrier reef system (Carrigy and Fairbridge 1954). One of the major features of NMP is the bathymetry which sees a very rapid drop-off in bottom depth in the northern part of the Marine Park in front of Cape Range (LeProvost Dames and Moore 2000). This results in a narrow shelf with its landward edge unusually close to the shore, i.e. between Point Cloates and Jurabi Point, depths of 100m occur within 6 km of the shore and 500 m within 15 km, which brings oceanic species like whales and pelagic fish to come relatively close to shore (LeProvost Dames and Moore 2000). At the southern part of NMP the shelf broadens to greater than 30 km near Amherst Point (LeProvost Dames and Moore 2000). The location and morphology of the reef environments has a critical relationship with the oceanography within and surrounding the marine reserves and the complex intertidal and subtidal geomorphology of the reserves plays a significant role in the variety of marine habitat types and correspondingly high species diversity.

Previous studies suggest the substrate of the deeper waters of the northern NMP in general consists of a varying veneer of sand overlying limestone with a predominant sessile flora and fauna of algae and sponges with a diverse mobile crustacean and mollusc fauna (LeProvost Dames and Moore 2000). The Western Australian Museum (1988) discovered that the bottom fauna in waters >40 m is dominated by sponges; however, the sponge assemblages have never been systematically examined.

The aims of the project are to develop broadscale habitat maps of the deepwater component of NMP (offshore of the fringing reef), in the context of providing surrogate information for broadscale biodiversity assessments; undertake a broadscale characterisation of the biodiversity of the deepwater habitats of NMP based on historical information and that to be provided through deepwater broadscale habitat mapping; characterise the diversity and abundance of filter feeding communities in NMP, especially in the deeper waters; characterise the surficial sediments and seabed geomorphology of the deeper waters of NMP; and characterise finfish diversity and abundance in the deeper waters of NMP and support the development of management targets for commercially and recreationally targeted species.

In April/May 2006 the Australian Institute of Marine Science (AIMS), in conjunction with FUGRO SURVEY PTY LTD, the Western Australian Museum and students from the University of Western Australia (UWA) and Curtin University of Technology (CUT), initiated surveys in the northern part of NMP to develop broadscale habitat maps of the deepwater component of the reserves (offshore of the fringing reef), identify the species present, and describe their basic patterns of distribution (Barnes et al. 2006).

Broadscale bathymetry of the continental shelf adjacent to the northern part of NMP was examined prior to the survey. The 2004 AIMS study (Rees et al. 2004) and Faircopy nautical charts supplied under licence by the Australian Hydrographic Office of the Royal Australian Navy (RAN) to the Applied Sedimentology and Marine Geoscience Group Department of Applied Geology Curtin University of Technology, and a fine scale multibeam hydro acoustic survey carried out by Fugro Survey Pty Ltd (FUGRO) on behalf of AIMS were the primary tools used prior to this survey to identify areas of bathymetric, topographical, benthic and piscatorial interest in areas with different levels of conservation protection. A singlebeam hydro acoustic survey carried out by the Centre of Marine Science and Technology (CMST) at CUT was used to gather data during the survey to identify areas of interest for sampling.

A towed video system, stereo baited underwater video systems (stereo-BRUVs) and a benthic sled were used to sample the biodiversity, diversity and abundance of filter feeding communities, finfish and invertebrate diversity and abundance. Single and multibeam acoustic surveys and sediment grabs were used to investigate and sample surficial sediments and seabed geomorphology of the deeper waters of NMP. No nautical charts for the southern part of the NMP exist so this approach will need to be modified for the 2007 survey.

Bathymetry and backscatter data from the multibeam was input into ESRI ArcGIS™ software to form the base map layer for the area surveyed. This allowed for detailed visual analysis of the survey area. The singlebeam and multibeam acoustics achieved during the 2006 survey has provided detail of the seafloor in a limited area of NMP (Figure 3). Different habitats, based on bathymetry and geomorphology could be distinguished within this area. Sediment generation, transport and deposition patterns were evident, ridge systems could be identified and patches of previously unknown rubble mounds were evident. A considerable amount of spatial detail was gained. Acoustics combined with sedimentological and geomorphological data enabled us to categorise different habitats according to depth, topography, substrate stability, hardness and roughness, grain size and suitability to support significant biota, from the back of the reef slop (beyond the fringing reef) out to the edge of the continental shelf plateau.

The continental shelf within the northern NMP is narrow and preliminary results show a clear zonation of habitats across the shelf. There is a strong association between geomorphology and benthic habitats with communities taking advantage of the availability of Last Interglacial substrates composed of fossilised limestone. Substrata in the shallow reef slope zone consist of a thin veneer of Holocene coralgal growth. In the 30-40 m zone hard corals rapidly disappear, gradually replaced by a mixed deep-water benthic community dominated by sponges, crinoids, turf algae and *Halimeda*, with some soft corals (gorgonians, sea whips), ascidians and sea pens. There is an extensive middle shelf sand plain where sediment thickness is variable overlying limestone pavement and low relief systems. Here communities of sponges, crinoids, sea pens, sea whips and hydroids are patchy with higher abundance associated with hard substrates. Bioturbation was evident from echinoderm feeding traces, polychaetes and burrowing fish and a diverse infauna have reworked the sediments to build mounds and burrows. Large ridges have been identified at various depths with an extensive system on the outer shelf (75-125 m). Exposed limestone substrates are dominated by sponge and gorgonian gardens, some of the sponges and gorgonian sampled from these gardens are likely to be new species. In the Cloates Sancturary Zone (SZ) fossil reefs support a diverse coralgal and sponge community. Here corals persist to greater depths (40-50 m) than those observed further north in the NMP.

Towed video allowed us to detect and target different benthic communities so species and functional groups could be identified and their distribution, abundance, biomass and size composition investigated. Analysis of towed video identified seven broad habitats, six substrata and sixteen different benthos categories. Further analysis will investigate percent cover of habitat, substrate and benthos for each tow, the relationship with water depth and the relationship between consolidated and non consolidated substrata and different benthos categories.

Preliminary identification (ID) of the dominant benthos (sponges and soft corals) has started at the West Australian Museum and further IDs will include digital photographs and analysis of dominant sponge spicule preparations, sponge and soft coral *in situ* and specimen ID digital photographs. These will be input into the ArcGIS software to create an interactive interface correlated to date, time, position and depth. Future analysis will also include biomass estimates of the dominant benthos using weight as a surrogate measure.

The Geographical Information System (GIS) layers generated include high resolution aerial mosaics, marine and shoreline habitat information and coastal outlines and marine fauna observations. From the April/May 2006 data survey, the acoustic data has been included as both point and raster (gridded) GIS datasets. Other layers include demersal fish assemblages surveyed and benthic habitat data using stereo-BRUVS and towed video. ArcGIS point shape file have been created for these with attributes including date, time, and operational code for each camera deployment. Video samples from each deployment have also been added as an attribute to utilise the hyperlink functionality of ArcMap. Point and line shape files showing the start/end point and track for each benthic sled tow and still images from samples acquired will be attached using the hyperlink technique. Sediment grab data included point shape file showing date, time, operational code and locations of each grab. Grain size will be displayed for each sample taken.

The Stereo-BRUVS survey identified 319 species of finfish from 54 families and analysis suggests the stereo-BRUVS have underestimated overall species richness for both commonly encountered and rare species. The same habitats at different depths were often associated with significantly different fish fauna. Coral reefs in 15-30 m supported a different fish assemblage to those in 30-50 m. Fish assemblages in rhodolith habitat in 30-50 m were significantly different to those at 50-70 m. Fish assemblages associated with sand habitat differed between all depth ranges with the exception of 30-50 and 50-70 m depths. Likewise, fish fauna found in sponge habitat at 90+ m were different to those found at both 50-70 and 70-90 m depths. Rhodolith habitat supported similar fish assemblages across all depth ranges with the exception of those found in the midshelf depths of 30-50-70 m. Sponge and sand habitat supported similar fish assemblages between 50-70-90 m depths. Further analysis of relative abundance and size frequency will be carried out using newly developed software.

Significant findings of this survey included diverse sponge and soft coral communities in the deeper waters of the continental shelf (50-110 m) with potentially high and unique biodiversity values, two large rigid systems parallel to the coastline supporting a vast array of species with diverse piscatorial associations, and several patches of previously unknown and unidentified rubble mounds. Low species diversity in the areas behind the back reef may be due to sediment transport and deposition, whereas, areas in deep water closer to the NMP seaward boundary with more stable sediments are inhabited by diverse benthic assemblages. Few hard corals were evident beyond 40-50 m during the survey. Large sand and rhodolith habitats were also evident.

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INTRODUCTION

The area between the lowest tides down to the edges of the continental shelf is one of the most productive zones in the sea (Burke et al. 2001). Light typically penetrates 50-100 m but can reach below 200 m in clear oceanic waters, supporting benthic as well as planktonic photosynthesis (Burke et al. 2001). Inputs of organic and inorganic materials from adjacent land areas further enhance such productivity (Burke et al. 2001). Site-specific studies of geophysical characterization or mapping of near-shore benthic habitats are few and have only recently been developed to help guide managers in the appropriate placement of Marine Protected Areas (MPAs).

The primary criteria identified for establishing MPAs are that they contain a comprehensive, adequate and representative (CAR) sample of marine biodiversity (Jordan et al. 2005). Comprehensive with regards to the extent to which the full range of ecosystems and habitats are included in MPAs; adequate with regard to the degree to which the size, boundaries and location of MPAs are adequate to maintain biodiversity and ecological patterns and processes, especially in relation to the ability to manage impacting activities; and representative with regard to the extent to which MPAs reflect the range of biological diversity of communities within ecosystems and habitats (Jordan et al. 2005).

In broad outline, the global distribution of marine biodiversity has been established. Theory, however, to account for these patterns generally lacks explanatory power especially at scales of 100's to 1000's of kms (Roff et al. 2003). There has been a lack of investigations into relationships between biodiversity and habitat characteristics (through geophysical factors) at such scales, yet it is at this scale that nations exert jurisdiction over their marine resources and can best effect conservation measures (Roff et al. 2003). Zacharias and Roff (2001b) showed that intertidal diversity was strongly related to the geophysical environment, as a function of seasonal variations of temperature, salinity and exposure to wave action. These types of analyses between biodiversity and geophysical factors are vital to systematically implemented conservation efforts at these scales.

Seabed habitat mapping is increasingly being used to identify the distribution and structure of marine ecosystems and as surrogate measures of biodiversity for MPA planning (Jordan et al. 2005). The representative protection of marine biota in Australia would ideally be based upon extensive knowledge of the distribution of biota and ecosystem components (Post 2006). Identifying and protecting all habitats is an essential objective for a network of reserves (Roberts et al. 2003). Optimal placement of MPAs requires identification of the range of habitats used by species of concern, determination of their demographic rates in these habitats and comparisons of species abundances over a broad range of habitats (Eggleston and Dahlgren 2001). Such information, however, is not always readily available. Habitat heterogeneity, acting as a proxy for maximizing the number of species protected, can be used in its place to guide the selection of individual reserve units (Roberts et al. 2003). For example, as the number of habitats increases at a site, the site becomes more heterogeneous and so does its value as a reserve (Roberts et al. 2003).

Choosing the most suitable mapping method, out of the many techniques available depends on the objective(s) of each project, particularly with respect to the scale and distribution of the sea floor features of interest and the required resolution of the resulting maps (Diaz et al. 2004). The application of acoustic technologies to sea floor mapping has enabled effective collection of data on sea floor substrata and has led many mapping studies to equate benthic habitat with bottom sediment or substratum type (Ball et al. 2006). This approach to mapping emphasises the concept of benthic habitat as a ‘dwelling place’ or ‘preferred substratum’ for biota, from species to entire communities, with the biota representing a form of cover overlying the physical bottom features (Ball et al. 2006). This approach can be limiting, however as many such studies also include biological sampling or observations (e.g. underwater video) to verify and identify presumed connections between physical characteristics and distribution of biota (Ball et al. 2006).

Ningaloo Marine Park

Ningaloo Marine Park (NMP) is situated on the northern extremity of the Dirk Hartog Shelf of Western Australia and extends 260 km west of Cape Range peninsula from Point Murat near North West Cape south to Amherst Point, beyond Coral Bay (21°50'S to 23°35'S) encompassing most of Ningaloo Reef (Carrigy and Fairbridge 1954; LeProvost Dames and Moore 2000). The submarine shelf is gently sloping underlain by Pleistocene limestone with a veneer of marine sediments and interrupting this shelf, a fringing barrier reef system (Carrigy and Fairbridge 1954). One of the major features of NMP is the bathymetry which sees a very rapid drop-off in bottom depth in the northern part of the Marine Park in front of Cape Range (LeProvost Dames and Moore 2000). This results in a narrow shelf with its landward edge unusually close to the shore, i.e. between Point Cloates and Jurabi Point, depths of 100m occur within 6 km of the shore and 500 m within 15 km, which brings oceanic species like whales and pelagic fish to come relatively close to shore (LeProvost Dames and Moore 2000). At the southern part of NMP the shelf broadens to greater than 30 km near Amherst Point (LeProvost Dames and Moore 2000). The location and morphology of the reef environments has a critical relationship with the oceanography within and surrounding the marine reserves and the complex intertidal and subtidal geomorphology of the reserves plays a significant role in the variety of marine habitat types and correspondingly high species diversity.

NMP includes area under Commonwealth (2,326 km^2) and State (2,240 km2) jurisdiction (Fig. 1) and covers a total area of 4,566 km^2 from the shoreline to the continental slope. The State jurisdiction extends 5.5 km seaward of the outer edge of the reef crest and comprises the narrow terrestrial strip from Amherst Point to Winderabandi Point, the fringing reef, and back reef lagoon adjacent to the land and 5.5 km seaward of the reef crest. Seaward of the State waters are Commonwealth waters that extend a further 6 to 15 km, widening to the south of Point Cloates.

Ningaloo Reef forms a discontinuous barrier enclosing a shallow, narrow lagoon (2 to 4 m depth) varying in width from 200 m to more than 7 km (MPRA CALM CCPAC. 2005). From the reef crest seaward, the reef drops gently from 8 to 10 m depth and then gently to 100 m approximately 5 to 6 km from the reef edge. Ningaloo Reef is a unique fringing reef, the largest in Australia and among the longest fringing corals reefs in the world (MPRA CALM CCPAC 2005). Ningaloo Reef is one of the most biologically diverse shallow water marine ecosystems in the world. It is also a marine biodiversity hotspot. Little, however, is known about the benthic habitats and communities in the deeper waters (>20 m) beyond the fringing reef which makes up the majority of the marine parks 4,566 km^2. Roberts et al. (2002) identified the NW Cape and Ningaloo Region as one of the 18 richest multi-taxon centres of endemism. Many coral reef taxa have restricted ranges, and are clustered into centres of endemism, making them vulnerable to extinction (Roberts et al. 2002). The paucity of knowledge about seabed biodiversity in the intermediate and deeper waters of the NMP has been recognised since its inception in 1987.

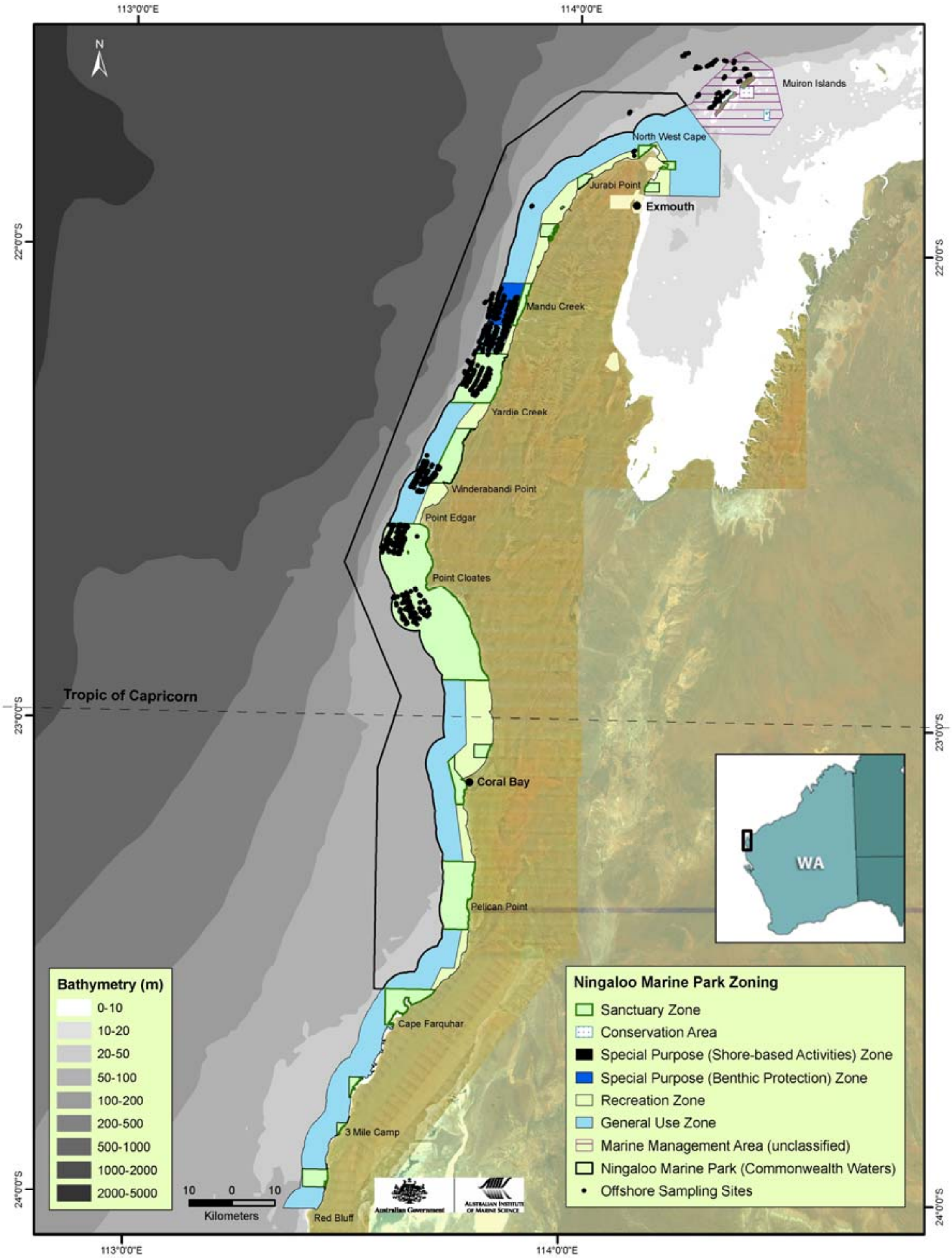

Figure 1. Map of Ningaloo Marine Park and Muiron Island Marine Management Area zoning, deepwater bathymetry and all the benthic offshore sampling sites.

Dominant Benthic Communities

Due to the logistical constraints sampling benthos in deeper waters of the NMP (20-110 m), few studies have investigated the major species/functional groups that make up the major benthic communities and the geomorphology/surficial sediments underpinning these communities on the scale of this investigation, especially in the southern part of the Shelf (Carrigy and Fairbridge 1954; Wilson 1972; Western Australian Museum 1988; Rees et al. 2004). Previous studies suggest that the substrate of the deeper waters of the northern NMP consist, in general of a varying veneer of sand overlying limestone with a predominant sessile flora and fauna of algae and sponges with a diverse mobile crustacean and mollusc fauna (LeProvost Dames and Moore 2000). The Western Australian Museum (1988) discovered that the bottom fauna in waters >40 m is dominated by sponges; however the sponge assemblages have never been systematically examined.

Biodiversity analyses of Australian tropical fauna, at smaller intra-regional spatial scales, indicate that sponges frequently form spatially heterogeneous assemblages with patchy distributions in deeper waters of the NMP (Wörheide et al. 2005). These assemblages often contain high numbers of species not found in adjacent communities (i.e. apparent endemics), sometimes with as little as 15% similarity in species composition (Wörheide et al. 2005). Studies of cross-shelf distributions have shown certain environmental variables to be linked to community heterogeneity, most notably light, depth, substrate quality and nature such as coralline vs. non-coralline, hard vs. soft substrata, local reef geomorphology indicative of the presence or absence of specialised niches, water quality and flow regimes, food particle size availability, and larval recruitment and survival (Wörheide et al. 2005).

Marine sponges are a highly diverse group with global diversity estimated to be approximately 15,000 species, of which about 7000 are currently known (Hooper and Weidenmayer 1994; Hooper and van Soest 2002). Marine sponges provide shelter and food for many other sessile and mobile organisms, are major contributors to nutrient and chemical exchange with the water column, and are important economically for the production of novel chemical substances for biomedical research and public health (Fromont et al. 2006).

Sponges are old and diverse metazoans, with complex distributional patterns, environmental requirements, and types of reproduction (de Voogd et al. 2006). Sponges are considered taxonomically difficult, and as a result, are poorly documented in many regions of the world (Fromont et al. 2006). The unresolved taxonomy of many sponges has hampered studies of sponge ecology, and few studies have addressed sponge distribution and biodiversity (de Voogd et al. 2006). It appears there is a significant difference in species composition from the Dampier Archipelago region to the north and the NMP (Fromont pers. comm. 2006). Quantifying the spatial patterns of sponges is important for understanding the factors that most influence their distribution and abundance. Due to a lack of surveys on similar water depths to the north and south of the NMP, and unresolved taxonomy of sponge communities generally, it is difficult to determine the biogeographic relationships of the deepwater Ningaloo biota (WA Museum 2006). It is imperative to describe existing natural patterns of species distribution and abundance in the NMP so that changes to biodiversity can be quantified in the future.

Project Aims

The aims of the project are:

- To develop broadscale habitat maps of the deepwater component of the NMP (offshore of the fringing reef), in the context of providing surrogate information for broadscale biodiversity assessments.
- Undertake a broadscale characterisation of the biodiversity of the deepwater habitats of the NMP based on historical information and information to be provided through deepwater broadscale habitat mapping as part of this study.
- Characterise the diversity and abundance of filter feeding communities in the NMP, especially in its deeper waters.
- Characterise the surficial sediments and seabed geomorphology of the deeper waters of the NMP.
- Characterise finfish diversity and abundance in the deeper waters of the NMP and support the development of management targets for commercially and recreationally targeted species.

2006 Survey

In April/May 2006 the Australian Institute of Marine Science (AIMS), in conjunction with FUGRO SURVEY PTY LTD, the Western Australian Museum, and students from the University of Western Australia (UWA) and Curtin University of Technology (CUT), initiated surveys in the northern part of the NMP to develop broadscale habitat maps of the deepwater component of the reserves (offshore of the fringing reef), identify the species present, and describe their basic patterns of distribution (Barnes et al. 2006). Due to the size of the NMP the sampling effort will be spread over three years with the 2006 survey focusing on the northern part of the park (Fig. 1). Different methods with varying degrees of resolution were used and will continue to be used in the subsequent surveys. The focal point of the biodiversity survey was benthic habitats in depth strata between 20 and 110 m in all the regions surveyed. All the surveys were conducted on the AIMS research vessel RV Cape Ferguson.

METHOD AND DESIGN

A previous survey by AIMS in 2004 focused on Mandu, Point Cloates and Point Maud to test the spatial variation of benthic communities along a north-south gradient at a range of spatial scales and depths in both the NMP and adjacent Commonwealth waters (Rees et al. 2004). Broadscale bathymetry of the continental shelf adjacent to the northern part of the NMP was examined prior to this survey. The 2004 AIMS study and Faircopy nautical charts supplied under licence by the Australian Hydrographic Office of the Royal Australian Navy (RAN) to the Applied Sedimentology and Marine Geoscience Group Department of Applied Geology Curtin University of Technology and a fine scale multibeam hydro acoustic survey carried out by Fugro Survey Pty Ltd (FUGRO) on behalf of AIMS were the primary tools used prior to the survey to identify areas of bathymetric, topographical, benthic and piscatorial interest in areas with different levels of conservation protection. A singlebeam hydro acoustic survey carried out by the Centre of Marine Science and Technology (CMST) at CUT was used to gather data during the survey to identify areas of interest for sampling.

Historical sounding data from RAN was digitised as 55,000 points within ESRI ArcGIS™ (v9) software to create XYZ (latitude/longitude/depth) data. The resulting bathymetry was examined by interpolation using an inverse distance weighting algorithm and a Triangular Irregular Network (TIN) created within ArcGIS 3D Analyst (Fig. 2). The models were viewed within ArcGIS and the boat position was tracked using a Differential Global Positioning System (DGPS) to allow live onboard spatial analysis.

The creation of bathymetric models and contour maps allowed the identification of geomorphic features, such as offshore ridge systems of structural and piscatorial interest at different depth contours which were targeted during habitat, fish and geomorphologic sampling programs. The data gathered and synthesised from the multibeam and singlebeam surveys will form the base layer of the habitat maps for the deeper waters of the northern part of the NMP.

A towed video system, baited underwater stereo video systems (stereo-BRUVs) and a benthic sled were used to sample the biodiversity, diversity and abundance of filter feeding communities, finfish and invertebrate diversity and abundance. The single and multibeam acoustic surveys and sediment grabs were used to sample surficial sediments and seabed geomorphology of the deeper waters of the NMP. No nautical charts for the southern part of the NMP exist so this approach will need to be modified for the 2007 survey.

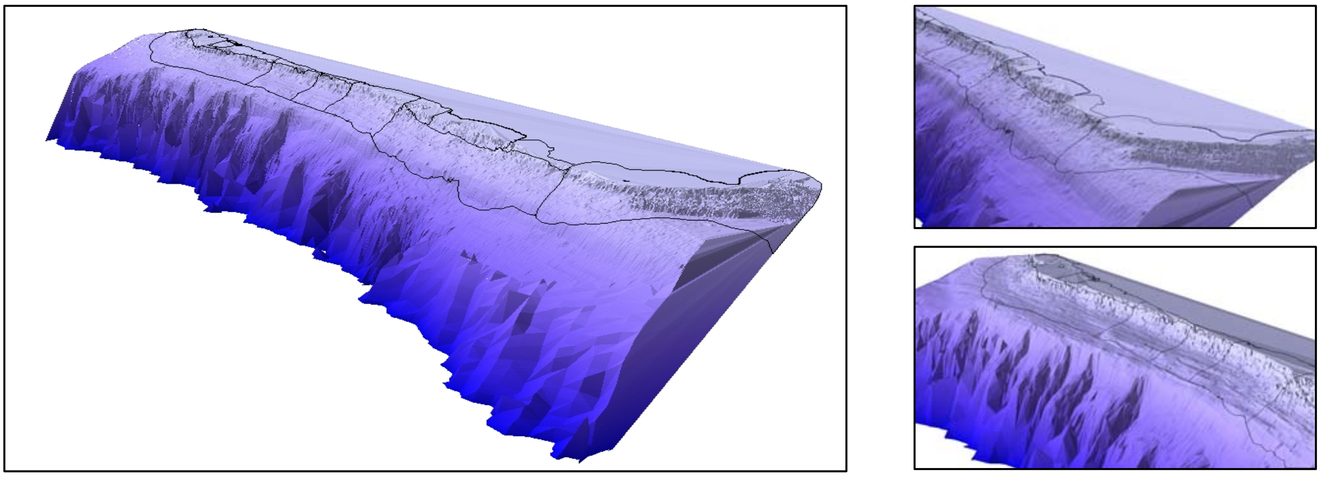

Figure 2. 3D TIN (Triangular Irregular Network) model of bathymetry in the northern Ningaloo Marine Park from Point Cloates in the south to Tantabiddi in the north with sanctuary zones overlaid.

ACOUSTIC SURVEYS

FUGRO Habitat Mapping Hydro Acoustic Survey (Multibeam) 10-18 April 2006

Marine survey specialists FUGRO were contracted to conduct a habitat mapping hydro acoustic survey covering three distinct areas of the NMP in close proximity to each other; Osprey, Boat Passage and Mandu (Fig. 3).

The Multibeam survey was limited to three regions (Fig. 3) due to cost constraints and the need for a preliminary assessment of the results from this particular survey technique. The survey was carried out onboard the AIMS Research Vessel RV Cape Ferguson. This survey provides detailed seafloor raster imagery of both bathymetry (shape) and backscatter (texture) to enable the preparation of high resolution habitat maps of the areas surveyed. Reson Seabat 8101 Multibeam sonar was used and configured to output snippet backscatter data, which permits a geo-referenced textured map to be generated across the survey area. Complete coverage was achieved in the Osprey and Boat Passage regions, however due to time, weather and safety constraints, only the near shore portions of the Mandu region were surveyed (Fig. 3).

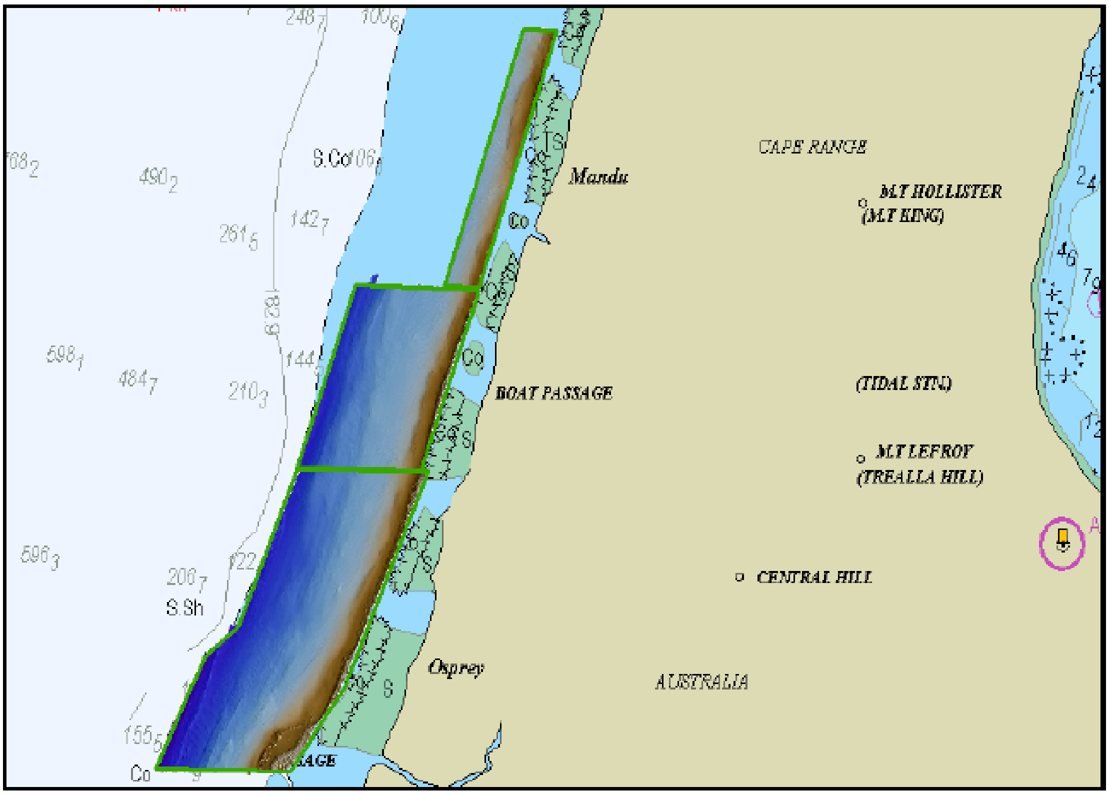

Figure 3. Broadscale bathymetry overview of FUGROs hydro acoustic survey 2006 for the northern part of NMP

The bathymetry and backscatter data was rasterised using a mean gridded depth algorithm and rendered at a 2.5 m interval. The data are presented in ESRI ASCII grid file format allowing easy integration into the ESRI ArcGIS platform, and many other GIS/CAD environments. Coordinates are referenced to the Geocentric Datum of Australia 1994 (GDA94). Both bathymetry and backscatter data from the multibeam survey showed detailed distribution of sedimentary bed-forms, such as sand ripples, sand waves, mega ripples, sand ridges, and reef structures, such as drowned reefs and channels. The multibeam data allows us to characterise and classify the seafloor in terms relevant to the distribution of benthic habitats and help us understand the spatial and temporal distribution and dynamics of the deep water marine environment of the NMP (Figs. 3; GIS Database AIMS 2007). The combination of topography and textural surfaces provide an excellent reference dataset for research and management of the NMP. The bathymetry and backscatter data was input into ESRI ArcGIS™ software to form the base map layer for the area surveyed. This allowed for detailed visual analysis of the area surveyed. Unusual large gravel mound fields, sponge and soft coral communities, rhodolith beds, fore reef habitat and sand dominated habitats were identified and will be ground-truthed in the 2007/2008 surveys.

Even though the multibeam survey was limited to a relatively small area, the detail it provides will allow us to compare and contrast the methods used in this surveywith other methods proposed for other areas of the park. The complete FUGRO Report for the Ningaloo Habitat Mapping Marine Hydro Acoustic Survey (Operations and Results) is provided in Appendix 1.2 (Electronic PDF).

Singlebeam Acoustic Survey

With the assistance of the CMST CUT, two areas in the Cloates Sanctuary Zone (SZ) (mid and north), one area in the Mandu SZ, one reference area outside the Cloates SZ, and a reference area outside the Osprey SZ were surveyed in transects using a Simrad EQ60 Singlebeam echo-sounder providing cross and along shelf profiles for each surveyed area (Fig 4, Appendix 1.1). Detailed soundings with dates, times and coordinates (latitude and longitude) were recorded for each area (Appendix 1.1)

Preliminary onboard processing of singlebeam acoustic backscatter data for the Mandu area displayed differences in seabed acoustic roughness (irregularities in topography – E1) and hardness (type of substrate – E2) aiding in the identification of broadscale habitats for sampling (Fig 5 & 6). The backscatter (Sv) values from the transect data were examined using Nearest Neighbour Interpolation within ESRI ArcGIS™ Spatial Analyst Tool. Further processing of the backscatter data, currently underway, will aid in the preparation of broadscale marine habitat maps of the areas surveyed, and provide surrogate information for additional broadscale biodiversity assessments.

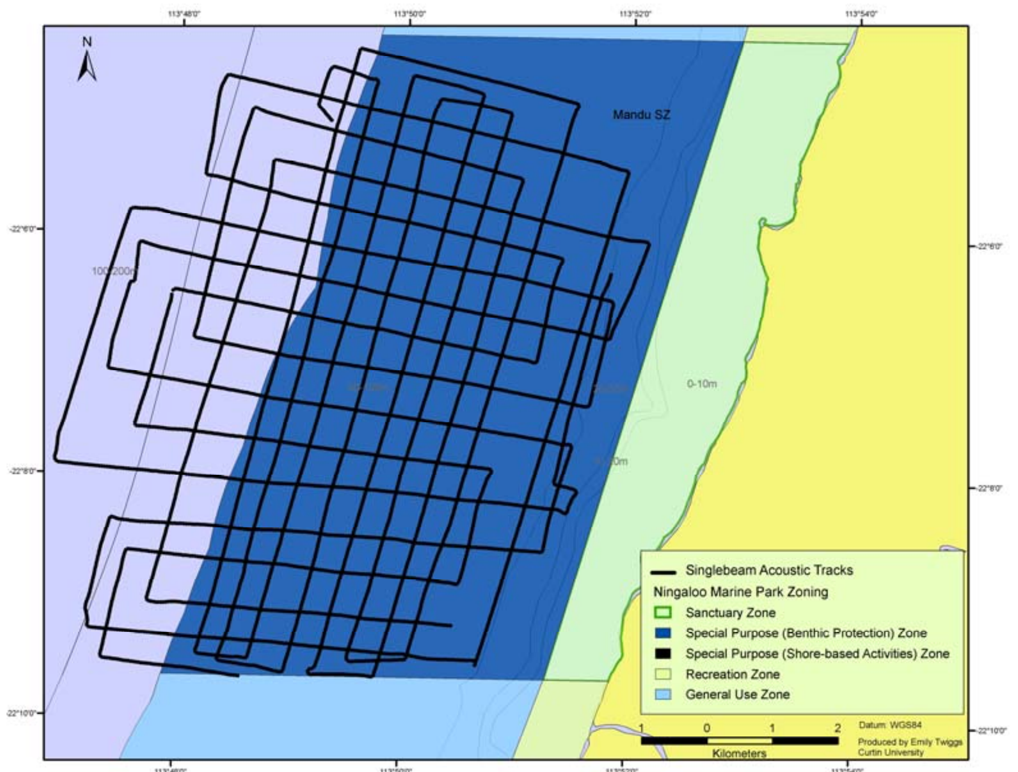

Figure 4. Singlebeam acoustic tracks for the Mandu area

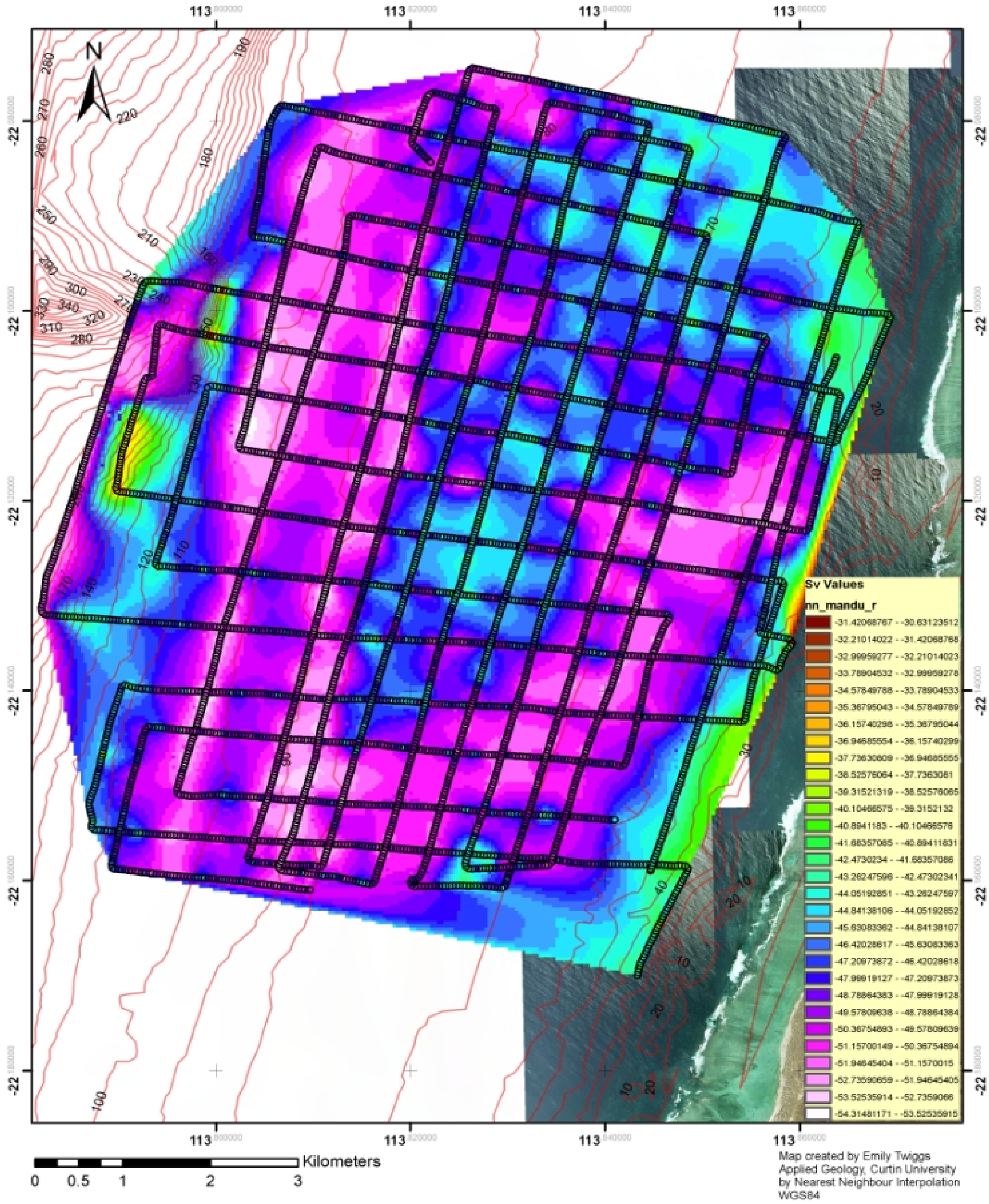

Figure 5. Mapped Roughness (E1) values for Mandu Sanctuary Zone.

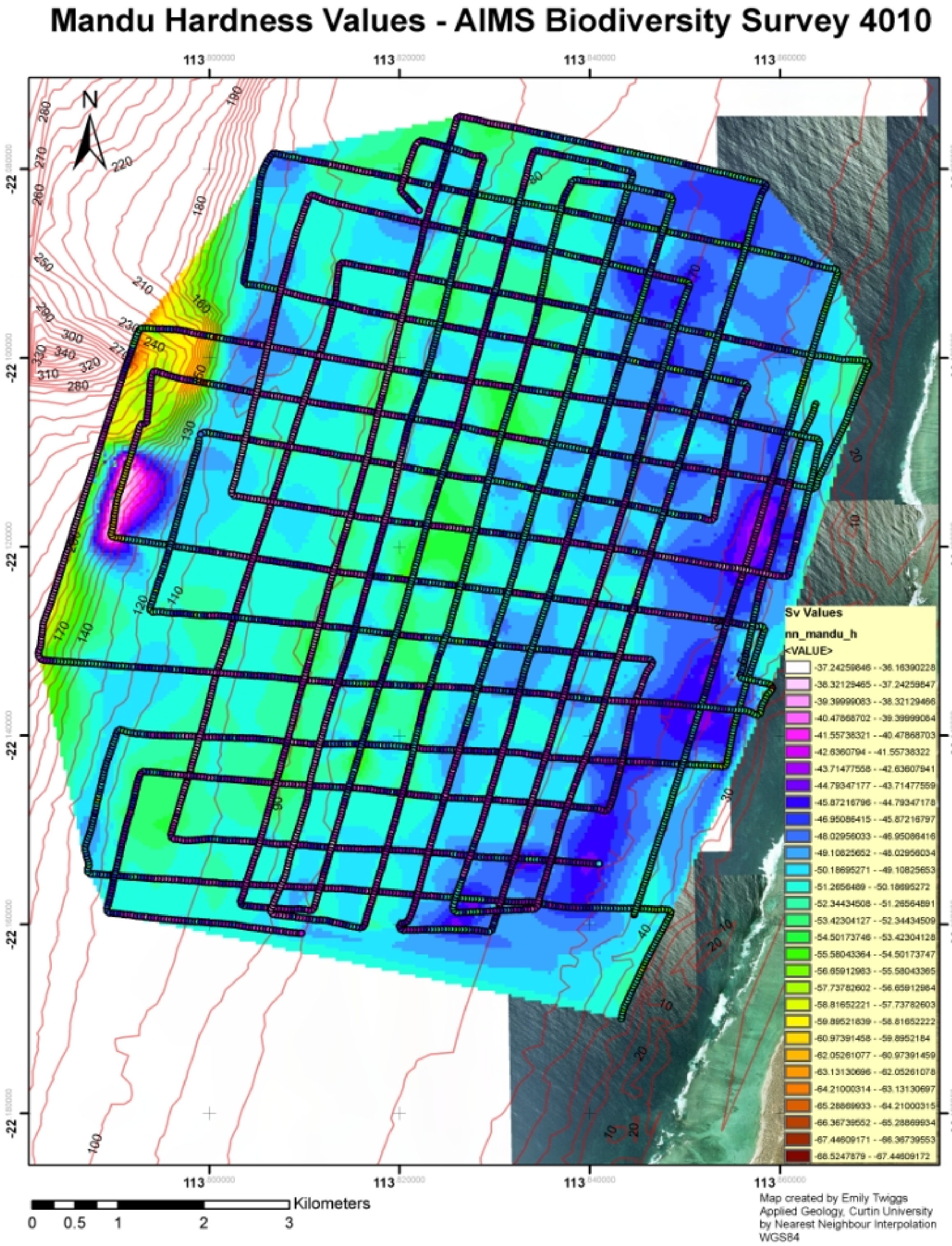

Figure 6. Mapped Hardness (E2) values for Mandu Sanctuary Zone.

GEOMORPHOLOGY AND SEDIMENTS

Long Term Goal

Geological and sedimentological data are to be consolidated into a Geographic Information System (GIS) to aid in the production of geomorphic, sedimentary facies and benthic habitat maps of the continental shelf of the NMP. Habitat maps will provide stakeholders, managers, regulators and policy makers with crucial georeferenced information that will aid in the conservation, preservation and sustainable use of the NMP environment and its values. This research will establish a baseline understanding of the geomorphology and sediment distribution in the deeper offshore waters of the NMP between 30 and 120 m. The interrelationship between sedimentary characteristics and seabed geomorphology, and its influence on the spatial distribution of benthic habitats and communities will be determined. The project will focus on mapping the seafloor with acoustics (multibeam, singlebeam and sidescan sonar) and collecting georeferenced video data, sediment grabs and dredged rock samples to verify acoustic interpretations. The characterisations determined at this scale will improve our understanding of benthic habitat variability across the NMP.

Introduction

The characterisation of benthic habitats and communities based on physical factors is central in the selection and ongoing monitoring of MPAs and the development of the NMP management plans. Physical factors including geomorphology, sediment composition (texture, mineralogy and constituents), mobility of the substrate, bathymetry, the hardness and roughness of the seabed and water depth can be used as surrogates to describe the distribution of benthic biota and habitat types over broad geographic regions (Roff et al. 2003; Beaman et al. 2005). A number of studies in a range of settings around the Australian margin (Post 2006) have shown that physical surrogates can be used to predict biological distributions.

Seabed geomorphology determines the long-term stability of the substrate which in turn represents a major control on biological diversity (Freeman and Rogers 2003). Sedimentary and geomorphic investigations can be used to ground-truth acoustic surveys (Bale and Kenny 2005) and help to classify and map geophysical factors. These classifications and maps help characterise the nature of the seabed over the broadscale in terms of surficial sediment distribution, benthic habitats and their patchiness, and provide a basis to relate physical information to ecological information about benthic biota and associated fish and invertebrate distributions (Bale and Kenny 2005).

Regional Geology

The NMP lies across the boundary of the Northern and Southern Carnarvon Basins with the majority of its area located in the Exmouth Sub-Basin of the Northern Carnarvon Basin (Fig. 7). This large Palaeozoic to recent, mainly offshore basin, on the Northwest Shelf, is Australia's premier hydrocarbon province where the majority of deepwater wells have been drilled (greater than 500 metres water depth (mwd)). The Tertiary Cape Range Anticline is one of the dominant features of the terrestrial landscape of the Exmouth Sub-Basin (Johnston et al. 1976). The Muiron Islands to the north-east are recognised as extensions of the anticline (Johnston et al. 1976). Cape Range, Ningaloo Reef and Exmouth Gulf, are underlain by thick sedimentary sequences ranging from Palaeozoic to Holocene in age (van de Graaff et al. 1980; Hocking et al. 1983; Collins et al. 2006). Emergent, tectonically warped terraces overlying mid - late Tertiary units are present on the western side of Cape Range (Wyrwoll et al. 1993).

The youngest terrace, Tantabiddi, is of Last Interglacial age (ca. 125 ka; Stirling et al. 1998) and lacks deformation, attesting to the tectonic stability of the region since that time. The Tantabiddi precedes the present day Ningaloo Reef and represents a far larger reef system (Collins et al. 2003) with outcrops along the modern shoreline and underlying the coastal plain. (Fig. 8). The continental slope and shelf comprise the Northern Carnarvon Ramp (formally the Dirk Hartog Shelf) to the west of the Cape Range peninsula, Rowley Shelf to the north-east, and Exmouth Gulf to the east.

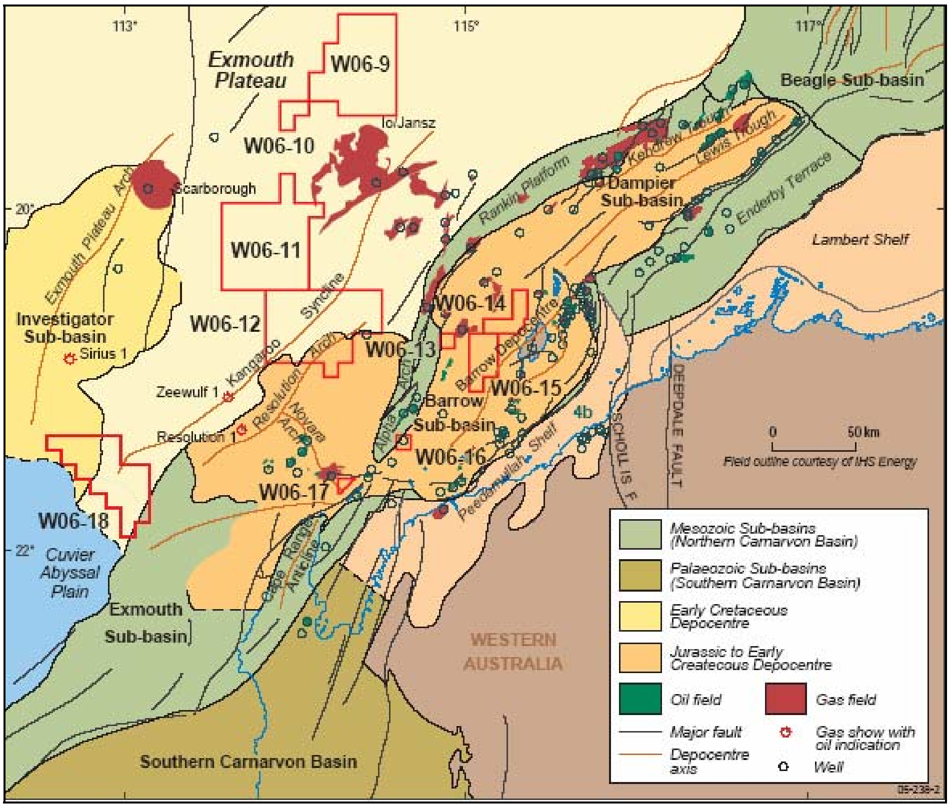

Figure 7. Structural elements of the Carnarvon Basin. From (Offshore Acreage Release 2006)

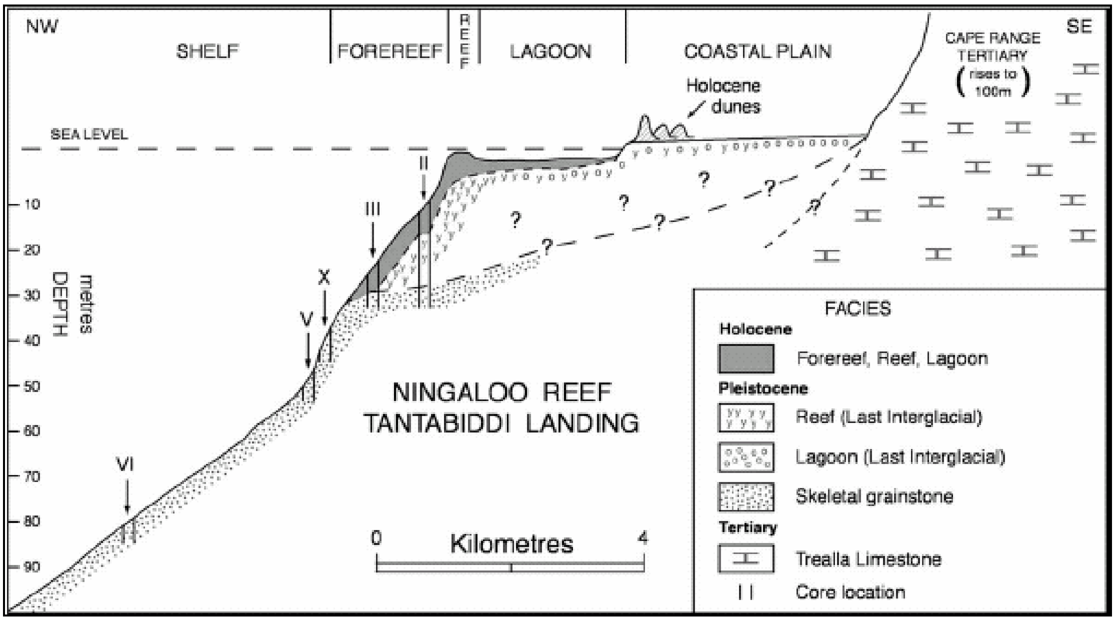

Figure 8. Idealised northwest-southeast cross section of northern Ningaloo Reef based on the cored transect and seismic data at Tantabiddi (Collins et al. 2003).

Western Australian Continental Shelf Geomorphology and Sedimentology

The western continental margin of Australia provides a significant regional context to study carbonate sediment facies transitions from cool to warm water (Collins et al.

1997). This gradational setting spans from the cool-water setting in the south (Collins 1988) to the Ningaloo fringing reef in the north. The Rottnest Shelf to the south is open, wave-dominated and characterised by cool-water carbonate sedimentation. Carbonate grains in this area originate from temperate assemblages with bryozoans and coralline algae being the dominant biotic constituents. Linear topographic ridges of Pleistocene limestone partition the shelf into varying physical energy, biota and sediment supply.

The Houtman Abrolhos coral reefs comprise three shelf-edge carbonate platforms which together form the discontinuously rimmed Abrolhos Shelf. This shelf lies in the biotic transition zone between the northern tropical and southern temperate environments and is reflected in the carbonate facies with cool-water carbonate shelf to the south and increasing coral development in the north (Collins 1997).

The Carnarvon Ramp stretching from Shark Bay to Ningaloo Reef is gently inclined throughout, and in places, there is no declivity to mark the shelf edge. This is currently a 'starved' tropical ramp (James et al. 1999) where although bottom temperatures are tropical, the biota is largely subtropical with an absence of modern carbonate production on the mid to outer ramp. Biodegraded sediments and clasts do, however, indicate carbonate production in the recent past; implying that as sea level rose, carbonate production has decreased.

The Northwest Shelf to the north of Ningaloo is an ocean-facing carbonate ramp that lies in a warm water setting and is one of the largest such systems in the carbonate realm (James 2004; Dix 2005). Northwest Shelf sediments have diverse particle types and ages and can largely be explained in the context of modern and late Quaternary oceanography where the shallow water sediments were stranded by a rapid rise in sea-level which changed the character of the sediments from photozoan (warm-water carbonate deposits) to heterozoan (cool-water carbonate deposits) (James 2004).

Methods

Surficial Sediments

Sample Design and Collection

A total of 141 sediment samples were collected using a van Veen grab sampler (Figs. 9 & 10) to collect surface and subsurface material to a depth of ~10 cm. Sampling sites were chosen to include all geomorphic provinces of the shelf from the base of the reef slope/inner-shelf to the outer continental shelf/upper slope. A widely spaced systematic grid of samples was used in order to characterise each region and these were stratified by depth contours across the shelf (Fig. 9, Appendix 2.1 & 2.2). Positions were fixed using a Differential Global Positioning System (DGPS) and imported directly into ArcGIS for live onboard spatial analysis. Grabs were dropped at, or close to, video stations to obtain habitat linkages to surficial sediment facies, and infer biological activity and sediment transport pathways from sedimentary bedforms identified on the towed video data. The sediment/substrate data will provide ground-truthing and add value to the acoustic backscatter data.

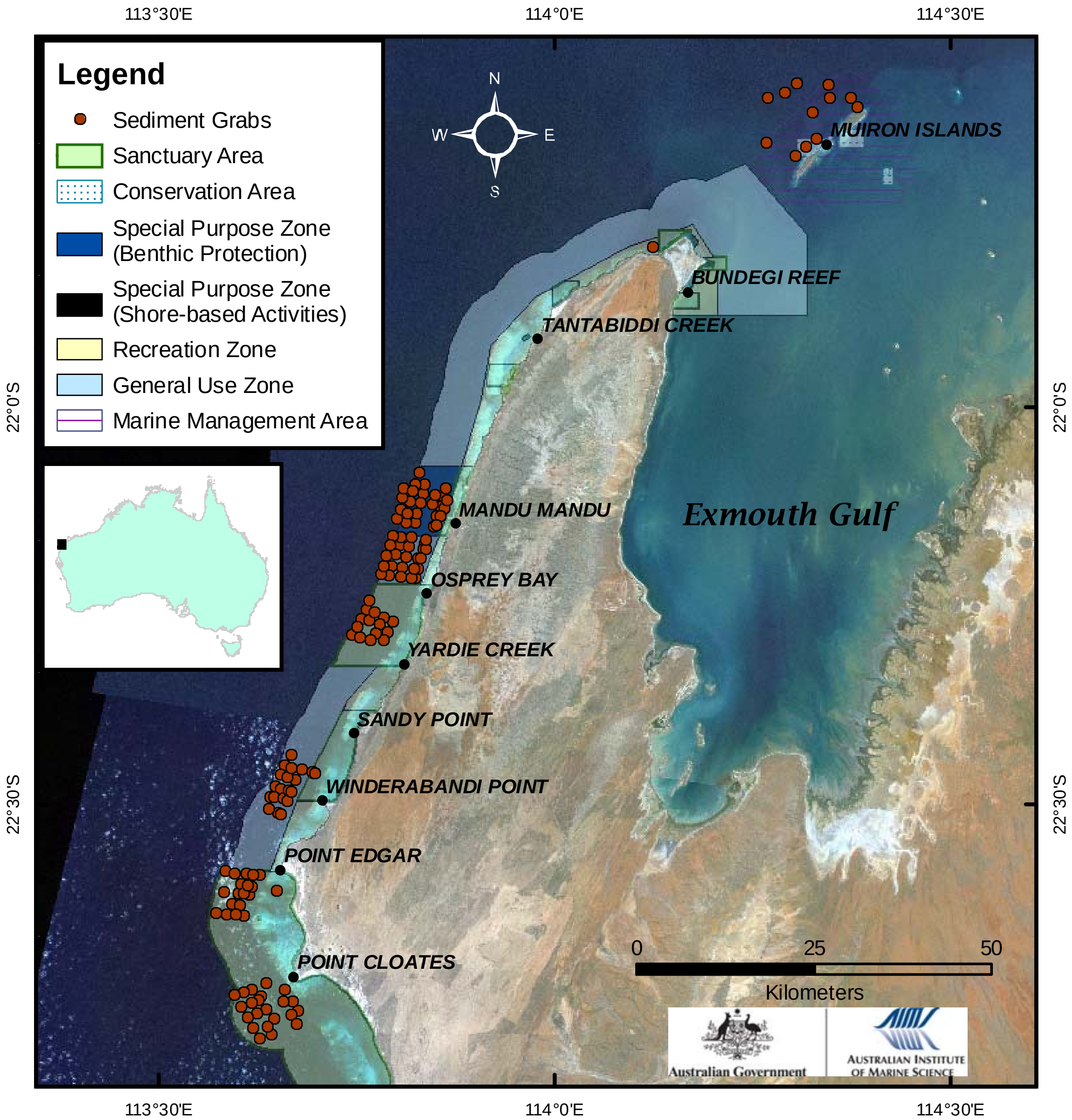

Figure 9. Sediment Grab sampling locations in the northern Ningaloo Marine Park (compiled by Felicity McAllister, AIMS)

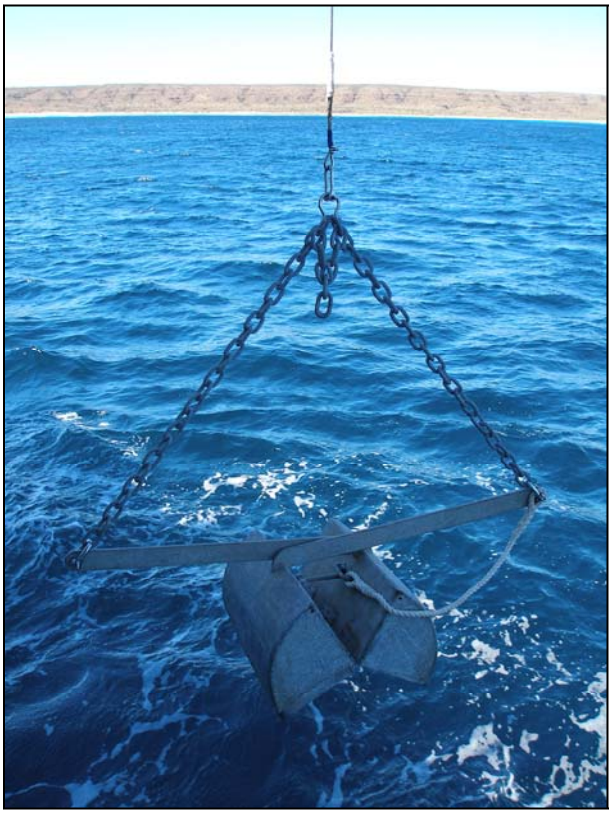

Figure 10. van Veen grab sampler for collecting surface and subsurface material to a depth of ~ 10 cm from the northern part of the NMP.

Limestone substrate samples and a coral sample at ~75 m from offshore ridges were dredged and recovered using a benthic sled. The coral sample will be dated using U-series TIMS (Triangular Irregular Network) method, providing an insight into the geological and sea-level history of the continental shelf in this region.

Granulometric and Component Analysis

Sediment samples were initially washed in distilled water to remove salts and then dried and subsampled using the cone and quartering method, to provide representative subsamples of the bulk sample. Sediment fractions were separated for; grain size, component analysis, taxonomy of the main biological constituents, and X-ray diffraction (XRD) to determine ratios of carbonate mineralogy.

General binocular descriptions for all loose samples were undertaken in the laboratory for components, gross lithology, grain size, texture, roundness and sphericity. Dried samples were sieved using a mechanical sieve shaker with -1 – 4 phi (Ø) sieve units at 0.5 Ø intervals based on the Udden-Wentworth (Udden 1914; Wentworth 1922) grain size scale (Appendix 2.3, Table 1). Wet sieving was necessary for samples with a silt and clay fraction exceeding 10% using a 4 Ø sieve. Detailed grain size analysis is an essential tool for classifying sedimentary environments and will provide important clues to the sediment provenance, transport history and depositional conditions on the Ningaloo continental shelf.

GRADISTAT software (Blott and Pye 2001) was used to calculate grain size statistics, textural parameters and descriptive terminology, allowing both tabular and graphical output into Microsoft Excel™ format. The physical description of the textural group from which the sample belongs, and the sediment name (such as “fine gravelly coarse sand”) is based on the classification by Folk (1954). Appendix 2.3, Table 2 outlines the calculation of grain size statistics.

Biological components were examined on selected cross-shelf sediment samples using both a binocular microscope for loose grains, and a transmitted-light polarizing petrographic microscope for grain mounted thin-sections.

Results

Shelf Geomorphology

The continental shelf at Ningaloo (Fig. 11 a-f) has: a seaward reef slope 30-40 mwd; an inner-shelf between 40-60 mwd; a wide, flat middle shelf plain in 60-75 mwd, interrupted by low relief ridge systems; an outer shelf sand plain and ridge system at 75-125 mwd; and a shelf break and deep sea canyon heads around 125 mwd. A more complex history of constructional and pre-existing antecedent topography exists at Cloates SZ (Fig. 11 f), where Tertiary limestone surfaces, paleo-stillstand escarpments and shorelines, and stepwise Last Interglacial (LI, ca. 125 ka) fossil reefs have created a complex environment with numerous ridges and pinnacles.

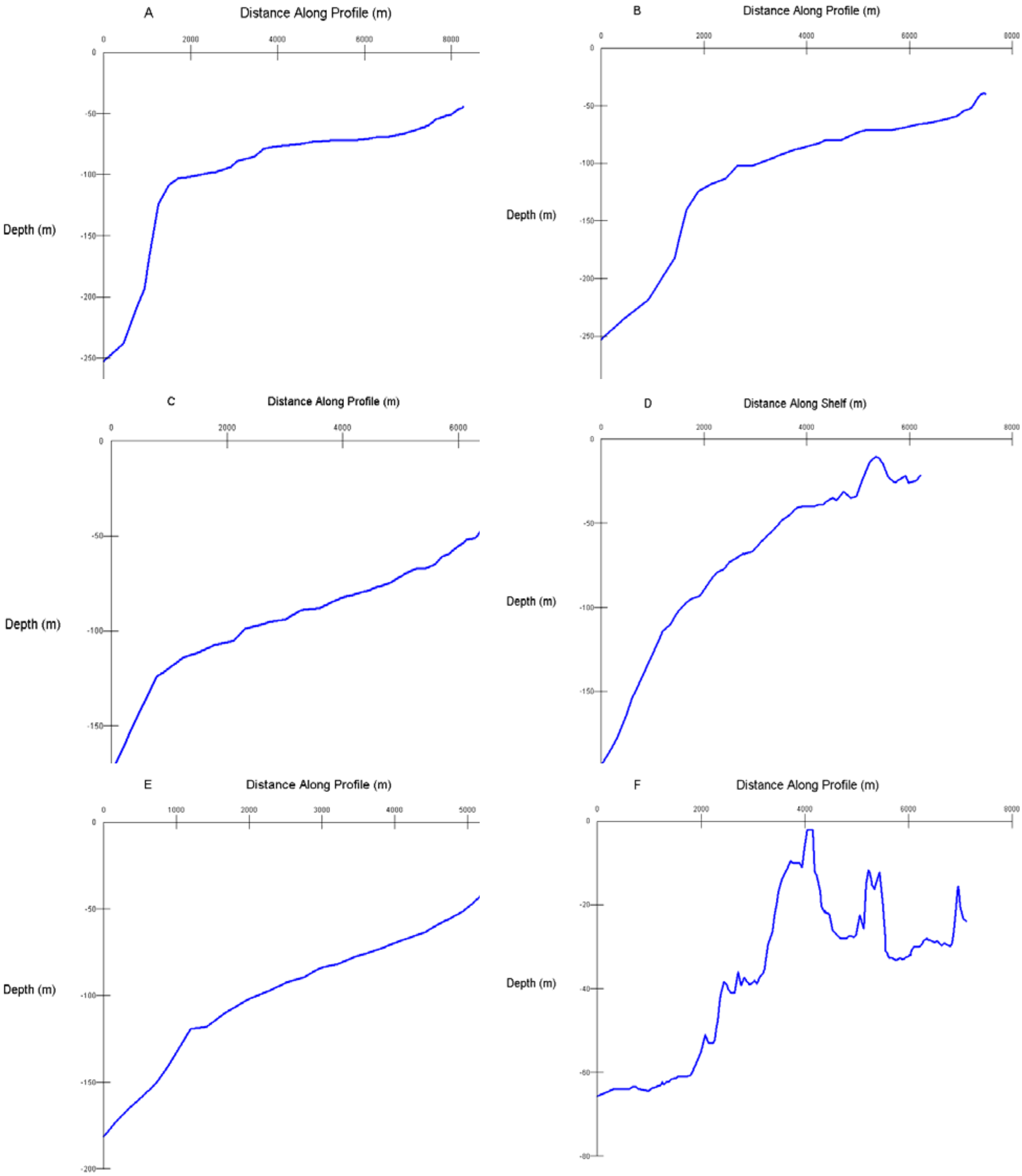

Figure 11. a-f Bathymetric profiles across the continental shelf of northern Ningaloo (from RAN TIN model in ArcGIS); a) Mandu Sanctuary Zone, b) Osprey Reference, c) Osprey Sanctuary Zone, d) Cloates Reference, e) North Cloates Sanctuary Zone, and f) Mid Cloates Sanctuary Zone (through Black Rock).

Geomorphic Features

Submarine fans

Submarine fans adjacent to reef passes, are clearly seen on the backscatter images (Fig. 12). The sediments within these fans are finer and well sorted compared to the surrounding areas and suggest flushing of lagoonal sediments offshore onto the inner - mid shelf area, where they are mixing with relic mid shelf sands. These sediments appear to have been subsequently entrained northwards on the mid shelf as a result of the dominant southwest swell direction.

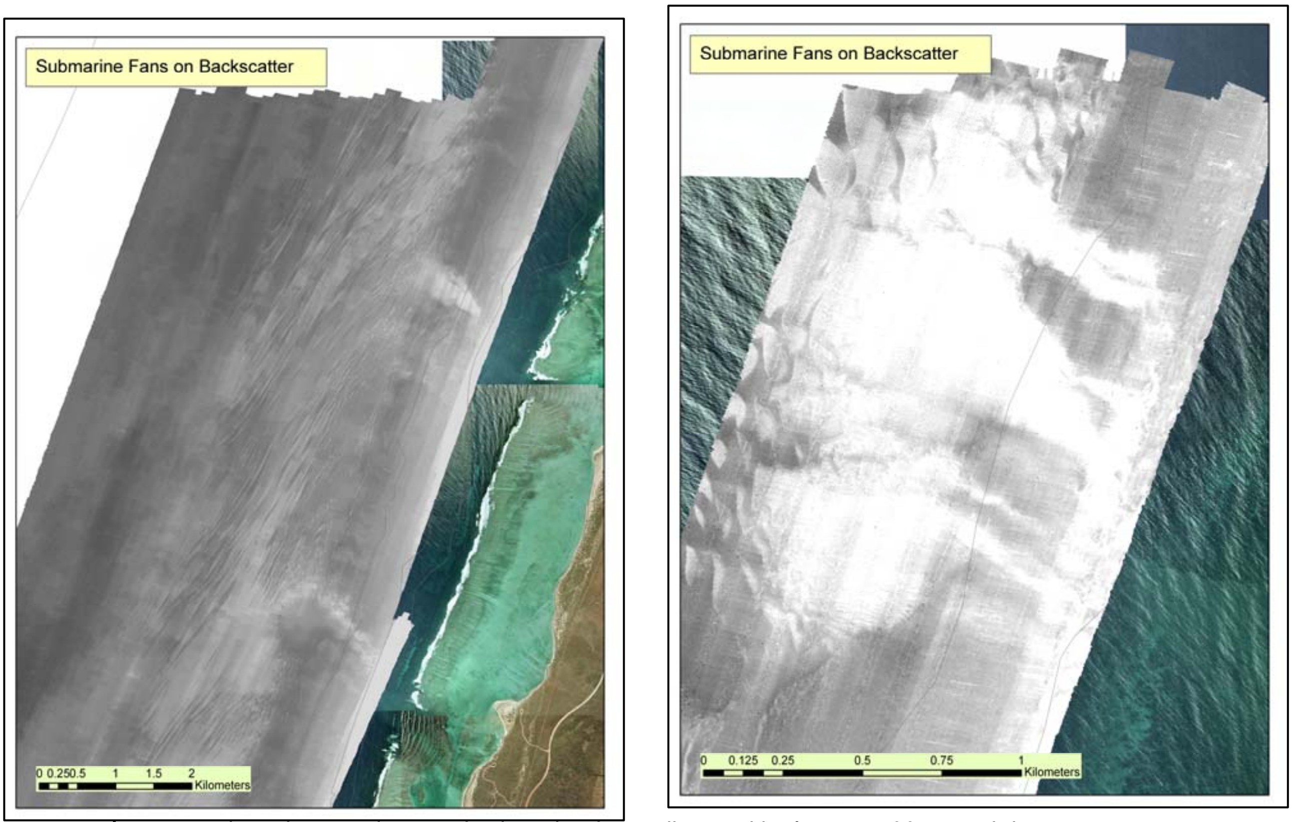

Figure 12. a) Backscatter image of submarine fan sediments b) Close up of fans and dunes

Mid shelf dune field

Large dune features have been identified on the multibeam backscatter data (Fig. 13.). Dunes with a northeast-southeast crest orientation occur on the mid shelf and the texture of the backscatter and sediment grab data indicate alternation between more gravelly (darker) and more sandy (lighter) sediments. These are more prevalent adjacent to submarine fans and indicate strong currents from lagoonal flushing and tidal flow.

Figure 13. Backscatter image of mid-shelf dune fields

Offshore ridge systems

A number of low relief ridges have been identified at various depths on the outer shelf at around 75-125 mwd (Fig. 14) The ridges are composed of fossilised limestone reef surfaces, karstified in places due to subaerial exposure on the shelf during glacial lowstands. A ridge at 125 m is identified as the Last Glacial lowstand shoreline (ca. 20 ka) and this can be seen clearly on cross-shelf profiles in Figure 11a-f. A limestone sample recovered from the benthic sled contained well preserved corals. Further samples will be recovered from these ridge systems and dated to provide an insight into the geological and sea-level history of the continental shelf in this region.

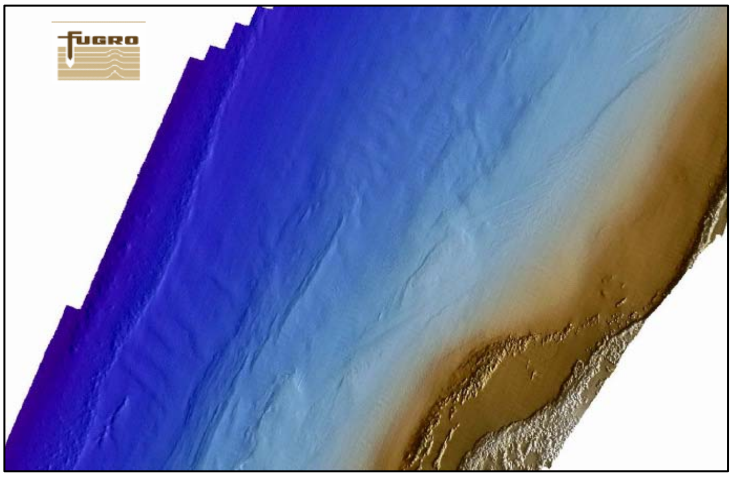

Figure 14. Multibeam bathymetry image of Osprey SZ showing ridge systems on the mid and outer shelf.

Gravel mound fields

Large gravelly sand mounds have been identified at around the 80-85 m contour on the outer shelf. These features were initially identified from the towed video and are also clearly present on the multibeam backscatter image (Fig. 15). The backscatter indicates an area of 400 m x 200 m with over 30 of these features; many of them are 15-20 m in basal diameter. Three mound fields of similar dimensions are present in the Osprey-Mandu region and a further investigation into these features will be underway during the 2007 survey.

a.

b.

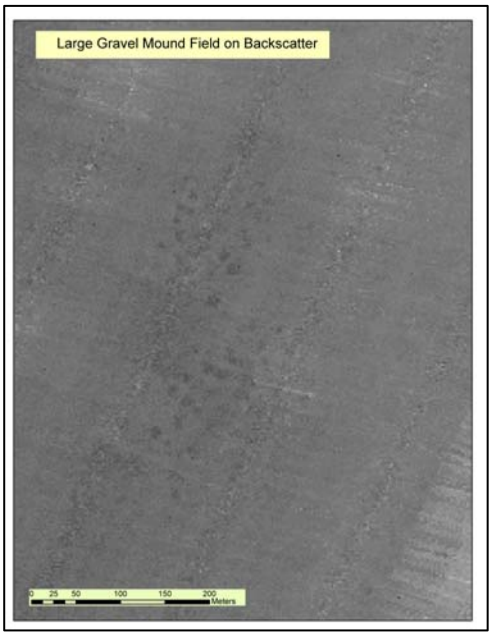

Figure 15. a)Video still image of large gravel mounds (~5 m diameter) b) Gravel mound field identified from multibeam backscatter imagery.

Substrate and Sedimentary Bedform Distribution

Sedimentary bedform distribution is closely linked with geomorphic provinces and features on the shelf, and a number of sub-parallel cross-shelf zones have been identified.

Inner-shelf rhodolith gravel beds

At the transition between the base of the reef slope and the inner-shelf, rhodolith gravel beds are the dominant substrate (Fig. 16). The density of gravel is influenced by local oceanographic processes including flushing of lagoonal sediments through reef passes.

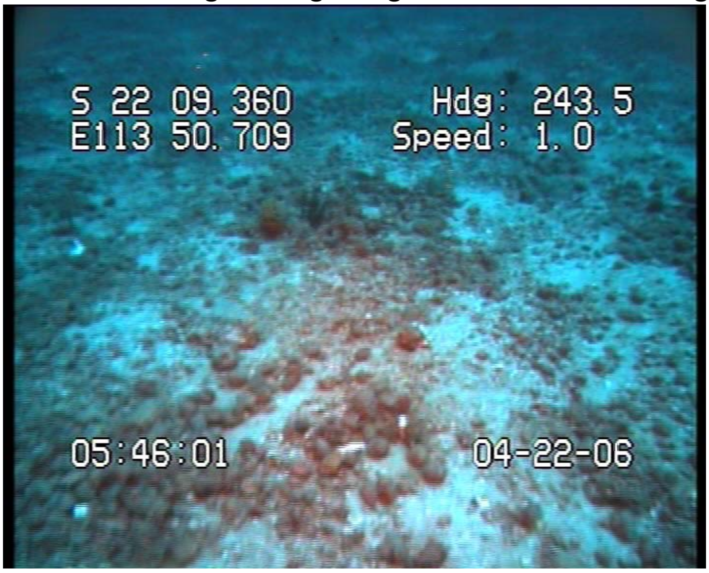

Figure 16. Rhodolith gravel beds (video A3)

Inner-shelf coarse gravelly burrowed sand

Rhodolith beds grade into course gravelly sand on the edge of the inner-shelf (Fig. 17). Bioturbation is present from echinoderms feeding traces, polychaetes and burrowing fish and a diverse infauna have reworked the sediments to build mounds and burrows. Feeding and resting traces from fish, echinoids and asteroids are common.

Figure 17. Biogenic sedimentary structures on gravelly sand (video A2)

Inner-shelf straight crested rippled sand adjacent to reef passes

Straight crested ripples were observed on the towed videos adjacent to reef passes (Fig. 18). The video sites correlate with the submarine fan features identified on the backscatter imagery and indicate currents flushing from the lagoon through reef passes, along with tidal influences.

Figure 18. Straight crested sand ripples (video A11)

Inner-mid shelf interference rippled sand and burrows

The inner-mid shelf is characterised by mounds and burrows, and interference ripples (Fig. 19). These ripples indicate multi-directional currents from lagoonal flushing, tides and the dominant southwest swell as well as other localised currents.

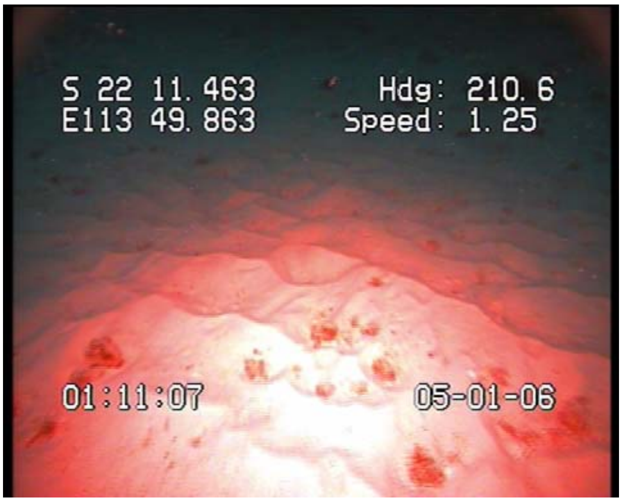

Figure 19. Interference ripples (video A61)

Outer shelf gravelly muddy sand with burrows and mounds

Bioturbation is the dominant sedimentary process occurring on the outer shelf. This region is below wave base and as a result the sediment is highly burrowed by infauna (Fig. 20.).

Figure 20. Burrows and mounds (video A34)

Mid-outer shelf low relief limestone ridges

Low relief limestone outcrops on the mid-outer shelf are karstified due to subaerial exposure at lower sea - levels during Glacial periods (Fig. 21). These features run sub-parallel to the modern reef and may indicate construction (reef building) or erosion during sea-level episodes since the Pleistocene.

Figure 21. Limestone outcrop (video A19)

High relief ridge systems, Cloates SZ

At Cloates SZ there are a number of ridge systems at approximately 60 mwd that have relief of up to 20 m (Fig. 22). Initial observation of these large features using towed video data indicates that many have spur and groove morphologies running perpendicular to the reef line, and attest to the high wave energy environment of this section of the reef.

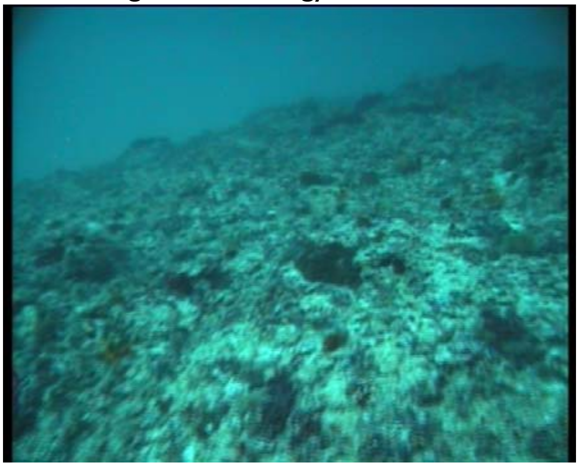

Figure 22. High relief ridges at Cloates SZ (video A86)

Large straight crested sand ripples with gravel lags, Cloates SZ

Separating these high relief ridges or `spurs` are coarse sandy areas `grooves` with large, straight-crested sand ripples and mega ripples (Fig. 23). Many of these ripples have gravel lags and seagrass debris in the troughs. Seagrass beds are present in the adjacent lagoon.

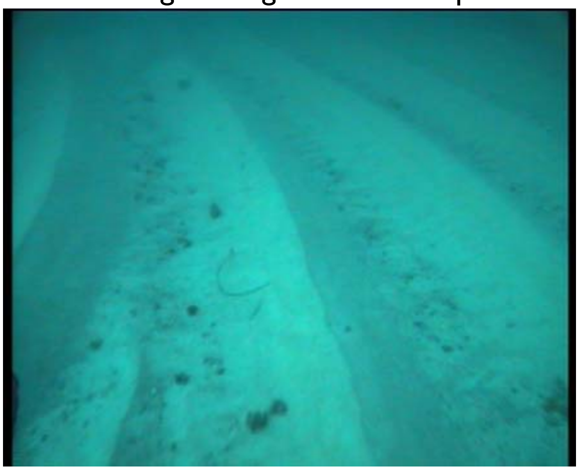

Figure 23: Straight crested sand ripples with gravel lags (video A86)

Sediment Grain Size Characteristics and Distribution

The textural analysis of the sediments identified sub-parallel belts across the shelf, which correlate well with the changes in the multibeam backscatter signatures and geomorphic features. Figures 24-25 illustrate the grain sizes for all sites. Appendix 2.6 contains detailed grain size graphs for each depth profile. Figures 25-29 shows interpolated maps of each area for grain size statistics/distribution.

Sediments on the Ningaloo shelf generally contain a high proportion of gravelly sands. The relative abundance of gravel, sand and mud across the study area is typical for carbonate shelf setting with gravels dominating the inner-shelf, sands in the middle shelf, with an increase in carbonate muds on the outer shelf. The inner-shelf is characterised by gravels and gravelly sands which are interpersed by well sorted sands in submarine fans adjacent to reef passes. Similar grain size distribution is reflected on the mid shelf dune field where these lagoon flushed sands have been deposited and entrained northwards in the dominant southwest swell. Further investigation into the biological constituents may confirm lagoonal counterparts. Sands further away from these features are coarser and moderately sorted, and have a higher density of relict Pleistocene grains. Outer shelf sediments are generally poorly sorted gravelly muddy sands and the mud component (up to 19%) reflects an increase in the contribution of planktonic foraminifera at this depth. The gravel content is high where limestone ridges outcrop on the mid-outer shelf.

This zonation is present at Mid Cloates SZ but the topographic complexity of ridge and pinnacle systems illustrates the relationship between geomorphology and grain size distribution. The inner-shelf contains well sorted medium to fine sands with finer sands adjacent to reef passes. Coarse gravels and gravelly sands are found close to ridges and pinnacle systems with medium grained sand flats in-between. There is an increase in mud content offshore but shallow depths of the widening shelf has resulted in lower percentages (up to 2%) compared to the sediments further north.

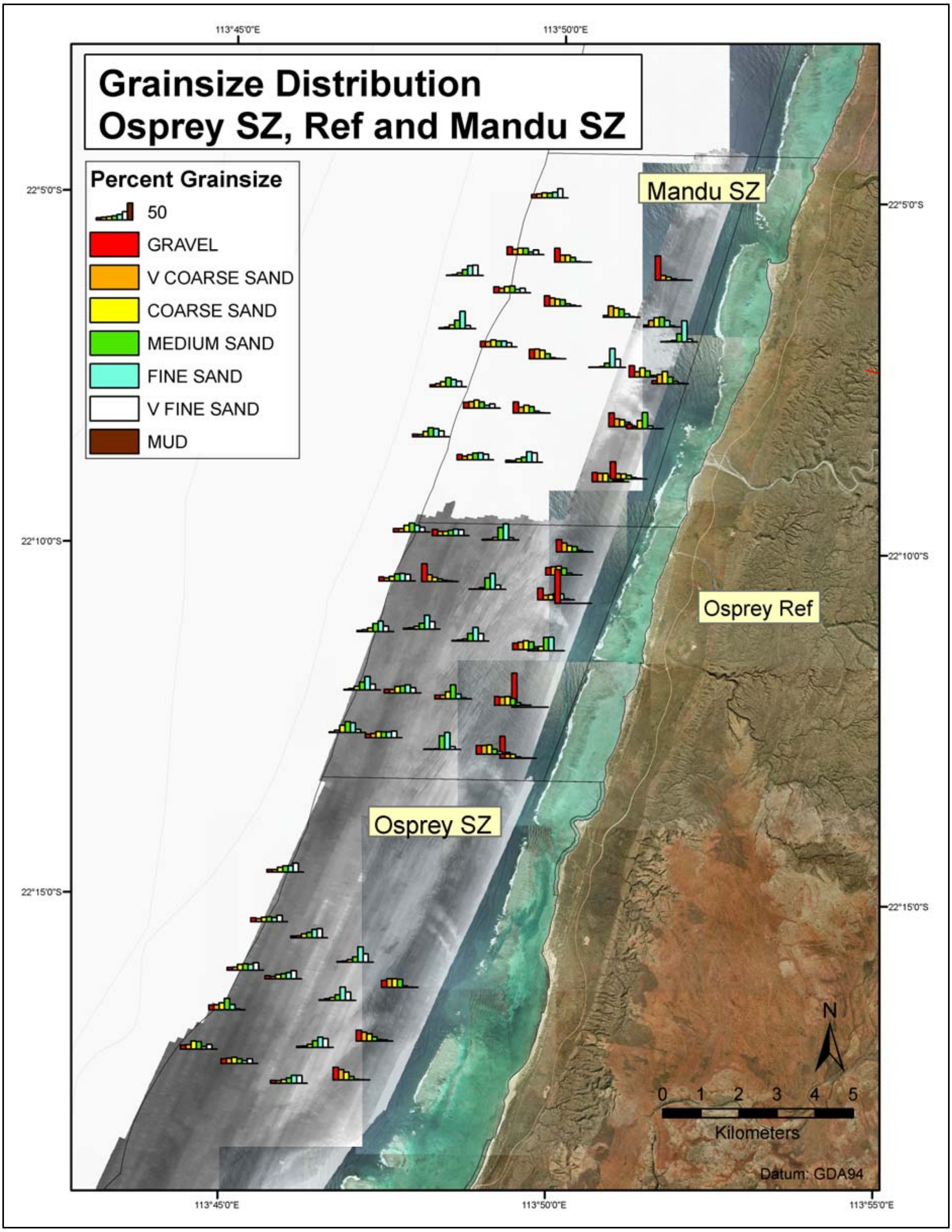

Figure 24. Grain size distributions for Osprey Sanctuary Zone, Osprey Reference and Mandu Sanctuary Zone.

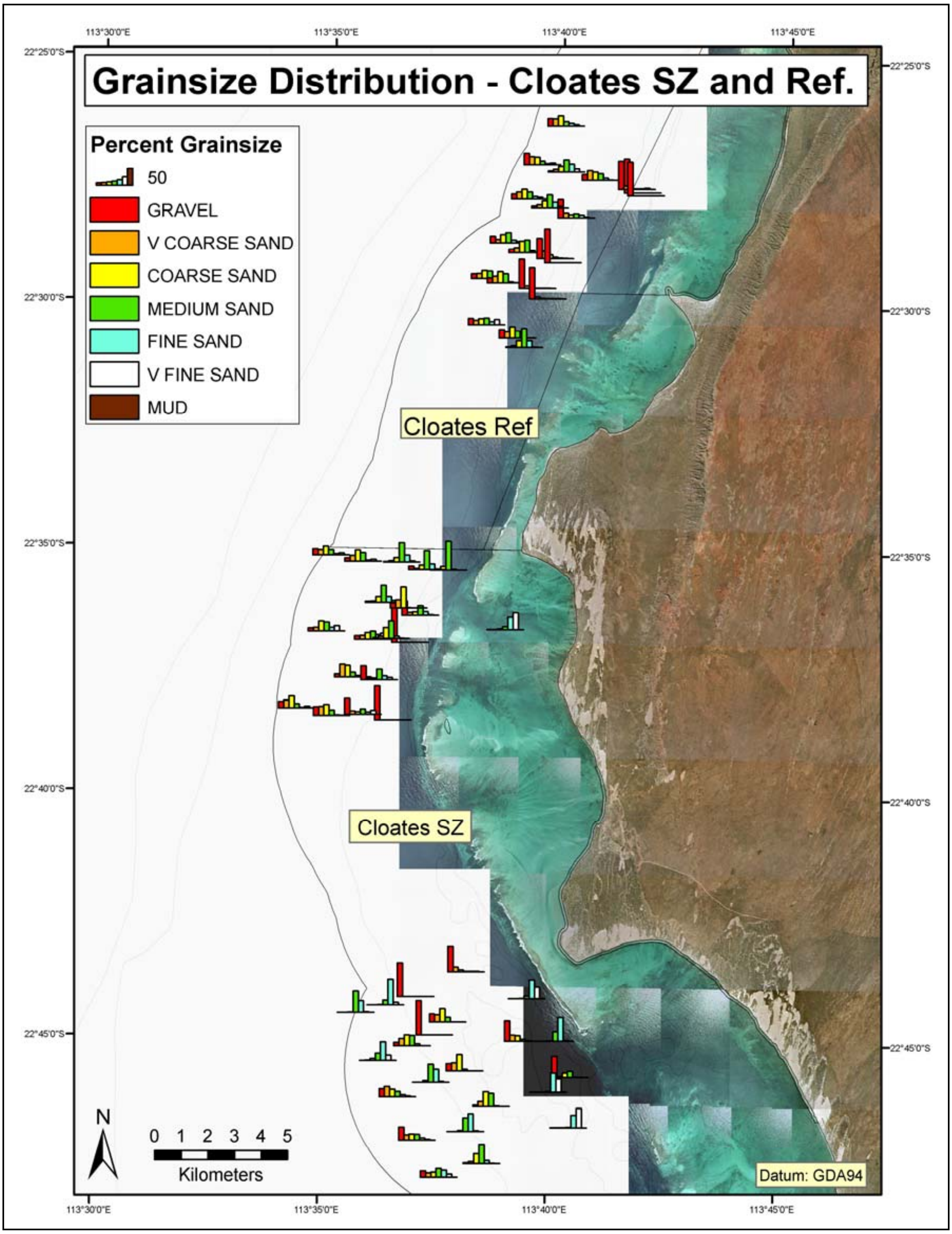

Figure 25. Grain size distribution for Cloates Sanctuary Zone Mid and North, and Cloates reference area.

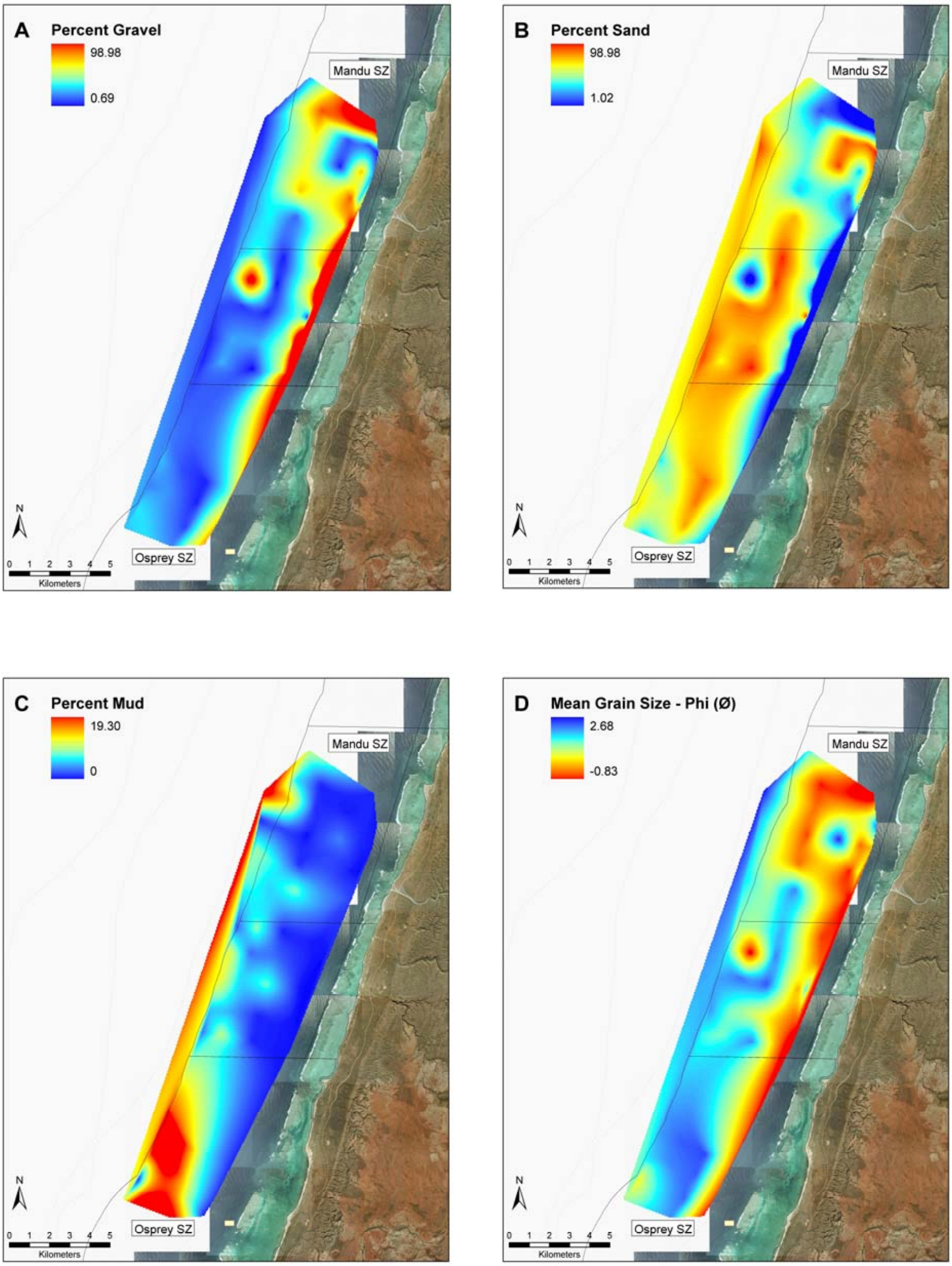

Figure 26. Interpolated distribution maps of grain size statistics for Osprey Sanctuary Zone , Osprey reference and Mandu Sanctuary Zone.

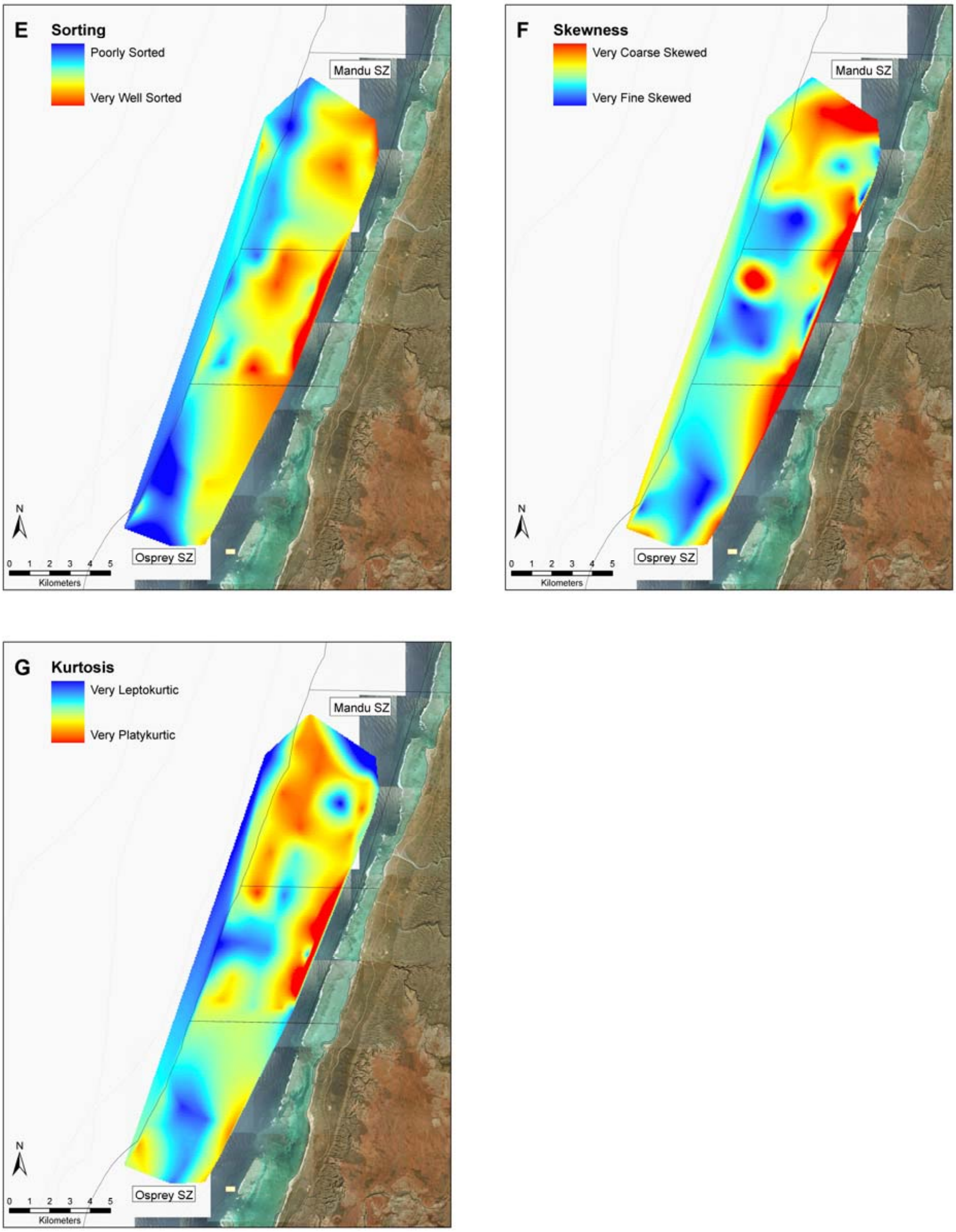

Figure 27. Interpolated distribution maps of grain size statistics for Osprey Sanctuary Zone, Osprey reference and Mandu Sanctuary Zone.

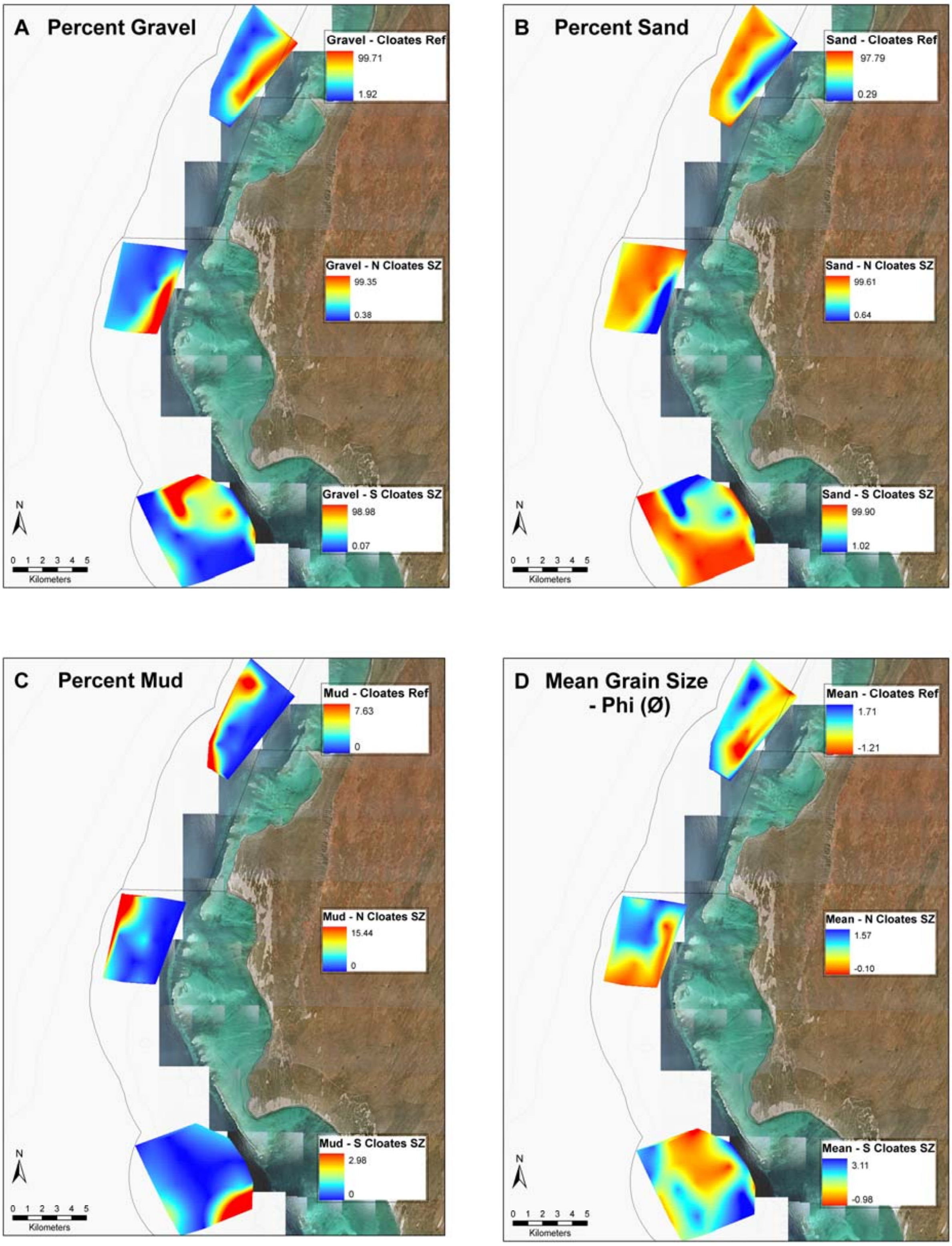

Figure 28. Interpolated distribution maps of grain size statistics for Cloates Sanctuary Zone and Cloates reference area.

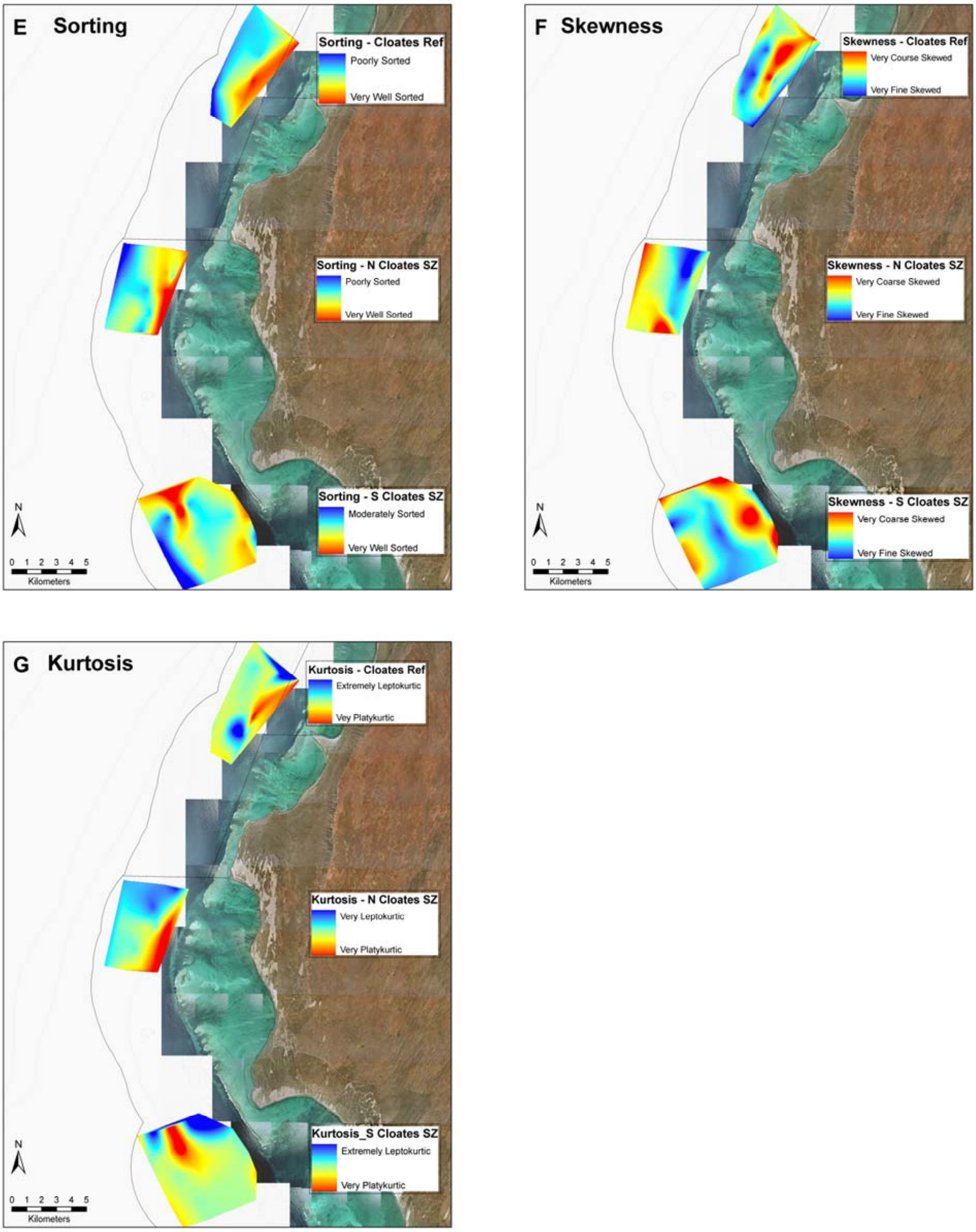

Figure 29. Interpolated distribution maps of grain size statistics for Cloates Sanctuary Zone and Cloates reference area.

Sediment Textural Classification

There are six sediment types based on textural classification (relative proportions of gravel:sand:mud) for the Ningaloo shelf (Fig. 30, Appendix 2.4). These can be further classified into sixteen sediment classes when the grain size of the sand fraction is taken into account (Appendix 2.5).

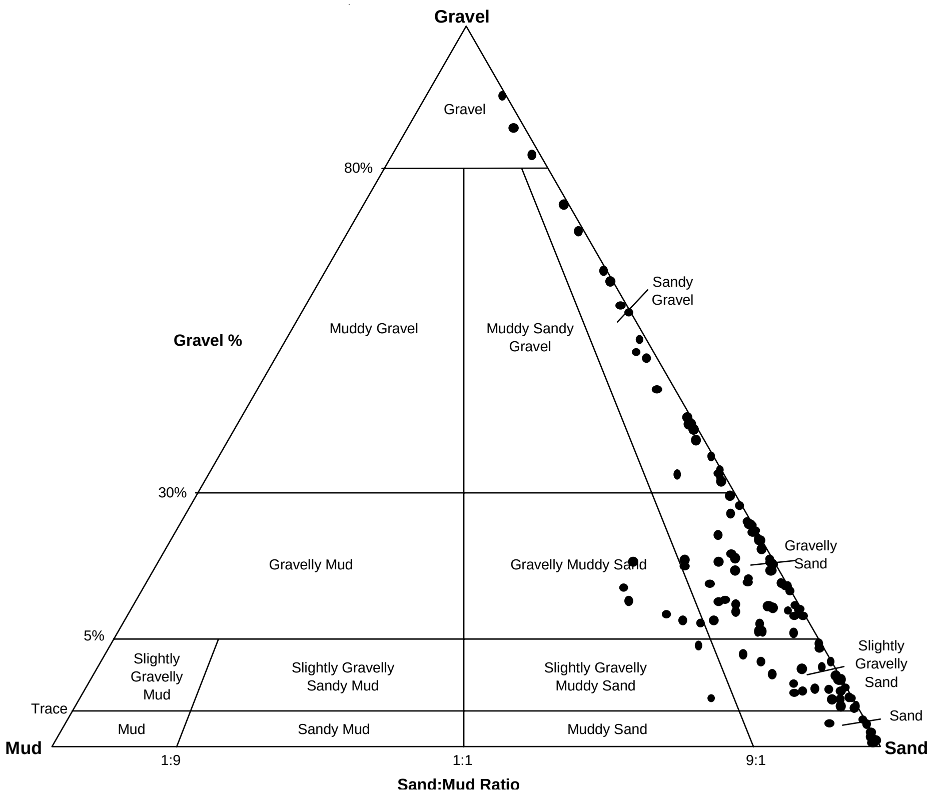

Figure 30. Ternary diagram showing the percentages of gravel:sand:mud for all sediment samples (Folk et al. 1970).

Table 1. Sediment name classes based on grain size analysis classification of Folk (1954).

Gravel	Sandy Gravel
Gravelly Coarse Sand	Slightly Gravelly Coarse Sand
Gravelly Fine Sand	Slightly Gravelly Medium Sand
Gravelly Medium Sand	Slightly Gravelly Fine Sand
Gravelly Muddy Coarse Sand	Slightly Gravelly Muddy Very Fine Sand
Gravelly Muddy Very Fine Sand	Slightly Gravelly Very Fine Sand
Gravelly Very Coarse Sand	Slightly Very Gravelly Very Coarse Sand
Gravelly Very Fine Sand	Very Coarse Rhodolite Gravel

Sediment Grain Components

The importance of calcium carbonate secreting organisms to the surficial sediments is evident. Grains are almost wholly biogenic in origin consisting of older relict and reworked grains mixed with modern skeletal fragments. Depth consistent sediment facies can be recognised on the basis of component composition. Inner-shelf sediments are dominated by hardground/rhodolith/coralline algal gravelly sands, modern skeletal rippled sands transported in submarine fans adjacent to reef passes, modern skeletal gravelly shelf sands dominated by a mixture of coralgal, molluscan, foraminiferal and bryozoan components and seagrass/sublittoral fine sands. Grains composing whole skeletons or fragments, and gravel sized clasts are heavily encrusted by coralline algae. Middle shelf sediment is dominated by foraminiferal dominated relict skeletal sands, with initial observations indicating modern counterparts in shallower water depths suggesting deposition during lower sea-level in the Pleistocene. Subphotic sediments on the outer shelf and upper slope are a mixture of modern cool-water, poorly sorted, bryozoan/molluscan dominated gravelly muddy sands with small benthic and planktonic forminifera, sponge spicules and brachiopods. Relict grains again were common (Fig. 31)

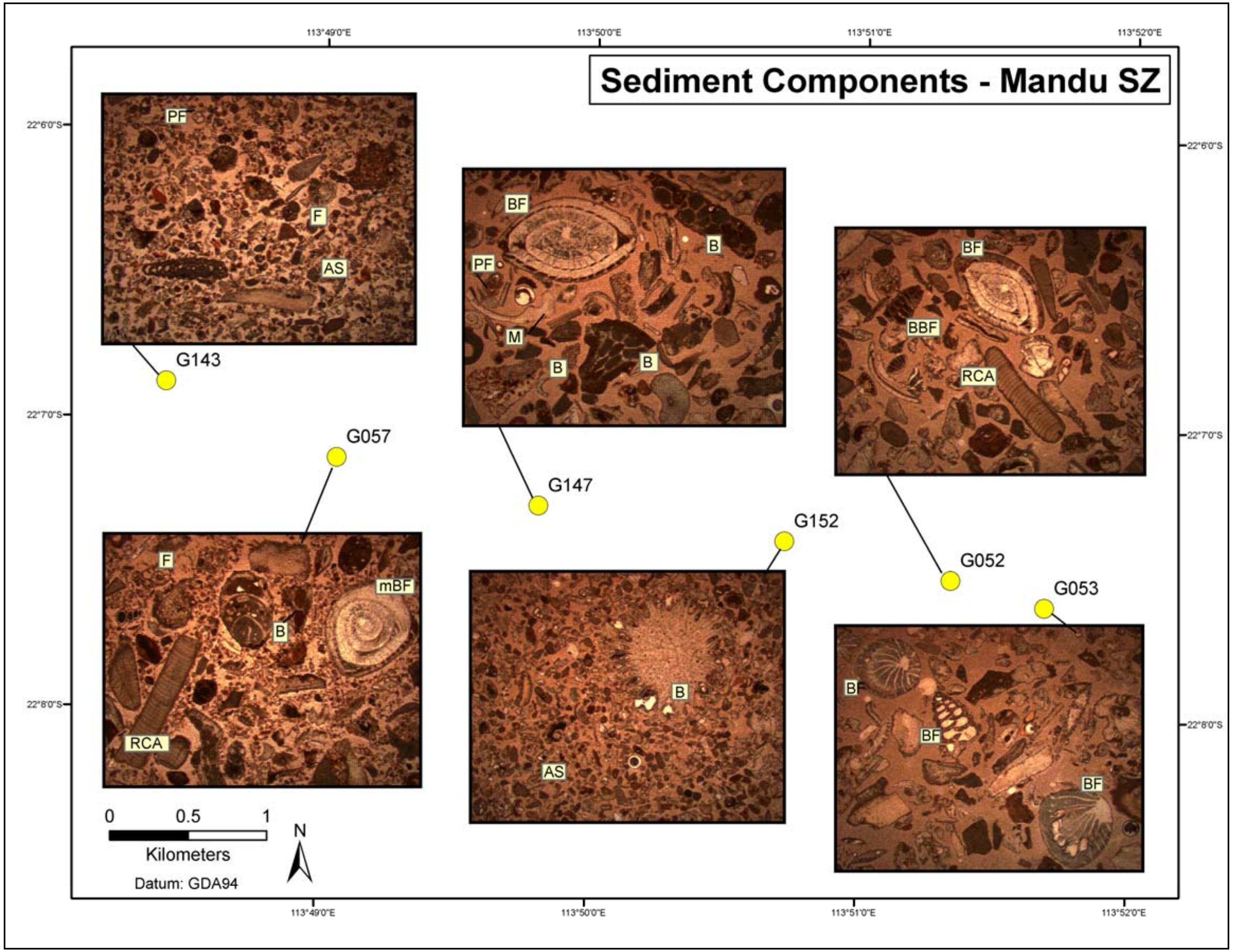

Figure 31.Map illustrating the typical grain components identified in selected cross-shelf sample transect from Mandu SZ, using grain mounted thin section photomicrographs. BF = benthic foraminifera, PF = planktonic foraminifera, BBF = biserial benthic foraminifera, mBF = miliolid benthic foraminifera, F = foraminifera, RCA = red coralline algae, M = mollusc, AS = angular skeletal grain).

Discussion

Habitat Linkages

The continental shelf within the northern NMP is narrow, and preliminary results show a clear zonation of habitats across the shelf. A strong association between geomorphology and benthic habitats is clear with communities taking advantage of the availability of Last Interglacial (LI, ca. 125 ka) substrates. The hard substrate is mainly composed of a fossilised limestone reef surface, karstified in places due to glacial lowstand subaerial exposure. In the shallow reef slope zone, a thin veneer of Holocene coralgal growth is largely determined by the antecedent LI topography. Between 30-40 mwd, even where hard substrates are still available, hard corals rapidly disappear, gradually replaced by a mixed deep-water benthic community. This transition, between the base of the reef slope and the inner-shelf is characterised by reef and rhodolith gravel that supply the hard substrate which supports a diverse community dominated by sponges, crinoids, turf algae and *Halimeda*, with minor soft corals (gorgonians, sea whips), ascidians and sea pens.

There is an extensive middle shelf sand plain where sediment thickness is variable overlying limestone pavement and low relief ridge systems. Here communities of sponges, crinoids, sea pens, sea whips and hydroids are patchy with higher abundance related to exposed LI surfaces. Bioturbation is present from echinoderm feeding traces, polychaetes and burrowing fish and a diverse infauna have reworked the sediments to build mounds and burrows.

A number of ridges have been identified at various depths with prominent and extensive systems on the outer shelf at around 75-125 m. Exposed limestone substrates are dominated by sponge and gorgonian gardens, some of the sponges and gorgonian sampled from these gardens are likely to be new species. Diversity is particularly high in areas adjacent to the continental slope canyons which are thought to bring nutrients to the shelf edge.

A more complex history of constructional and pre-existing antecedent topography exists at Cloates SZ, where Tertiary limestone surfaces, paleo stillstand escarpments and shorelines, and stepwise LI fossil reefs, support a diverse coralgal and sponge community. Here corals persist to greater depths (40-50 m) than those observed in the northern NMP.

Future Analysis

Detailed component analysis will be undertaken on representative cross-shelf sediment samples to examine the contribution of different marine organisms to shelf sediments. Grain mounted thin-sections will be examined with a transmitted light-polarizing petrographic microscope, using standard techniques. To provide an estimate of the frequency of components, all thin sections will be subjected to point-counting analysis using a grid of 300 points. Grains and components will be identified using standard classifications. Photographs of slides representing each main compositional group will be used as a reference to maintain identification consistency. A broad visual qualitative compositional estimate of the gravel fraction will be made. Taxonomy of the main species of bryozoans, foraminifera, molluscs and coralline algae will be identified in representative samples. X-ray diffraction (XRD) will help determine mineral composition on cross-shelf samples, mud size grains and ratios of carbonate mineralogy.

Multivariate statistical analysis of sedimentary, geomorphic, biological and textural variables will be undertaken using PRIMER™ v6 software package (Clarke, 1993; Clarke and Warwick, 2001) to establish trends and similarities across the study area. Relationships identified between these physical and biotic values may identify factors that are reliable indicators or 'surrogates' of specific habitats.

The sediment samples and video analysis will provide ground-truthing for the acoustics. Textural supervised image classification of single/multibeam acoustics from the 2006 survey and sidescan imaging from the 2007 survey will be used to aid in generating and classifying broad scale maps of benthic habitats, sediments and geomorphology of the seafloor.

BENTHIC COMMUNITIES

Towed Video

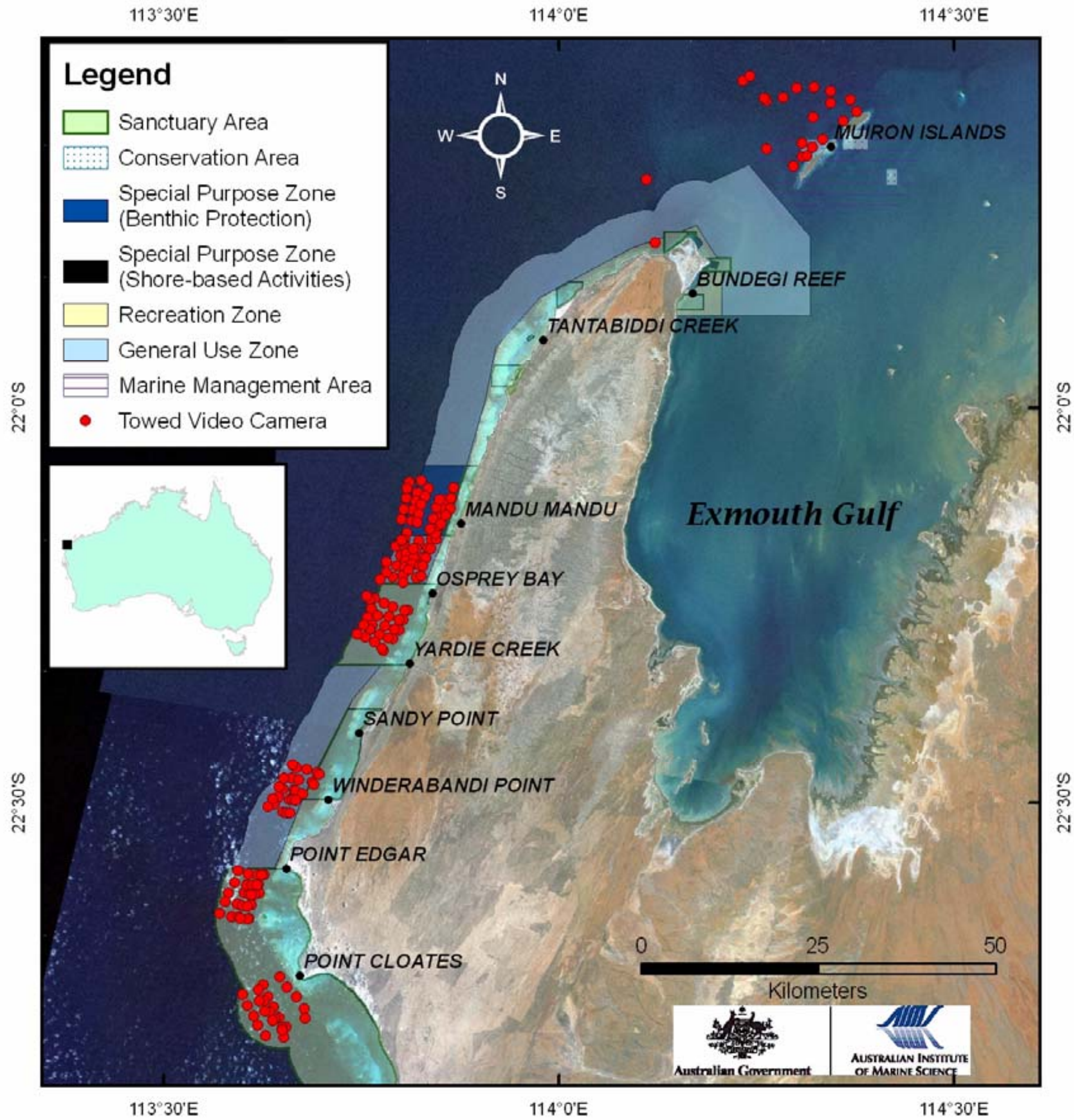

Figure 32. Towed video sampling locations in the northern Ningaloo Marine Park (compiled by Felicity McAllister, AIMS)

Method

Visual imagery of the benthos, in depths from 15 to 130 m, was captured using a 1/3 inch single CCD colour video camera mounted on a Para vane and controlled by a winch with 320 m of electromechanical cable (Figs. 33 & 34.). Two 12 Volt, 35 Watt underwater lights illuminated the field of view. The video signal was recorded on a shipboard miniDV tape recorder. In addition to the visual imagery the miniDV tape recorder received

Geographical Positioning System (GPS) data (latitude and longitude, ground speed, true heading, date and time), which was recorded on the audio track. An average speed of 1.5 knots was achieved over the towed video surveys equating to resolution of 6 m.

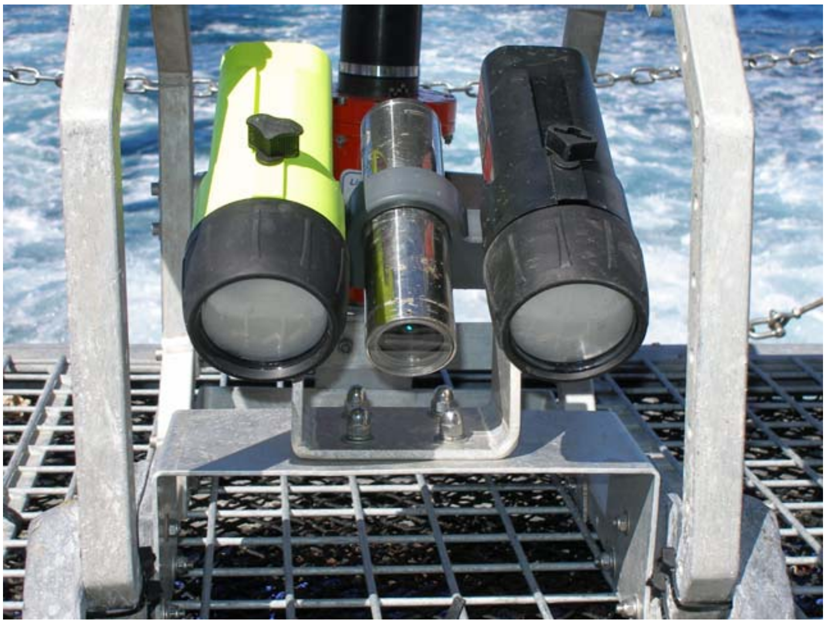

Figure 33. Towed video vane with video camera and lights

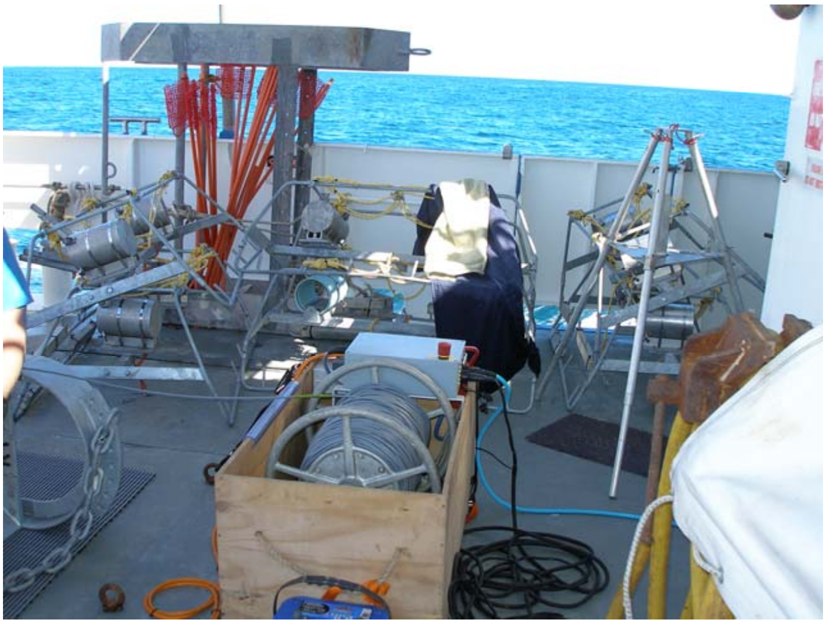

Figure 34. Towed video winch and electromechanical cable

Analysis

One hundred and ninety three towed video transects were analysed for general habitat type, substrate and benthos using the AIMS AVTAS software program, producing 38,200 data points, following the method described by Abdo et al. (2003). The sampling effort was highest for the 50-60 m depth strata and lowest in the 110-130 m depth (Fig. 35). Preliminary analysis has identified 7 habitats, 6 substrates, and 16 benthos categories (Table 2). AVTAS analysis also included identifying the stability of different substrates and a description of each benthos category. Further analysis will investigate percent cover of habitat, substrate and benthos for each tow and the relationship with water depth. Future analysis will also include the relationship between consolidated and non-consolidated substrates and different benthos categories.

Table 2. Towed video habitat, substrate and benthos categories derived from AVTAS analysis.

Habitat	Substrate	Benthos
Filter Feeders	Rubble	Rhodoliths
Rhodolith	Coarse Sand	Sponge
Coral Reef	Fine Sand	Soft Coral
Sand Mounds	Sand Rubble Veneer	Soft Coral Whip
Sand Waves	Bedrock	Hard Coral
Sand Flat	Calcium Carbonate	Algae
Sand Rubble		Bryozoan
		Crinoid
		Ascidian
		Coralline Algae
		Hydroid
		Gorgonian
		Halimeda
		Macroalgae
		Sea Pen
		Undefined

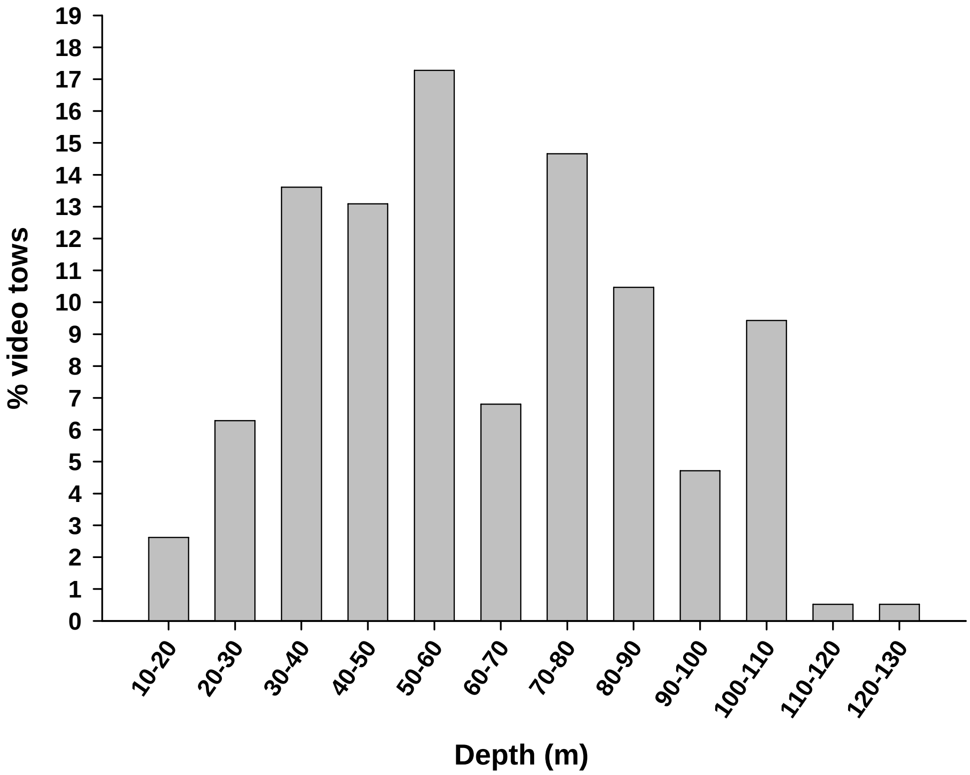

Figure 35. Depth strata surveyed with the towed underwater video

Benthic Sled

Towed video footage allowed us to detect and target different benthic communities so species and functional groups could be identified (Western Australian Museum) and their distribution, abundance, biomass and size composition investigated. A CSIRO designed steel sled was used to sample benthic communities in different depth contours at several different locations (Figs. 36 & 37) (Appendix 5). Forty nine sites were sampled, each sample covering approximately 500 x 1.5 m of seafloor. The sled was lowered to the bottom by a winch with steel cable and dragged along the bottom (Figs. 37 & 38). Each benthic sled sample went into a large net with cod end to allow for easy access and sorting.

A 1 m square mesh sorting tray was used on the back deck to sort all benthic specimens into different functional groups. Post processing was carried out in the field and specimens were sorted, labelled, dominant benthos photographed and preserved for identification by the West Australian Museum (Appendix 4.1). The dominant taxa from the main habitats were recognised for priority identification i.e. Porifera (sponges), Alcyonaria (gorgonians, whip corals). Biomass of the major sponge taxa was estimated by weighing each taxon identified in a sample.

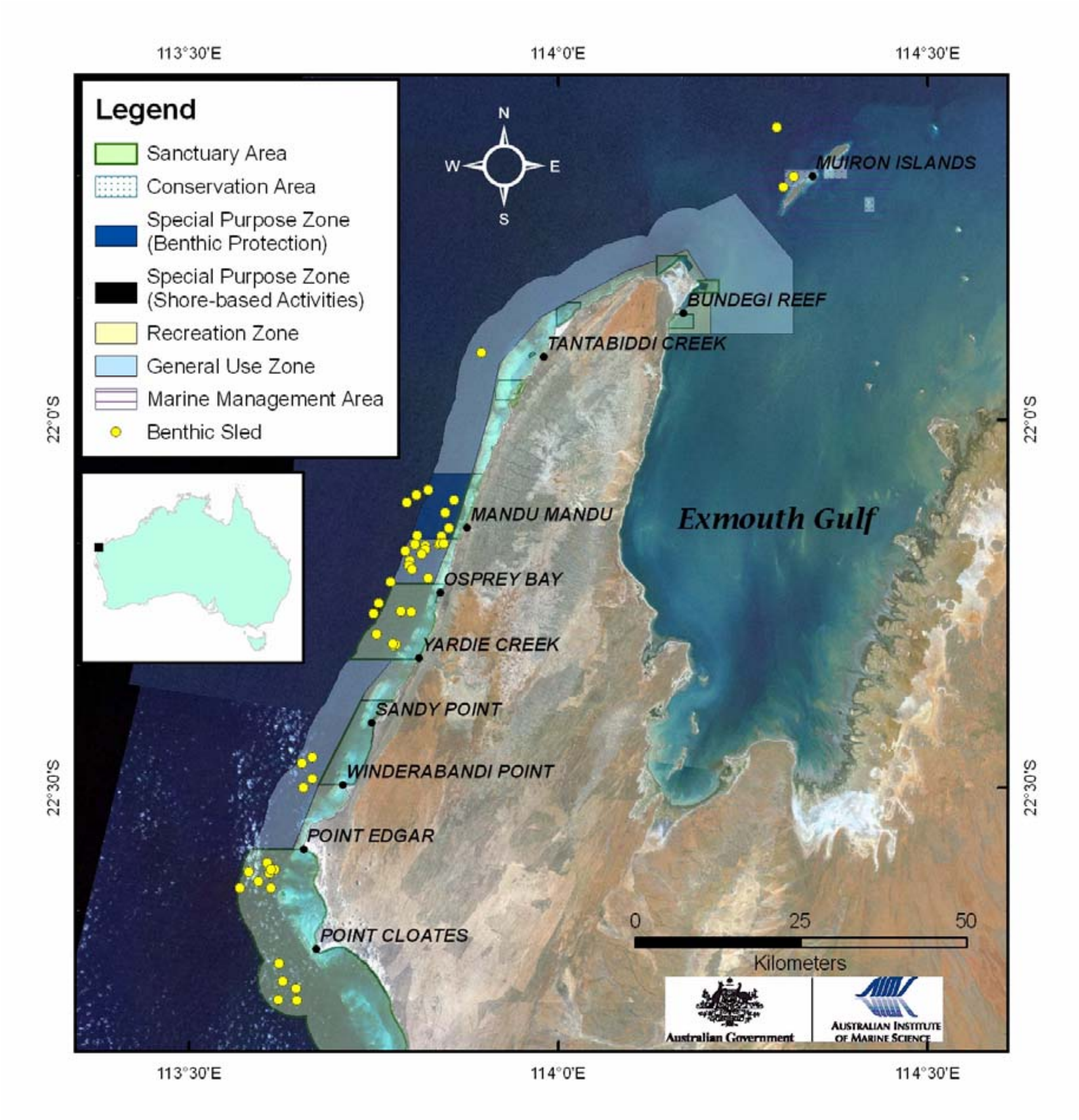

Figure 36. Benthic Sled sampling locations in the northern NMP (compiled by Felicity McAllister, AIMS)

Figure 37. Benthic sled used to sample taxa from targeted communities

Figure 38. Benthic sample from one site using the benthic sled

Analysis

Fifty benthic sled samples were taken at various depths and habitats across the survey area (Fig.36 & 39, Appendix 4). Due to varying depths, and the inability to know exactly when the sled was on the bottom, sampling for a standard time or distance was not achieved regularly. The crew operating the benthic sled winch used cable length as a surrogate for appropriate distance to the bottom. However this was not always accurate. Once the sled was considered to be on the bottom it was left on the bottom for 5 minutes with the boat doing approximately 1 to 2 knots depending on tide speed and direction and wind speed and direction. The deepest sample was 177 m and the shallowest 19.7 m (Fig. 39).

Preliminary identification of the dominant benthos (sponges and soft corals) was carried out by the West Australian Museum (Fromont 2006) (Appendix 4.1).

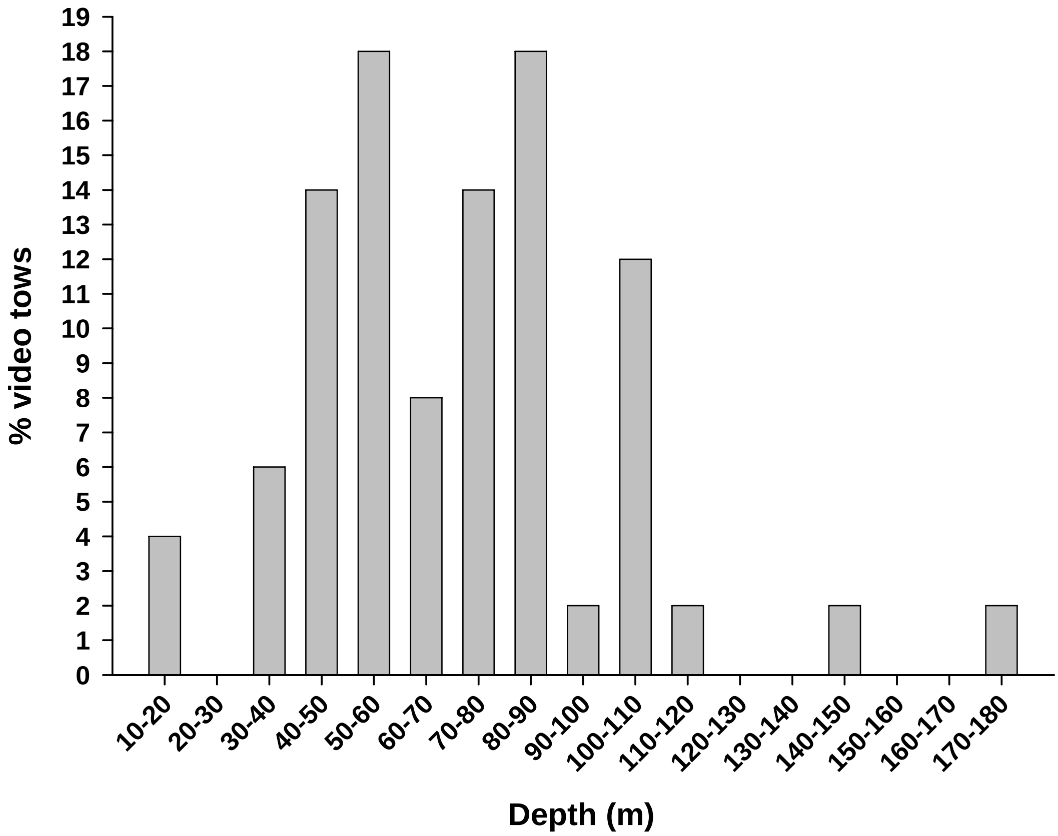

Figure 39. Percent depth strata surveyed with the benthic sled

Future Analysis

Future identification (ID) will include digital photographs and analysis of dominant sponge spicule preparations, sponge and soft coral *in situ* and specimen ID digital photographs. All photograph IDs generated will be input into ArcGIS software to create an interactive interface correlated to date, time, position, and depth. Analysis will include biomass estimates of dominant benthos (sponges, soft corals) using weight as a surrogate measure. Fine scale analysis of the dominant sponge and soft coral communities can be achieved by a more advance survey system like the AIMS Remote Operated Vehicles.

GIS Data Management

The ESRI™ suite of Geographical Information System (GIS) software ArcGIS™ is employed at AIMS as the preferred spatial data management system. AIMS utilises the add-on component Arc Spatial Data Engine (ArcSDE™) to provide a multi-user database environment incorporating the ORACLE™ database management system (DBMS). The ArcGIS software also interfaces directly with Microsoft Access™ Database (Access) format. The data collected as part of this study will be stored in the first instance in Access allowing a structured and relational storage system with the added advantage of ready spatial representation. This format is also widely used and is portable, allowing easy packaging of the data and associated maps etc for individual stakeholders. This will also assure secure access to the data until such time as this is no longer required. In the future, the data can be readily integrated into an enterprise database system such as the AIMS ORACLE/ArcSDE environment, which will allow extra functionality such as dynamic publication of data and maps to the Web.

Base spatial datasets have been provided primarily through the Western Australian Department of Environment and Conservation (DEC). These include high resolution aerial mosaics, marine and shoreline habitat information, coastal outlines and marine fauna observations. Multibeam surveys conducted by FUGRO have been included as both point and raster (gridded) GIS datasets. The GIS layers for the data collected in April – May 2006 are described below:

- Demersal Fish Assemblages Surveys using BRUVS – ArcGIS point shape file created with attributes including date, time and operational code for each camera deployment. Video samples from each deployment have also been added as an attribute to utilize the hyperlink functionality of ArcMap (the mapping component of ArcGIS). This allows the user to "click" on the location and launch the associated files application.
- Towed Video Surveys – ArcGIS point shape file created showing start and end points for each tow as well as an ArcGIS line shape file created showing the track. Attributes for each include date, time and operational codes for each tow. As for the BRUVS data, video files will be linked via an attribute and thus viewable from the ArcMap environment.
- Benthic Sled – ArcGIS point and line shape files showing the start/end point for each tow and tracks respectively. Still images from the samples acquired will be attached using the hyperlink technique.
- Sediment Grabs – ArcGIS point shape file created showing locations of each grab. Attributes include date, time and operational code for each grab.

Analysis data from each of the surveys can be attached via relational joins from their associated tables in the Access database. Alternatively, new layers with attributes that include the analysis data can be created.

Data can be exported from ArcMap™ to create Google Earth™ kml/kmz files. These files allow access to the data for non-GIS users. Additionally, a web-based system for viewing the data is being created to provide more access for non-GIS users.

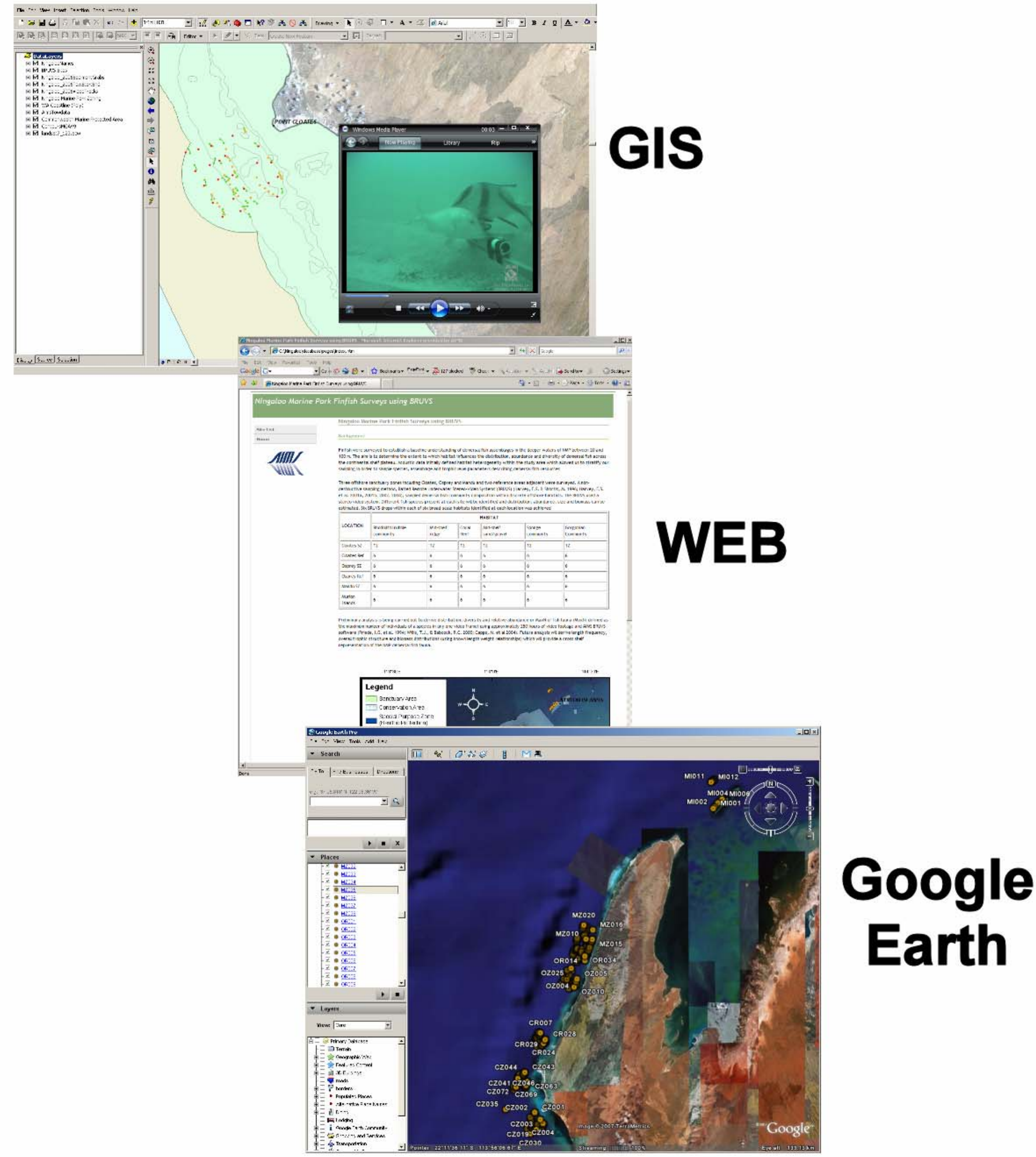

Figure 40. Different visual formats some of the data will take in the final GIS database

FIN FISH

The distribution and biodiversity of deepwater benthic fishes of the northern Ningaloo Marine Park

Introduction

This research aims to characterize the structure and distribution of deepwater fish assemblages (greater than 10 m depth) outside the crest of the Ningaloo Reef. It will provide information about the diversity, spatial distribution and habitat affiliation of demersal fin fishes across a range of depths and habitats within the northern section of the NMP (Fig. 41).

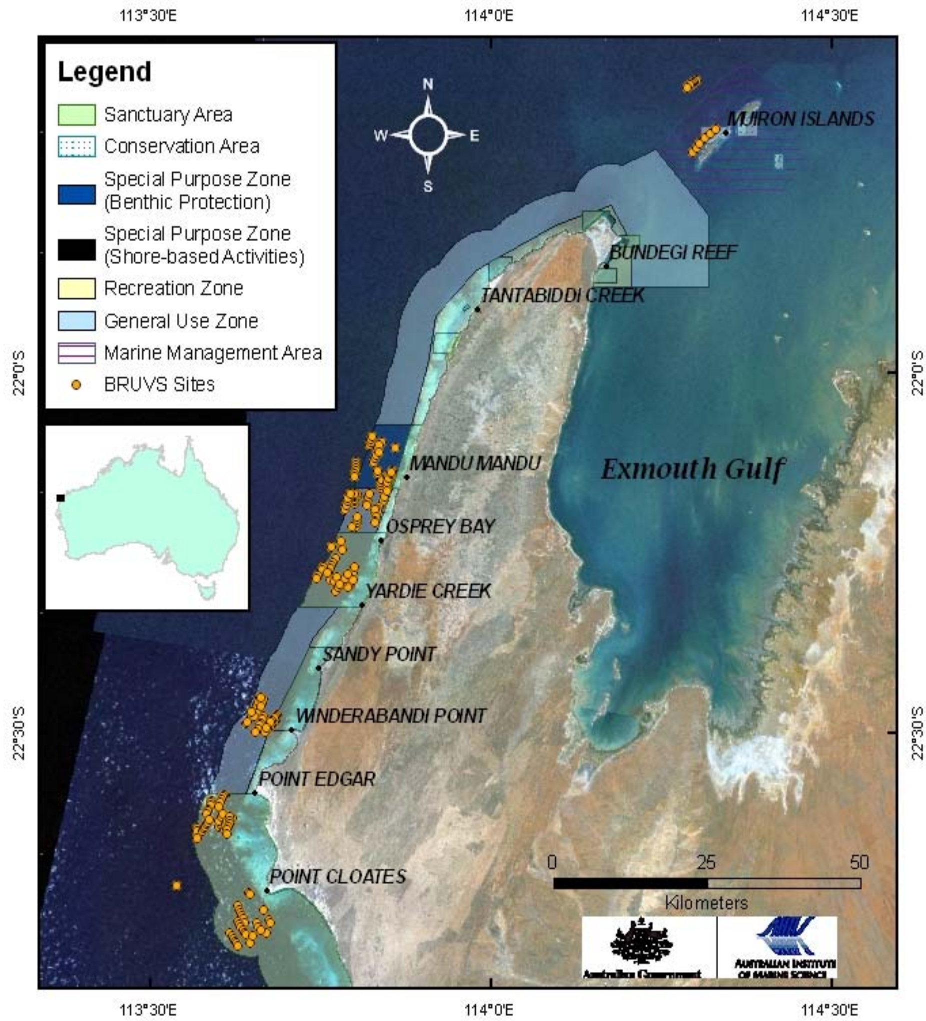

Figure 41. Stereo-BRUVs sampling locations in the northern NMP (compiled by Felicity McAllister, AIMS)

Methods

The field survey was planned around the outcomes of the towed video and acoustic survey undertaken by AIMS staff and FUGRO in April of 2006. The towed video and acoustic survey provided information on the distribution of benthic habitats in the area between the 15 and 100 m depth contours and allowed us to target sampling within specific habitats and depths. Within these areas a number of random samples were allocated. Sampling occurred in five areas including Mandu, Osprey and Cloates Sanctuary Zones, and Osprey and Cloates reference areas (Figure 41, Table 3).

Table 3. Depth/habitat factor groups and corresponding stereo-BRUVS replicates undertaken.

Depth / Habitat	Replicates
90+ sponge sand	23
90+ sand	17
70-90 sponge sand	26
70-90 sand	27
50-70 rhodolith	27
50-70 sand	16
50-70 sponge sand	2
30-50 sand	7
30-50 coral reef	11
30-50 rhodolith	27
10-30 rhodolith	2
10-30 coral reef	27
Total	**185**

Data collection

The survey investigated the diversity and relative abundances of demersal fish and elasmobranchs at five areas between 22 April and 20 May 2006 (Figure 41). Water depths at all areas ranged from 15–100 m and 185 stereo-Baited Remote Underwater Video System (stereo-BRUVS) samples in total were collected. The stereo-BRUVS (see Harvey and Shortis, 1996, 1998; Harvey et al. 2002 for stereo-video design and measurement procedures) used Sony HC15 digital camcorders within waterproof housings. Bait arms made of 20 mm plastic conduit with a standard rock lobster bait canister fastened to one end were attached to the stereo-video frame and detached after deployment (Watson et al. 2005). We used ~ 800 gms of crushed *Sardinops sagax* placed in the bait bag for each deployment. The stereo-BRUVS were retrieved after recording for one hour at each station. At deep sites where available light was extremely low on the seafloor, the stereo-BRUVS were set to record on night shot. Stereo-BRUVS rather than single cameras were used due to their ability to capture a baseline of the relative abundance of fishes and their length frequency. Single video BRUVS can only provide a measure of absence or presence of a species as data cannot be standardized for area sampled. Stereo-BRUVs facilitate measurement of distance (Harvey et al. 2004) allowing a consistent area to be defined and used spatially and temporally. This report presents an analysis of demersal fish presence/absence data. The stereo-BRUVS measurements necessary for quantitative counts are currently being analysed and will be present in subsequent reports.

Image analysis

Interrogation of each tape was conducted using a custom interface (BRUVS1.5.mdb©, Australian Institute of Marine Science 2006) to manage data from field operations, tape reading, capture the timing of events, capture reference images of the seafloor and fish in the field of view. The following data were recorded for each species; the time of first sighting, time of first feeding at the bait, the maximum number seen together at any one time on the whole tape (*MaxN)*, time at which *MaxN* occurred, and any intraspecific and interspecific behaviour. The use of *MaxN* as an estimator of relative abundance has been reviewed in detail by Cappo et al. (2003, 2004). Estimates of *MaxN* are considered conservative, particularly in areas where fish occur in high densities.

Statistical analysis

Two outlying stereo-BRUVS drops where no species were recorded were omitted from this analysis. Records of schooling fish species that appeared in high numbers (100s - 1000s) on individual stereo-BRUV samples but were seen rarely on other samples were also omitted.

Assemblage data

A two way non-parametric multivariate analysis of variance (PERMANOVA, Anderson 2001, Anderson and Robinson 2003, Anderson 2005, Anderson and Gorley 2007) was used to detect differences in fish assemblages between habitats and depth zones. The statistical analyses consisted of two factors: depth (five levels, fixed) and habitat (four levels, fixed). Because not all habitats were present in all depth zones, there needs to be further thought given to whether habitat should be classified as a random factor nested within depth. The data was transformed for presence/absence of species and the Bray Curtis dissimilarity matrix used prior to the PERMANOVA.

Because the use of MaxN for analysing stereo-BRUVS video tapes results in conservative estimates of the relative abundance of fish (Cappo et al. 2003). A Modified Gower Logbase 10 dissimilarity measure (Anderson et al. 2006) will be used when we analyse the final data set based on relative abundances. For the assemblage data Modified Gower Log10 places less emphasis on compositional change of the assemblage and more on changes in relative abundance (Anderson et al. 2006). For each term in the analysis, 4999 permutations of the raw data units were computed to obtain *P*- values. Where significant main effects or interactions were detected, pair-wise comparisons were undertaken to investigate where the differences were occurring.

To visually compare the assemblages between different depths and habitats, plots of the principal coordinates were constructed from a constrained Canonical Analysis of Principal Coordinates (CAP) (Anderson and Robinson 2003, Anderson and Willis 2003).

Species richness

To assess how accurately stereo-BRUVS reflected overall species richness, species accumulation curves were constructed. Three indices of species accumulation were used including: the observed dataset itself, the Chao2 estimator based upon presence/absence data and Jacknife 1 estimator based on species that occur only in one sample (Clark and Warwick 2001). By considering species that occur only once, the Jacknife1 estimator provides a curve that estimates the rate of accumulation of rare species, therefore providing a measure of sampling efficiency of the stereo-BRUVS. Alternatively the Chao2 estimator is based on presence absence data, thereby incorporating consideration of the accumulation of both rare and common species with sampling intensity.

Statistical differences were tested for in species richness (calculated as the sum total number of all fish species (*Nsp*)) sampled by stereo-BRUVS between different depths and habitats. Because normality was not a reasonable assumption, due to the predominance of zeros and the variability amongst habitats and depth zones, permutational analysis of variance was used (Anderson and Millar 2004). The data was analysed using the model described above (4999 permutations) based on Euclidean distance with no transformation (Anderson and Millar 2004).

Results

Assemblage structure

There was a significant interaction between multivariate assemblage structure, depth and habitat (Table 4). Detailed pair-wise comparisons investigating where these differences were occurring revealed that of the 22 possible combinations, 15 were found to be significant (Table 5). Within each depth range, pair-wise comparisons found significant differences in assemblages between sand, rhodolith and coral reef habitats in 30-50 m. There were also significant differences between sand and rhodolith habitat in 50-70 m and sand and sponge habitats in 50-70 m and 90+ m (Table 5). Alternatively, insignificant results between shallow rhodolith and coral reef habitats, and sponge and sand and sponge and rhodolith habitats at 50-70 m suggest factors in addition to those considered are responsible for the observed distribution of fish assemblages.

Table 4. Multivariate PERMANOVA results displaying the significance of interactions between assemblage structure and depth, habitat and depth/habitat terms, using 4999 permutations. Figures in bold indicate significant results.

Source	df	SS	MS	Pseudo-F	P(perm)
Habitat	3	26827	8942.4	3.244	***<0.001***
Depth	4	51282	12820	4.651	***<0.001***
Hab.x Depth	4	13982	3495.5	1.268	0.077
Res	191	5.26E+05	2756.5		
Total	**202**	**7.19E+05**			

The same habitats at different depths were often associated with significantly different fish fauna. Coral reefs in 15-30 m supported a different fish assemblage to those in 30-50 m. Fish assemblages in rhodolith habitat in 30-50 m differed significantly to those at 50-70 m. Fish assemblages differed with sand habitat between all depth ranges with the exception of 30-50 and 50-70 m depths. Likewise fish assemblages found in sponge habitat at 90+ m were different to those found at both 50-70 and 70-90 m depths (Table 5). Rhodolith habitat essentially supported similar fish assemblages across all depth ranges with the exception of those found in the midshelf depths of 30-50-70 m. Sponge and sand habitat supported similar fish assemblages between 50-70-90 m depths.

Table 5. Significance of pair-wise tests for presence/absence multivariate assemblage structure at all depth/habitat combinations.

Level	Groups	t	P(perm)
10_30	rhodolith, coral reef	0.972	0.530
30-50	sand, rhodolith	1.888	***<0.001***
30-50	sand, coral reef	1.929	***0.001***
30-50	rhodolith, coral reef	2.732	***<0.001***
50-70	sponge, sand	1.146	0.281
50-70	sponge, rhodolith	1.145	0.202
50-70	sand, rhodolith	1.426	***0.032***
70-90	sponge, sand	1.868	***<0.001***
90+	sponge, sand	1.575	***0.013***
coral reef	10-30, 30-50	1.447	***0.003***
rhodolith	10-30, 30-50	1.164	0.167
rhodolith	50-70, 30-50	1.762	***0.001***
rhodolith	50-70, 10-30	1.284	0.092
sand	50-70, 30-50	1.267	0.105
sand	70-90, 30-50	2.104	***<0.001***
sand	70-90, 50-70	1.774	***0.002***
sand	90+, 30-50	2.246	***<0.001***
sand	90+, 50-70	2.345	***<0.001***
sand	90+, 70-90	2.305	***<0.001***
sponge	70-90, 50-70	0.800	0.844
sponge	90+, 50-70	1.586	***0.007***
sponge	90+, 70-90	2.471	***<0.001***

A Canonical Analysis of Principle Components (CAP) was used to elucidate the constrained multivariate relationship between samples. This ordination displays the amount of difference in fish assemblages among habitat/depth groups and clearly displays the relative dissimilarity between samples, from coral reef sites in the bottom left to deepwater sponge sites in the bottom right (Fig. 42). This approach is also useful for identifying significant species of fish that drive the similarity between groups. A number of these species together with the significance of their correlation with depth/habitat groups is represented in the CAP ordination by vectors of varying length and direction. Clearly species such as *Variola louti* (coronation trout), *Lethrinus miniatus* (red-throat emperor) and *Pristipomoides multidens* (goldband snapper) are all strongly related to distinct depth/habitat groups identified in this study. This CAP analysis identified a total of 30 species that have an r value >0.3 for either CAP1 or CAP 2 (Table 6). The species are from a number of different families and functional groups, and all represent strong correlations with particular depth/habitat types.

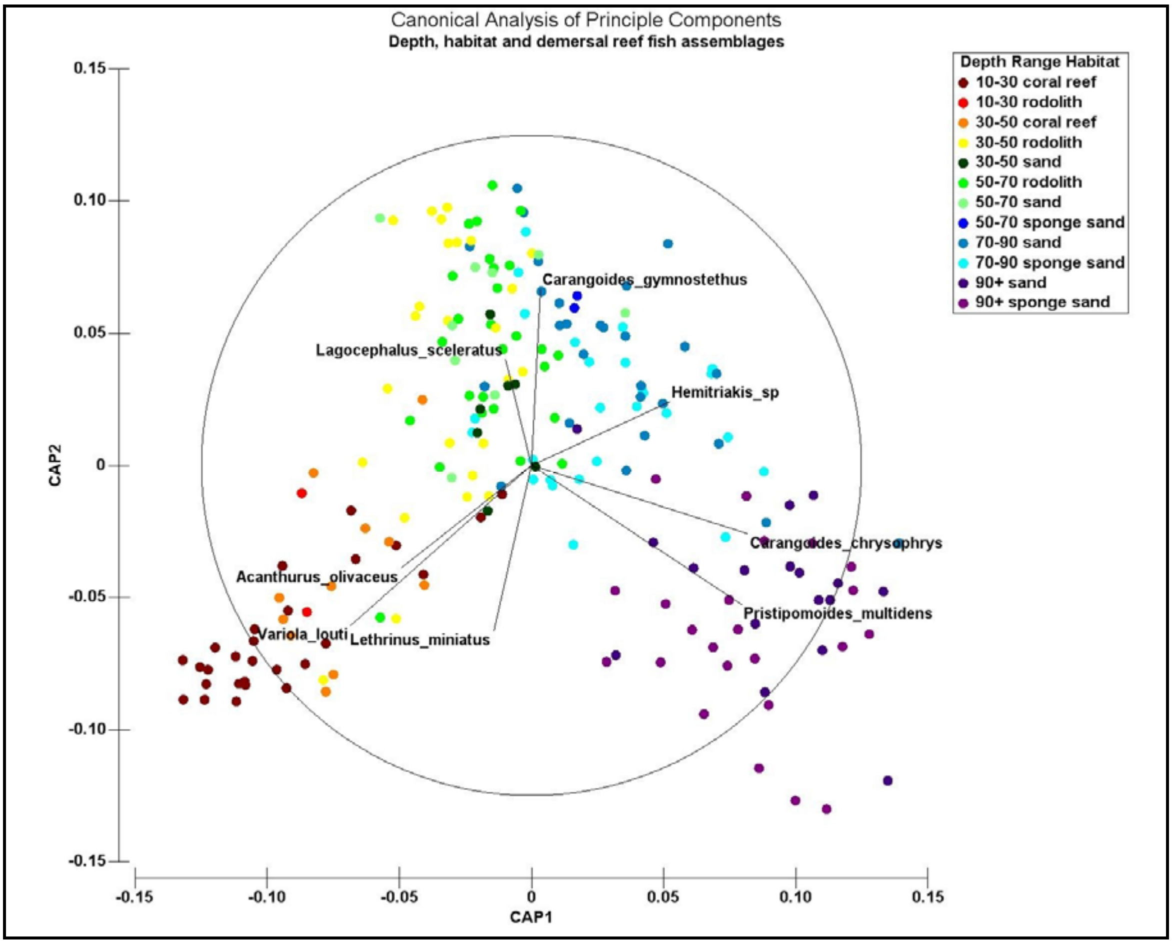

Figure 32. Plot constructed from a constrained Canonical Analysis of Principal Coordinates representing fish assemblages between different depth and habitat groups.

Table 6. Species with an r value >0.3 were identified and can explain a majority of the differences between habitat/depth groups. Species in bold are target recreational species.

Species	r Cap1	r Cap2
Abalistes_stellatus	0.18	0.55
Acanthurus_grammoptilus	-0.37	-0.30
Acanthurus_olivaceus	-0.39	-0.31
Argyrops_spinifer	**0.44**	**-0.20**
Bodianus_axillaris	-0.34	-0.30
Bodianus_bilunulatus	-0.46	-0.47
Carangoides_caeruleopinnatus	0.40	0.05
Carangoides_chrysophrys	0.65	-0.21
Carangoides_fulvoguttatus	**-0.29**	**0.34**
Carangoides_gymnostethus	**0.03**	**0.53**
Chaetodon_auriga	-0.31	-0.30
Chaetodon_lunula	-0.46	-0.38
Chaetodon_plebeius	-0.40	-0.35
Chaetodon_unimaculatus	-0.36	-0.32
Chromis_weberi	-0.30	-0.27
Ctenochaetus_striatus	-0.42	-0.35
Epinephelus_rivulatus	**-0.03**	**-0.31**
Fistularia_commersonii	-0.36	-0.17
Gymnocranius_audleyi	0.37	-0.17
Gymnothorax_javanicus	-0.46	-0.35
Hemitriakis_sp	0.42	0.19
Labroides_dimidiatus	-0.36	-0.29
Lagocephalus_sceleratus	-0.08	0.32
Lethrinus_atkinsoni	-0.63	-0.50
Lethrinus_miniatus	**-0.11**	**-0.50**
Lethrinus_nebulosus	**-0.21**	**0.26**
Lethrinus_ravus	-0.33	0.17
Lutjanus_sebae	**0.31**	**0.18**
Melichthys_vidua	-0.41	-0.35
Naso_lituratus	-0.38	-0.34
Parapercis_clathrata	-0.35	-0.21
Parupeneus_barberinoides	-0.40	-0.30
Parupeneus_cyclostomus	-0.47	-0.33
Parupeneus_spilurus	-0.18	-0.37
Pomacentrus_milleri	-0.35	-0.30
Pristipomoides_multidens	**0.64**	**-0.42**
Scarus_schlegeli	-0.35	-0.25
Scarus_sordidus	-0.43	-0.36
Thalassoma_lunare	-0.58	-0.49
Thalassoma_lutescens	-0.40	-0.28
Variola_louti	**-0.55**	**-0.49**
Zebrasoma_scopas	-0.39	-0.35

Species Richness

From the 185 stereo-BRUVS samples 319 species from 54 families were recorded (Appendix 5.1). A comparison of the species accumulation curves across all samples for observed species (Sobs), Jacknife1 and Chao2 indicators suggest that the stereo-BRUVS underestimate overall species richness for both commonly encountered and rare species. This indicates that a high rate of accumulation of rare species is a characteristic of using this particular sampling method in this environment (Fig. 43).

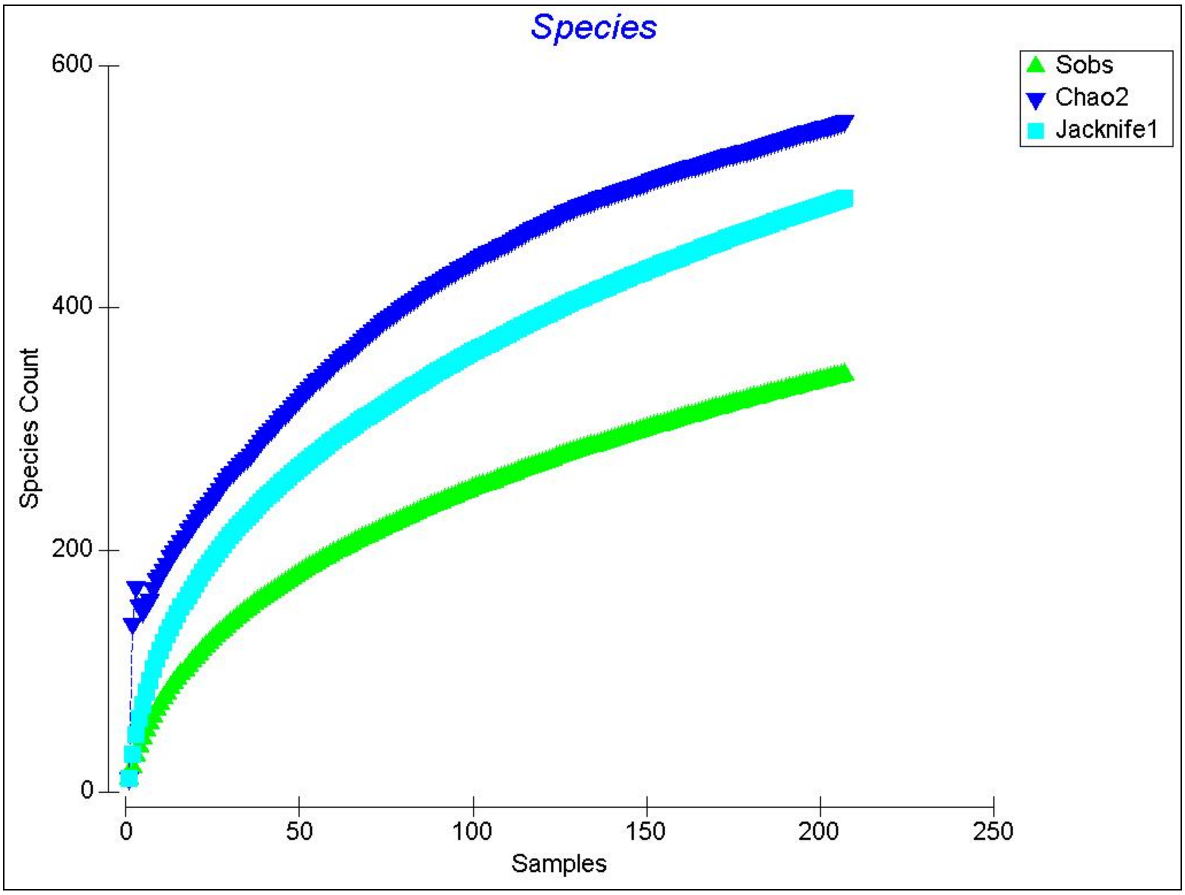

Figure 43. Overall species accumulation curve for offshore stereo-BRUVS samples in the Northern Ningaloo Marine Park. Indices measured include the observed species (Sobs), Jacknife 1 estimator based on species that occur only in one sample and the CHAO 2 estimator based upon presence absence data (Clark and Warwick, 2001).

The results of the univariate PERMANOVA highlight a significant main effect for habitat and depth (Table 7). More detailed consideration of the significant habitat interaction reveals these differences arise between; sand habitat and all of coral reef, rhodolith and sponge habitats; and rhodolith and coral reef habitats (Table 8). Alternatively, the significant species richness interaction with depth is driven primarily by the differences between 15-30 and 30-50 m depth ranges coinciding with the loss of photosynthetic benthos (Table 8). There is a significant interaction of declining species richness with increasing depths across all habitat types with the exception of sand which is in the opposite direction (Fig. 44).

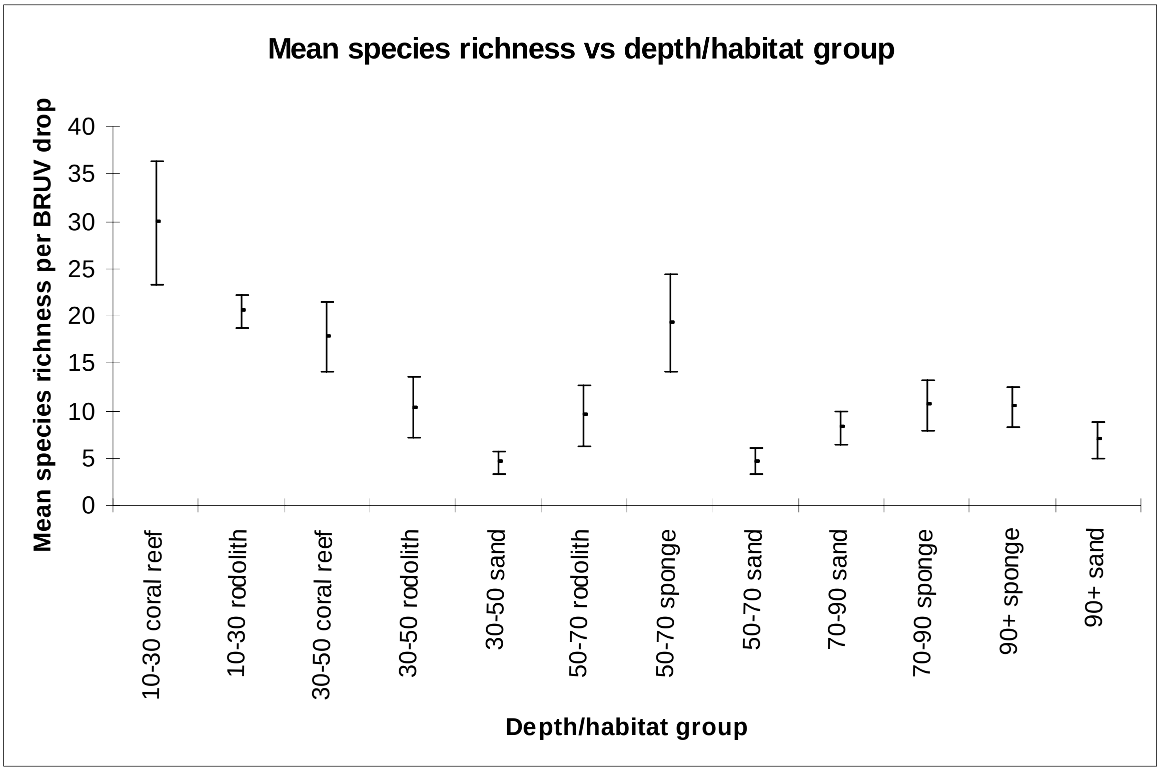

Figure 44. Mean species richness with S.E. for each of 12 depth/habitat groups defined in this study

Table 7. Univariate PERMANOVA results displaying the significance of interactions between species richness and depth, habitat and depth/habitat terms using 4999 permutations. Figures in bold indicate significant results

Source	df	SS	MS	Pseudo-F	P(perm)
Habitat	3	1644.4	548.14	12.547	***<0.001***
Depth	4	506.12	126.53	2.896	***0.033***
Hab. X Depth	4	83.089	20.772	0.475	0.717
Res	191	8344.1	43.686		
Total	**202**	**18016**			

Table 8. Significance of pair-wise tests for univariate species richness at all depth/habitat combinations using 4999 permutations

Groups	t	P(perm)
sponge, sand	3.954	***<0.001***
sponge, rhodolith	1.169	0.204
Sponge, coral reef	No test, df = 0	
sand, rhodolith	3.499	***0.002***
sand, coral reef	4.712	***<0.001***
rhodolith, coral reef	2.917	***0.008***
90+, 70-90	1.297	0.191
90+, 50-70	0.348	0.720
90+, 10-30	No test, df = 0	
90+, 30-50	0.892	0.373
70-90, 50-70	0.236	0.813
70-90, 10-30	No test, df = 0	
70-90, 30-50	1.296	0.194
50-70, 10-30	1.675	0.107
50-70, 30-50	0.280	0.781
10-30, 30-50	2.293	***0.030***

Future Progress

In addition to the species richness and assemblage data presented here, stereo-video will be analysed for relative abundance and size frequency data. The fish lengths and distances will be measured using a stereo photo-comparator. All of the imagery has been converted from digital video to AVIs (audio video interleaved files) and compressed with DivX to allow this. To measure fish lengths and distance we are using PhotoMeasure© (www.seagis.com.au). Over 100 stereo-BRUVS tapes have been analysed for length measures, with completion of this task pending. This will allow a far more detailed consideration of the interactions between demersal reef fish assemblages and depth and habitat in the northern NMP.

DISCUSSION

The singlebeam and multibeam acoustics surveys achieved during the 2006 have provided detail of the seafloor in a limited area of the NMP (Figure 3). Different habitats, based on bathymetry and geomorphology could be distinguished within this area. Sediment generation, transport and deposition patterns were evident, ridge systems could be identified, and patches of previously unknown rubble mounds were evident. A considerable amount of spatial detail was gained. Acoustics combined with sedimentalogical and geomorphological data enabled us to categorise different habitats according to depth, topography, substrate stability, hardness and roughness, grain size and suitability to support significant biota, from the back of the reef slope (beyond the fringing reef) out to the edge of the continental shelf plateau. The significance of the acoustic data collected in 2006 has prompted the survey team to reassess the survey plan to try and include the whole of the NMP in the next acoustic survey, try to improve the resolution of the data to allow for easier and to provide more accurate interpretations of the data. Therefore, more thorough and accurate acoustic data requisition will take place prior to sediment, benthos, and benthic fish surveys. This will ensure all potential habitats are included in the survey design, and adequate replication is accomplished throughout the survey area.

There are a number of important considerations when developing generalised habitat classification schemes (Roff and Taylor 2000). Initially, the potential (global) set of factors that can be used to discriminate among habitat types must be determined by what can be mapped from available geophysical data and what can be readily obtained by remote or *in situ* sensing (Roff et al. 2003). Secondly, there may be some redundancy between factors or some may need to be computed in different ways, and some combinations of factors may be used as surrogates for others (Roff et al. 2003).

Thirdly, the actual combination of factors chosen for a classification hierarchy within any region will depend upon the natural range of variation in each one (Roff et al. 2003). In tropical and sub-tropical regions, where there is little variation in several geophysical factors (e.g. temperature, salinity, stratification), we may need to place greater reliance on direct mapping of the biological communities themselves (Roff et al. 2003).

Developments in sidescan, singlebeam and multibeam sonar surveying techniques in conjunction with traditional survey techniques and precise navigation using GPS enables us to construct detailed images of the sea floor, and now even discriminate objects on the sea floor 0.5-10 m in size, depending on water depth (Pickrill and Todd 2003). These sonar systems operate by ensonifying a narrow strip of sea floor across the survey ship's track and detecting the bottom echo, allowing a measure of seabed elevation and amplitude of the backscattered acoustic signal (Pickrill and Todd 2003). The amplitude of the backscatter return off the sea floor materials enhances geological interpretation (Pickrill and Todd 2003). Due to the complexity of backscatter, it is interpreted in conjunction with other geophysical data (e.g. seismic reflection and sidescan sonograms) and geological samples of sea floor materials (Pickrill and Todd 2003). Pickrill and Todd (2003) suggest that nearly all decisions regarding use and management of seabed resources can be addressed by mapping three core elements of the environment: the depth and shape of the sea floor; the texture and composition of the sediments at, and immediately beneath, the sea floor and the plants and animals that constitute the benthic community.

Significant findings from this study include discovery of diverse sponge and soft coral communities in the deeper waters of the continental shelf (50-110 m) with potentially high and unique biodiversity values, two large ridge systems parallel to the coastline supporting a vast array of species with diverse piscatorial associations, and several patches of previously unknown and unidentified rubble mounds. Low species diversity in the areas behind the back reef may be due to sediment transport and deposition, whereas, areas in deep water closer to the NMP seaward boundary with more stable sediments are inhabited by diverse benthic assemblages. Few hard corals were evident beyond 40-50 m during the survey. Large sand and rhodolith habitats were also evident. Even though there have been very few surveys previously in this region, from the few surveys conducted north of the NMP, Hooper et al. (2002) identified the northwest shelf of Australia as a sponge biodiversity 'hotspot'. Our results support this conclusion.

ACKNOWLEDGEMENTS

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REFERENCES

Abdo, D., Burgess, S., Coleman, G. and Osborne, K. 2003. Surveys of Benthic Communities Using Underwater Video. Long-term Monitoring of the Great Barrier Reef Standard Operational Procedure Number 9, pp. 47. Australian Institute of Marine Science, Townsville, Queensland, Australia.

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. Aust. Ecol. 26, 32-46.

Anderson, M.J., Gorley, R.N. 2007. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E: Plymouth, UK.

Anderson, M.J., Millar, R.B. 2004. Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. J. Exp. Mar. Biol. Ecol. 305: 191-221.

Anderson, M.J., Robinson, J. 2003. Generalised discriminant analysis based on distances. Aust. N.Z. J. Stat 45(3): 301-318

Anderson, M.J., Willis, T.J. 2003. Canonical analysis of principle coordinates: A useful method of constrained ordination for ecology. Ecol. 82(2): 511-525

Anderson, M.J., Ellingsen, K.E., McArdle B.H. 2006. Multivariate dispersion as a measure of beta diversity. Ecol. Lett. 9(6):683-693.

Bale, A.J., Kenny, A.J. 2005. Chapter 2: Sediment Analysis and Seabed Characterisation. In: Methods for the Study of Marine Benthos. 3rd Edition (Ed. A. Eleftheriou and A. McIntyre), pp. 43-86. Blackwell Publishing.

Ball, D., Blake, S. Plummer, A. 2006. Review of Marine Habitat Classification Systems. Parks Victoria Technical Series No. 26, pp 50. Parks Victoria.

Barnes, P.B., Davis, A.R., Roberts, D.E. 2006. Sampling patchily distributed taxa: a case study using cost-benefit analyses for sponges and ascidians in coastal lakes of New South Wales, Australia. Mar. Ecol. Prog. Ser., 319: 55-64.

Beaman, R.J. Daniell, J.J., Harris, P.T. 2005. Geology: benthos relationships on a temperate rocky bank, eastern Bass Strait, Australia. Mar. Fr. Res., 56: 943-958.

Blott, S.J., Pye, K. 2001. GRADISTAT: A grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf. Process. Landforms 26: 1237-1248.

Burke, L., Kura, Y., Kassem, K., Revenga, C., Spalding, M., McAllister, D. 2001. Pilot analysis of global ecosystems: coastal ecostyems. World Resources Institute, Washington, 77pp. http://www.wri.org/wr2000/coast_page.html.

Cappo, M., Harvey, E., Malcolm, H., Speare, P. 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of Marine Protected Areas. In: Aquatic Protected Areas - what works best and how do we know?", (Eds Beumer, J.P., Grant, A., and Smith, D.C.) World Congress on Aquatic Protected Areas proceedings, Cairns, Australia, August 2002. p 455-464.

Cappo, M., Speare, P., De'ath, G. 2004. Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. J. Exp Mar. Bio. Ecol. 302.123-152.

Carrigy, M.A., Fairbridge, R.W. 1954. Recent Sedimentation, Physiography and Structure of the Continental Shelves of Western Australia. J. Roy. Soc. of W.A., 38: 65-95.

Clarke, K. R., Warwick, R. M. 2001a. A further biodiversity index applicable to species lists: variation in taxonomic distinctness. Mar. Ecol. Prog. Ser. Vol. 216: 265-278.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol. 19: 117-143.

Clarke, K.R., Warwick, R.M. 2001b. Change in marine communities: An approach to statistical analysis and interpretation. 2nd edition (PRIMER-E: Plymouth, UK).

Collins, L.B. 1988. Sediments and history of the Rottnest Shelf, southwest Australia: a swell dominated, non-tropical carbonate margin. Sed. Geol., 60:15-50.

Collins, L.B., France, R., Zhu, Z.R., Wyrwoll, K.H. 1997. Warm-water platform and cool-water carbonates of the Abrolhos Shelf, southwest Australia, in James, N.P. and Clarke, J.D.A., eds., Cool-Water Carbonates: SEPM, Special Publication 56:, 1: 23-36.

Collins, L.B., Read, J.F., Hogarth, J.W. Coffey, B.P. 2006. Facies, outcrop gamma ray and CO isotopic signature of exposed Miocene subtropical continental shelf carbonates, North West Cape, Western Australia. Sed. Geol., 185: 1-19.

Collins, L.B., Zhu, Z.R., Wyrwoll, K.H., Eisenhauer, A. 2003. Late Quaternary structure and development of the northern Ningaloo Reef, Australia. Sed. Geol., 159: 81-94.

de Voogd, N.J., Cleary, D.F.R., Hoeksema, B.W., Noor, A., van Soest, R.W.M. 2006. Sponge beta diversity in the Spermonde Archipelago, SW Sulawesi, Indonesia. Mar. Ecol. Prog. Ser., 309: 131-142.

Diaz, R.J., Solan, M., Valente, R.M. 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. J. Env. Man., 73: 165-181.

Dix, G.R., James, N.P., Kyser, T.K., Bone, Y., Collins, L.B. Genesis and dispersal of carbonate mud relative to Late Quaternary sea-level change along a distally-steepened carbonate ramp (Northwestern Shelf, Western Australia). J. Sed. Res., 75: 665-678.

Eggleston, D.B., Dahlgren, C.P. 2001. Distribution and abundance of Caribbean spiny lobsters in the Key West National Wildlife Refuge: relationship to habitat features and impact of an intensive recreational fishery. Mar. Fr. Res., 52: 1567-1576.

Folk, R.L. 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. J. Geol. 62: 344-359.

Folk, R.L., Andrews, P.B., Lewis, D.W. 1970. Detrital sedimentary rock classification and nomenclature for use in New Zealand. N.Z. J. Geol. Geophys.13:937-68.

Freeman, S.M., Rogers, S.I. 2003. A new analytical approach to the characterisation of macro-epibenthic habitats: linking species to the environment. Est., Coast. Shelf Res., 26: 1258-1280.

Fromont, J., Vanderklift, M.A., Kendrick, G.A. 2006. Marine sponges of the Dampier Archipelago, Western Australia: patterns of species distributions, abundance and diversity. Biod. Cons., 15: 3731-3750.

Harvey E.S, Fletcher D., Shortis M.R., Kendrick, G.A. 2004. A comparison of underwater visual distance estimates made by SCUBA divers and a stereo-video system: Implications for underwater visual census of reef fish abundance. Mar. Fre. Res. 55: 573-580.

Harvey, E.S., Shortis, M. 1996. A system for stereo?video measurement of subtidal organisms. Mar. Tech. Soc. J. 29 (4), 10-22.

Harvey, E.S., Shortis M. 1998. Calibration stability of and underwater stereo?video system: implications for measurement accuracy and precision. Mar. Tech. Soc. J. 32 (2), 3-17.

Harvey, E.S., Shortis, M.R., Stadler, M., Cappo, M., 2002. A comparison of the accuracy and precision of measurements from single and stereo? video systems. J. Mar. Soc. Technol. 36 (2), 38-49.

Hocking, R.M., Williams, S.J., Lavaring, I.H., Moore, P.S. 1983. Winning Pool-Manilya, Westren Australia 1:250,000 Geological Series Explanatory Notes. Sheets SF49-13, SF50-13 International Index. Geological Survey of Western Australia, Perth, Western Australia.

Hooper, J.N.A., van Soest, R.W.M. 2002. Systema Porifera: A Guide to the Classification of Sponges. Kluwer Academic/Plenum Press, New York.

Hooper, J.N.A., Wiedenmayer, F. 1994. Porifera. In: Wells, A. (ed.) Zoolog. Catalogue Aust. 12: 1-621.

Hooper, J.N.A., Kennedy, J.A., Quinn, R.J. 2002. Biodiversity hotspots, patterns of richness and endemism, and taxonomic affinities of tropical Australian sponges (Porifera). Biod. Cons., 11: 851-885.

James, N.P., Bone, Y., Kyser, T.K., Dix, G.R., Collins, L.B. 2004. Carbonate sedimentation on a tropical oceanic ramp: northwestern Australia. Sedimentology, 51:1-27.

James, N.P., Collins, L.B., Bone, Y., Hallock, P. 1999. Subtropical carbonates in a temperate realm: modern sediments on the southwest Australian shelf. J. Sed. Res., 69: 1297-1321.

Jordan, A., Lawler, M., Halley, V., Barrett, N. 2005. Seabed habitat mapping in the Kent Group of islands and its role in marine protected area planning. Aquatic Conservation: Marine and Freshwater Ecosystems, 15: 51-70.

Johnstone, M.H., Jones, D.K., Pearson, G.R., Smith, D.N., Thomas, G.M. 1976. The Phanerozoic of the Perth and Carnarvon Basins, WesternAustralia. 25th International Geological Congress, Sydney, Excursion Guide 39c.

LeProvost, Dames, Moore. 2000. Ningaloo Marine Park (Commonwealth Waters) Literature Review Prepared for Environment Australia. Report No. R726. Perth Western Australia.

MPRA CALM and CCPAC. 2005. Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005-2015, Management Plan No. 52, pp. 112.

Offshore Acreage Release 2006. Barrow and Exmouth sub basins, Carnarvon Basin, Western Australia. Department of Industry Tourism and Resources. http://www.industry.gov.au/acreagereleases/2006/HTML/Geo/areas/exmouth/exmouth _main.html

Pickrill, R.A., Todd, B.J. 2003. The multiple roles of acoustic mapping in integrated ocean management, Canadian Atlantic continental margin. Ocean & Coastal Management, 46: 601-614.

Post, A.L. 2006. Physical surrogates for benthic organisms in the southern Gulf of Carpentaria, Australia: Testing and application to the Northern Planning Area. Geoscience Australia, Record 2006/09. 46 pp.

Rees, M., Heyward, A., Cappo, M., Speare, P., Smith, L. 2004. Ningaloo Marine Park Initial Survey of Seabed Biodiversity in Intermediate and Deeper Waters (March 2004). Australian Institute of Marine Science, Townsville, Queensland.

Roberts, C.M., Andelman, S., Branch, G., Bustamante, R.H., Castilla, J.C., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., McArdle, D., Possingham, H.P., Ruckelshaus, M., Warner, R.R. 2003a. Ecological criteria for evaluating candidate sites for marine reserves. Ecol. Apps., 13(1) Supplement: 199-214.

Roberts, C.M., McClean, C.J., Veron, JE.N., Hawkins, J.P., Allen, G.R., McAllister, D.E., Mittermeier, C.G., Schueler, F.W., Spalding, M., Wells, F., Vynne, C., Werner, T.B. 2002. Marine Biodiversity Hotspots and Conservation Priorities for Tropical Reefs. Science 295: 1280-1284.

Roff, J.C., Taylor, M.E. 2000. National frameworks for marine conservation: a hierarchical geophysical approach. Aquatic Conservation: Marine and Freshwater Ecosystems, 10: 209-223.

Roff, J.C., Taylor, M.E., Laughren, J. 2003. Geophysical approaches to the classification, delineation and monitoring of marine habitats and their communities. Aquatic Conservation: Marine and Freshwater Ecosystems, 13: 77-90.

Speare, P., Cappo, M., Rees, M., Brownlie, J., Oxley, W. 2004. Deeper Water Fish and Benthic Surveys in the Lord Howe Island Marine Park (Commonwealth Waters): February 2004. Australian Institute of Marine Science, Townsville, Queensland.

Stirling, C.H., Esat, T.M., Lambeck, M.T., McCulloch, M.T. 1998. Timing and duration of the Last Interglacial: evidence for a restricted interval of widespread coral reef growth. Earth Planet. Sci. Lett. 160: 745-762.

Udden, J.A. 1914. Mechanical composition of clastic sediments. Bulletin of the Geol. Soc. Am. 25: 655-744.

Van der Graaff, W.J.E., Denman, P.D., Hocking, R.M., Baxter, J.L. 1980. Explanatory Notes on the Yanrey-Ningaloo 1:250,000 Geological Series, Geological Survey of Western Australia, Perth, Western Australia, 1-24.

Watson, D.L., Harvey, E.S., Anderson, M.J., Kendrick, G.A. 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. Mar. Biol. 148, 415-425.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. J. Geol. 30: 377-392.

Western Australian Museum. 1988. A feasibility study for the sampling of benthos in the Commonwealth waters of the Ningaloo Marine Park. Report to the Australian National Parks & Wildlife Service by the Western Australian Museum, Perth.

Wilson, B.R. 1972. New species and records of Volutidae from Western Australia. J. Mal. Soc. Aus., 2(3): 339-360.

Worheide, G., Sol-Cava, A.M., Hooper, J.N.A. 2005. Biodiversity, molecular ecology and phylogeography of marine sponges: patterns, implications and outlooks. Integr. Comp. Biol., 45: 377-385.

Wyrwoll, K.-H., Kendrick, G., Long, J.A. 1993. The geomorphology and Late Cenozoic geomorphological evolution of the Cape Range-Exmouth Gulf region. In: Humphreys, W.F. (Ed.), The Biogeography of Cape Range, Western Australia. Records of the Western Australian Museum. Supplement 45.

Zacharias, M.A., Roff, J.C. 2001b. Explanation of patterns of intertidal diversity at regional scales. J. Biog., 28: 471-483.

APPENDICES

APPENDIX 1: ACOUSTICS

Appendix 1.1: Singlebeam sounding maps
Appendix 1.2: Fugro Multibeam summary report (see electronic PDF)

APPENDIX 2: GEOMORPHOLOGY AND SEDIMENTOLOGY

Appendix 2.1: Sediment grab location maps
Appendix 2.2: Sediment grab operations data
Appendix 2.3: Grain size statistics
Appendix 2.4: Grain size percentages
Appendix 2.5: Grain size descriptive statistics
Appendix 2.6: Cross-shelf profiles of grain size percentages for all sampling sites

APPENDIX 3: TOWED VIDEO

Appendix 3.1: Towed Video operations data

APPENDIX 4: BENTHIC SLED

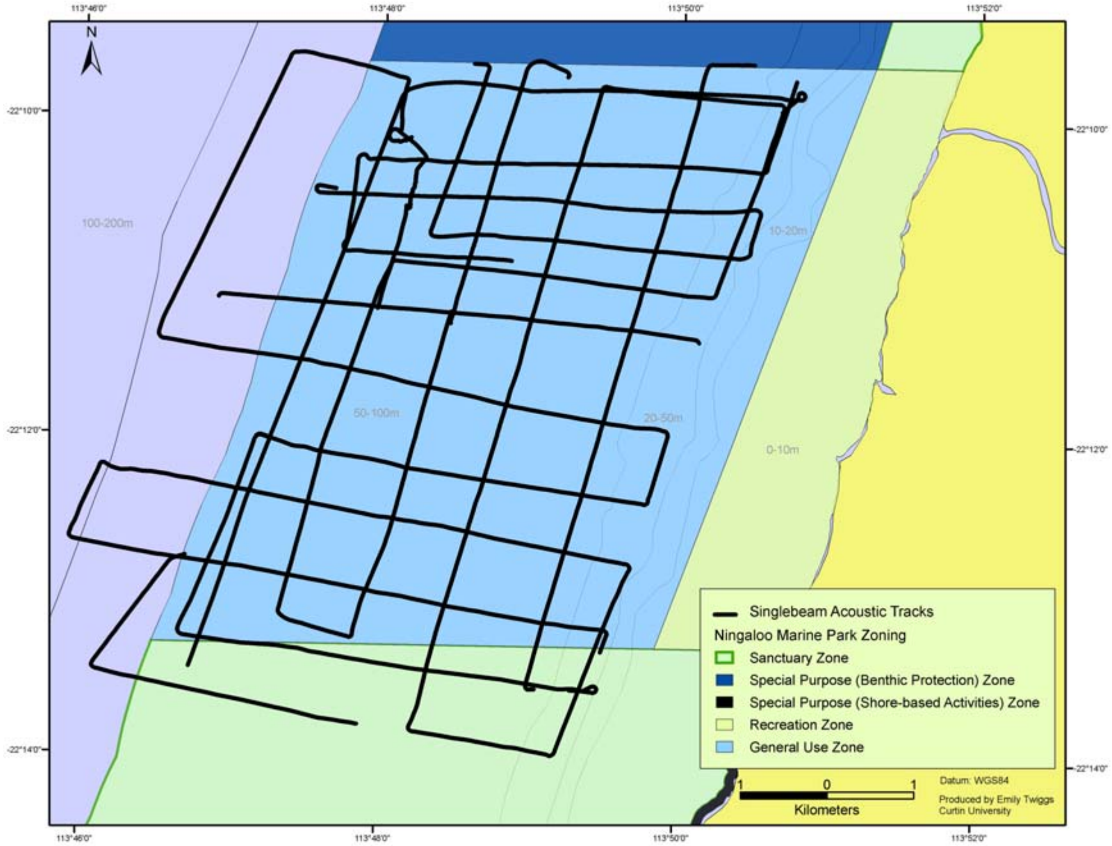
Appendix 4.1: WA Museum summary report

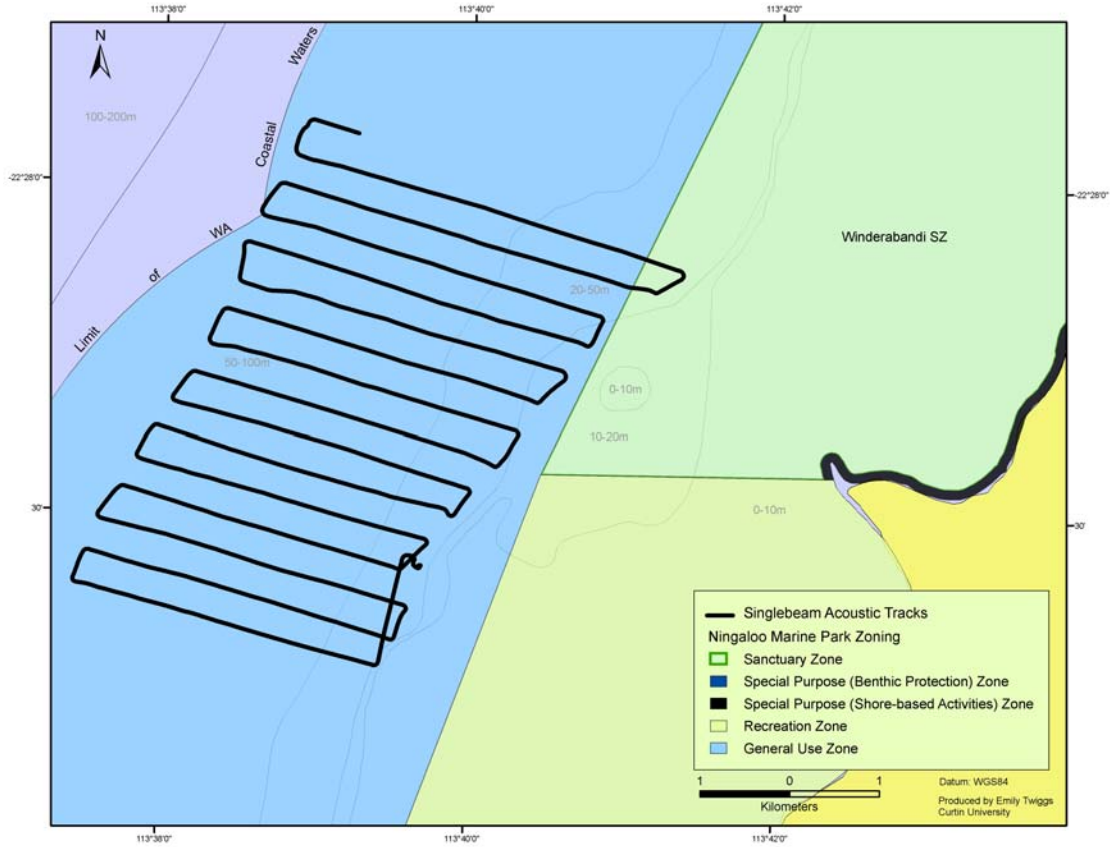
APPENDIX 5: STEREO-BAITED REMOTE UNDERWATER VIDEO

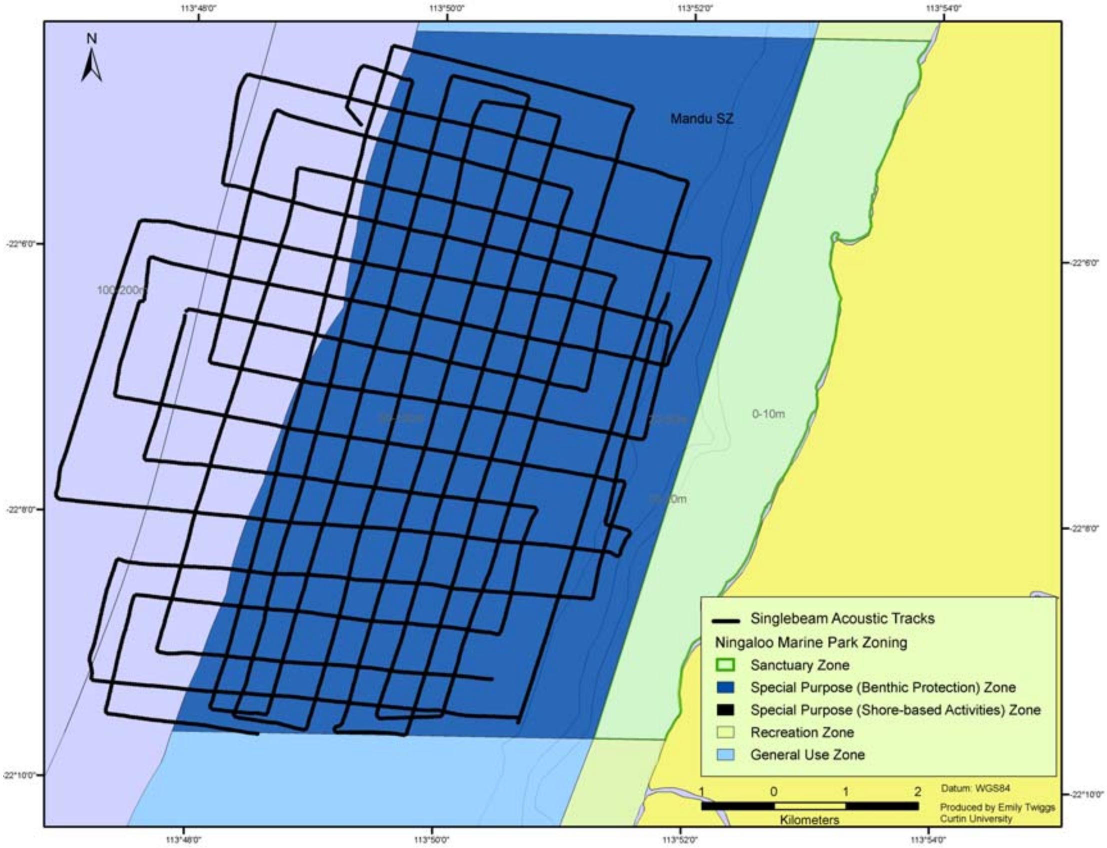
Appendix 5.1: Demersal reef fish species list
Appendix 5.2 Stereo-BRUVS operations data

Appendix 1: Acoustics

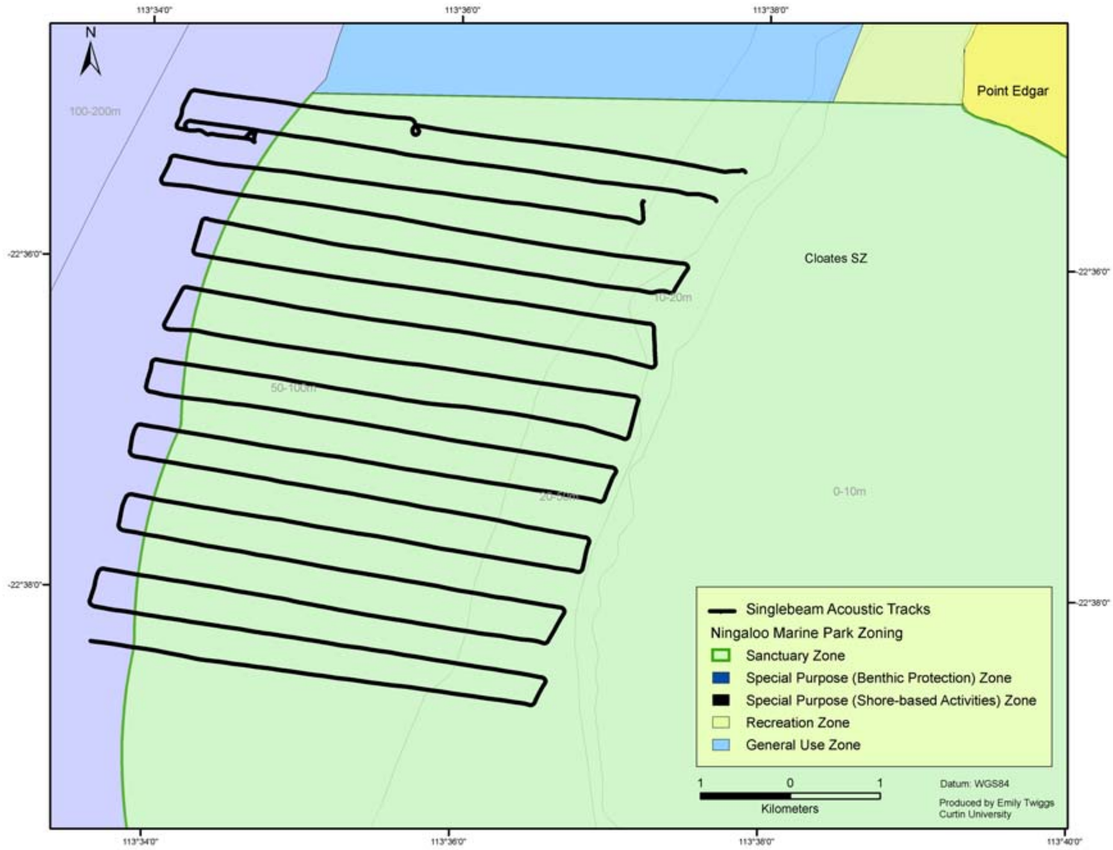
Appendix 1.1: Singlebeam sounding maps






Mandu SZ
100-200m
0-10m
Singlebeam Acoustic Tracks
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University

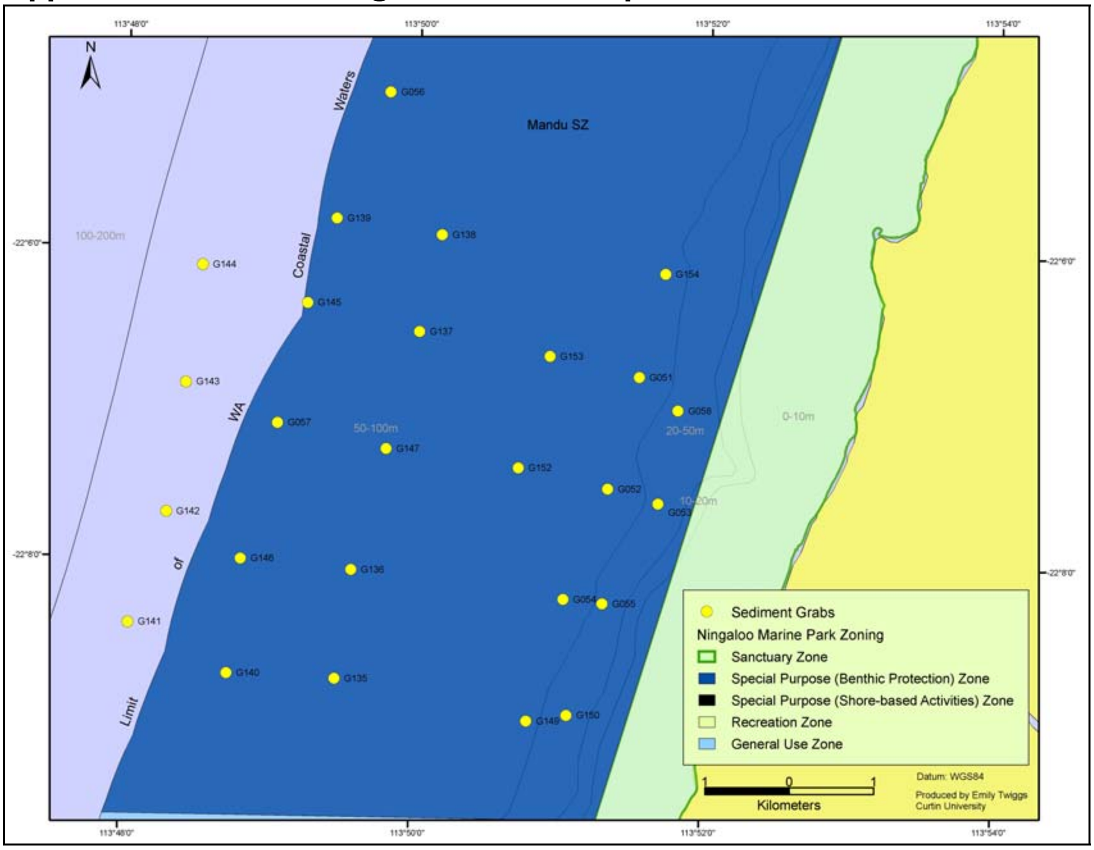

Point Cloates
Cloates SZ
10-20m
0-10m
50-100m
Singlebeam Acoustic Tracks
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University

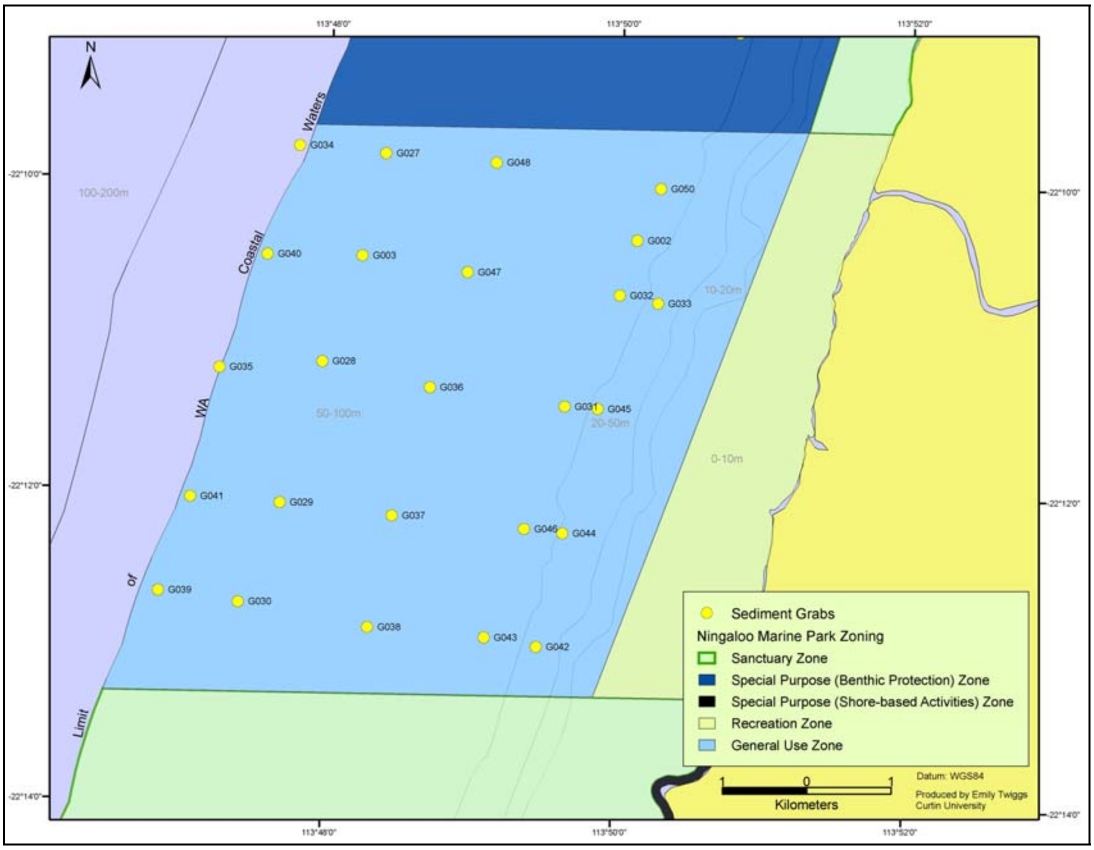

Point Edgar
Cloates SZ
100-200m
50-100m
10-20m
20-50m
0-10m
Singlebeam Acoustic Tracks
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University

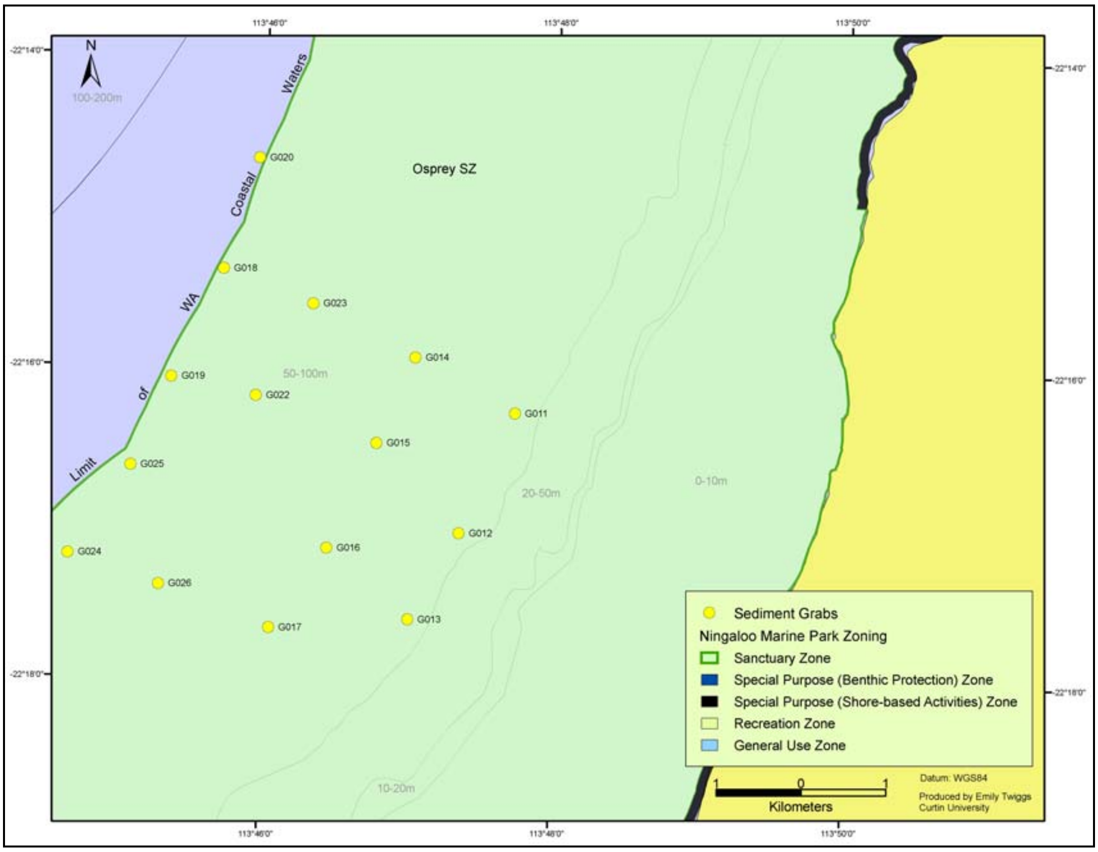
Appendix 1.2: Fugro Multibeam summary report (see electronic PDF)

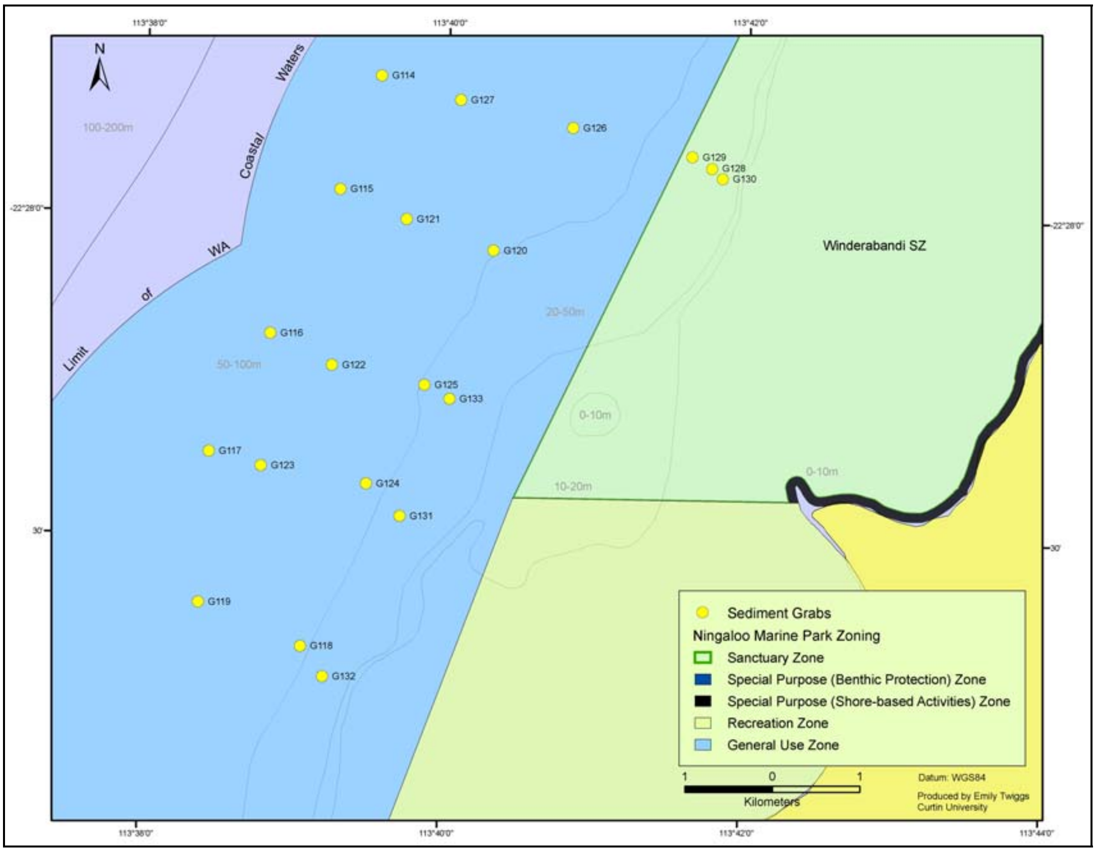
Appendix 2: Geomorphology and Sedimentology

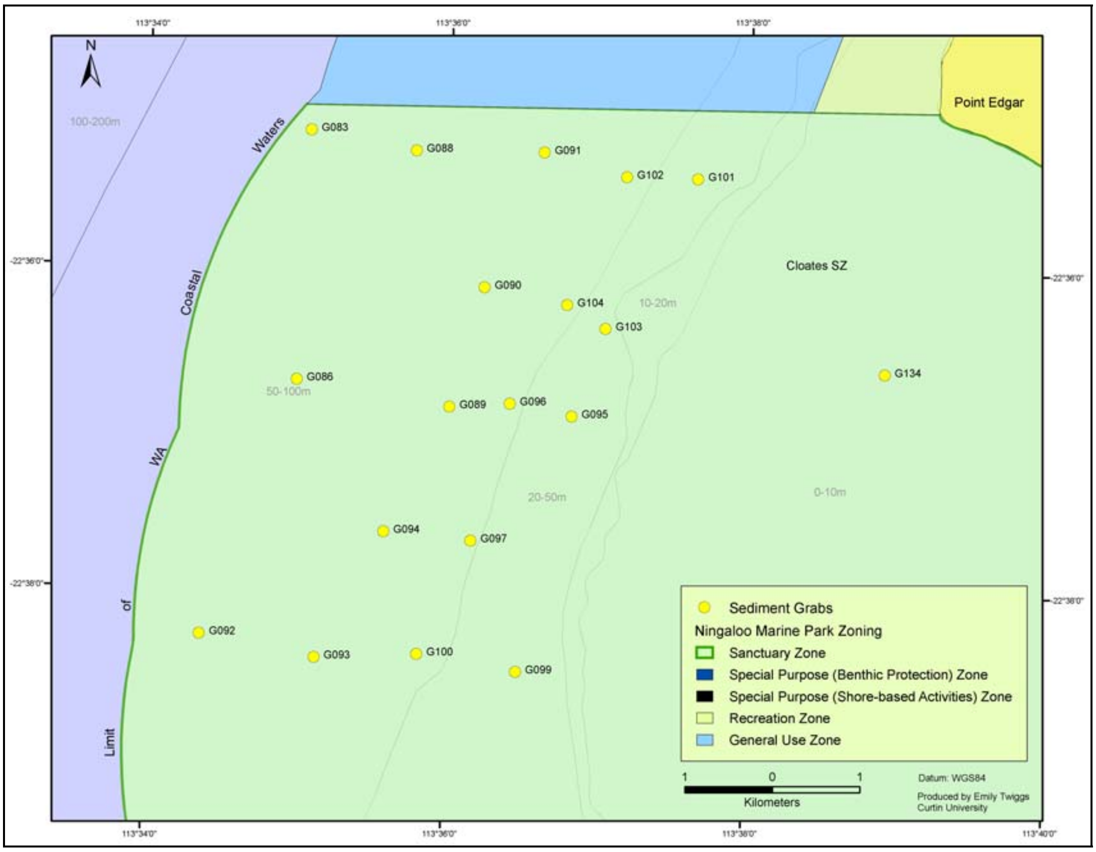
Appendix 2.1: Sediment grab location maps






Osprey SZ
Limit of WA Coastal Waters
100-200m
50-100m
20-50m
10-20m
0-10m
G020
G018
G023
G014
G019
G022
G011
G015
G025
G012
G024
G016
G026
G013
G017
Sediment Grabs
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University


Winderabandi SZ
Limit of WA Coastal Waters
100-200m
50-100m
20-50m
10-20m
0-10m
G114
G127
G126
G129
G128
G130
G115
G121
G120
G116
G122
G125
G133
G117
G123
G124
G131
G119
G118
G132
Sediment Grabs
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University


Point Edgar
Cloates SZ
G083
G088
G091
G102
G101
G090
G104
G103
G086
G089
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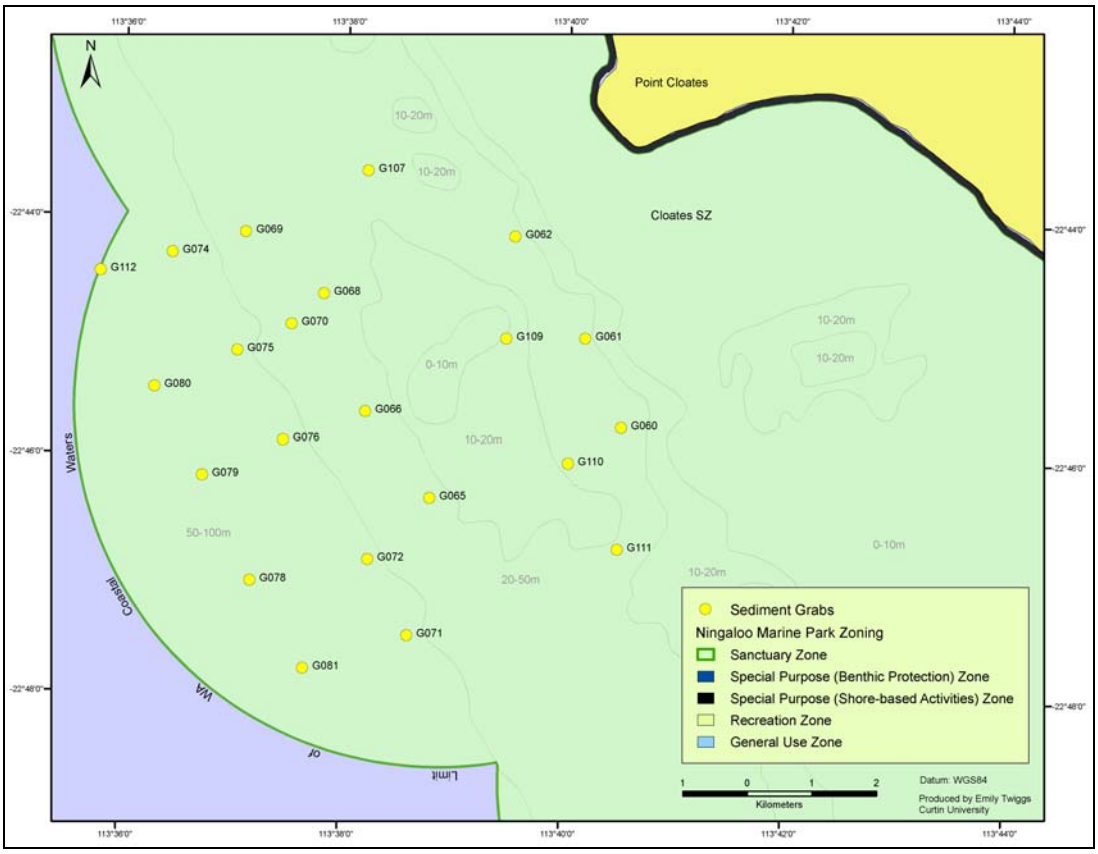
G095
G134
G094
G097
G092
G093
G100
G099
100-200m
50-100m
20-50m
10-20m
0-10m
WA Coastal Waters Limit of
Sediment Grabs
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University


Point Cloates
Cloates SZ
G107
G069
G074
G112
G062
G068
G070
G075
G109
G061
G080
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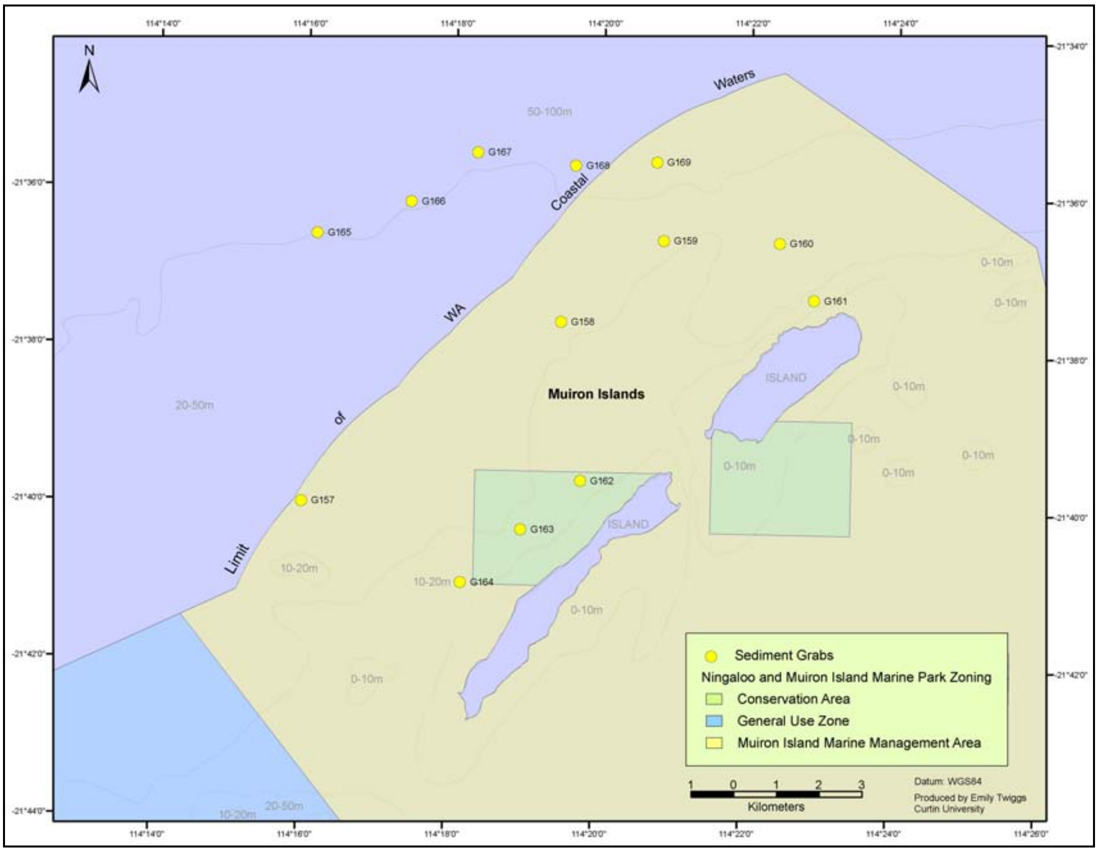
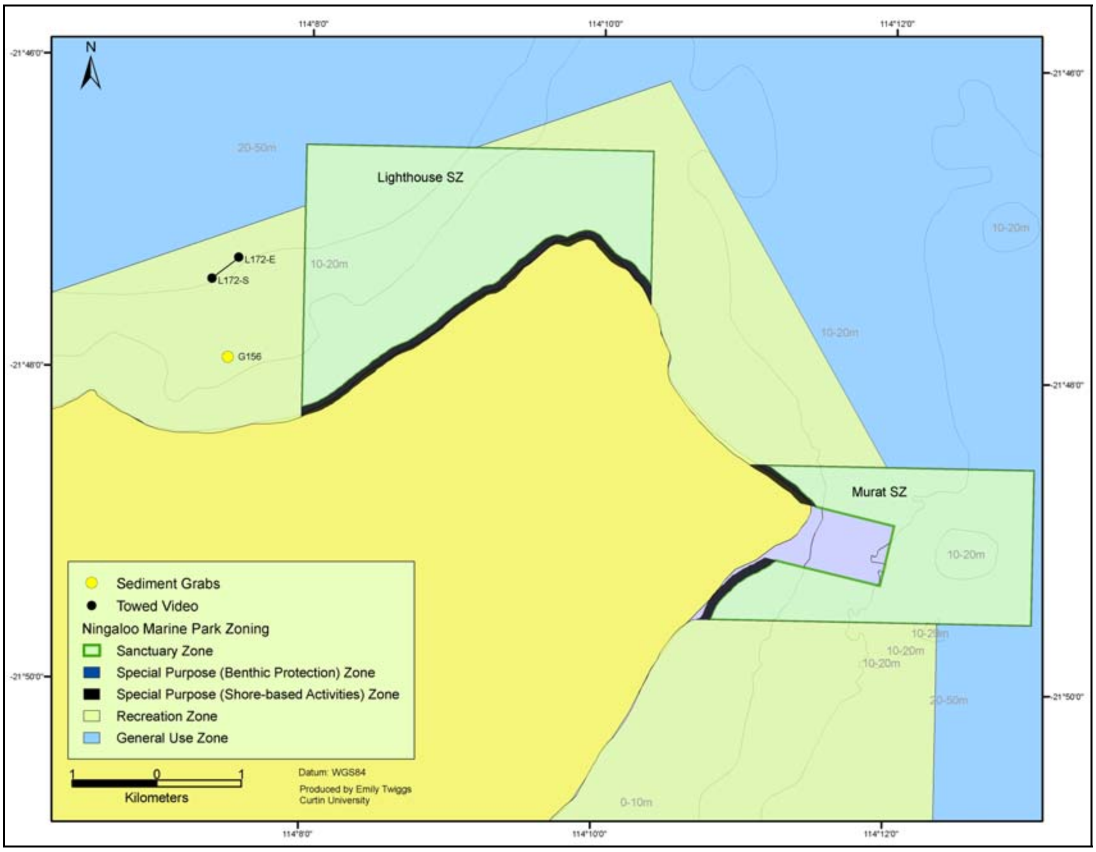
G076
G060
G079
G110
G065
G072
G111
G078
G071
G081
10-20m
0-10m
20-50m
50-100m
WA Coastal Waters Limit of
Sediment Grabs
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University


N
Waters
Coastal
WA
of
Limit
50-100m
20-50m
10-20m
0-10m
ISLAND
Muiron Islands
G157
G158
G159
G160
G161
G162
G163
G164
G165
G166
G167
G168
G169
Sediment Grabs
Ningaloo and Muiron Island Marine Park Zoning
Conservation Area
General Use Zone
Muiron Island Marine Management Area
1 0 1 2 3
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University


N
Lighthouse SZ
Murat SZ
L172-E
L172-S
G156
20-50m
10-20m
0-10m
Sediment Grabs
Towed Video
Ningaloo Marine Park Zoning
Sanctuary Zone
Special Purpose (Benthic Protection) Zone
Special Purpose (Shore-based Activities) Zone
Recreation Zone
General Use Zone
1 0 1
Kilometers
Datum: WGS84
Produced by Emily Twiggs
Curtin University

Appendix 2.2: Sediment grab operations data

SURVEY	TASK	LEADER	DATE	TIME	ID	LOCATION	LAT	LON	DEPTH
CF4010	Grab	Max Rees	22/04/06	16:27	**G002**	Osprey Ref	-22.1727	113.8353	60.8
CF4010	Grab	Max Rees	22/04/06	18:10	**G003**	Osprey Ref	-22.1748	113.8038	80.2
CF4010	Grab	Max Rees	25/04/06	9:57	**G011**	Osprey SZ	-22.2713	113.7955	58.4
CF4010	Grab	Max Rees	25/04/06	10:11	**G012**	Osprey SZ	-22.2842	113.7893	57.4
CF4010	Grab	Max Rees	25/04/06	10:22	**G013**	Osprey SZ	-22.2935	113.7836	56.2
CF4010	Grab	Max Rees	25/05/06	16:12	**G014**	Osprey SZ	-22.2655	113.784	75.2
CF4010	Grab	Max Rees	25/04/06	16:25	**G015**	Osprey SZ	-22.2747	113.7797	77.2
CF4010	Grab	Max Rees	25/04/06	16:39	**G016**	Osprey SZ	-22.286	113.7742	74.2
CF4010	Grab	Max Rees	25/04/06	16:53	**G017**	Osprey SZ	-22.2946	113.7677	76.7
CF4010	Grab	Max Rees	26/04/06	13:09	**G018**	Osprey SZ	-22.2563	113.7619	100.3
CF4010	Grab	Max Rees	26/04/06	13:35	**G019**	Osprey SZ	-22.2679	113.7561	103.5
CF4010	Grab	Max Rees	26/04/06	14:45	**G020**	Seaward Osprey SZ	-22.2444	113.7658	102
CF4010	Grab	Max Rees	27/04/06	11:20	**G022**	Osprey SZ	-22.2698	113.7658	92.6
CF4010	Grab	Max Rees	27/04/06	11:43	**G023**	Osprey SZ	-22.2599	113.7722	91.6
CF4010	Grab	Max Rees	27/04/06	14:04	**G024**	Osprey SZ	-22.2869	113.7446	102.2
CF4010	Grab	Max Rees	27/04/06	14:18	**G025**	Osprey SZ	-22.2774	113.7516	102.5
CF4010	Grab	Max Rees	27/04/06	14:38	**G026**	Osprey SZ	-22.2901	113.755	90.1
CF4010	Grab	Max Rees	28/04/06	12:03	**G027**	Osprey Ref	-22.1638	113.8063	86.5
CF4010	Grab	Max Rees	28/04/06	12:20	**G028**	Osprey Ref	-22.1862	113.7994	85.5
CF4010	Grab	Max Rees	28/04/06	14:27	**G029**	Osprey Ref	-22.2014	113.7948	82.6
CF4010	Grab	Max Rees	28/04/06	14:44	**G030**	Osprey Ref	-22.2121	113.7902	82.8
CF4010	Grab	Max Rees	28/04/06	16:33	**G031**	Osprey Ref	-22.1906	113.8273	60.1
CF4010	Grab	Max Rees	28/04/07	16:47	**G032**	Osprey Ref	-22.1786	113.8334	57.3
CF4010	Grab	Max Rees	28/04/07	16:55	**G033**	Osprey Ref	-22.1794	113.8378	42.9
CF4010	Grab	Max Rees	29/04/06	10:52	**G034**	Seaward Osprey Ref	-22.1631	113.7964	102.5
CF4010	Grab	Max Rees	29/04/06	11:23	**G035**	Osprey Ref	-22.187	113.7876	101.4
CF4010	Grab	Max Rees	29/04/06	15:49	**G036**	Osprey Ref	-22.1888	113.8118	71.9
CF4010	Grab	Max Rees	29/04/06	16:01	**G037**	Osprey Ref	-22.2026	113.8077	70.2
CF4010	Grab	Max Rees	29/04/06	16:11	**G038**	Osprey Ref	-22.2146	113.8051	71.2
CF4010	Grab	Max Rees	30/04/06	11:33	**G039**	Osprey Ref	-22.211	113.781	103.3
CF4010	Grab	Max Rees	30/04/06	12:13	**G040**	Osprey Ref	-22.1748	113.7929	100.1
CF4010	Grab	Max Rees	30/04/06	12:42	**G041**	Osprey Ref	-22.2009	113.7845	102.2
CF4010	Grab	Max Rees	01/05/06	10:58	**G042**	Osprey Ref	-22.2164	113.8245	44.6
CF4010	Grab	Max Rees	01/05/06	11:06	**G043**	Osprey Ref	-22.2155	113.8185	62.2
CF4010	Grab	Max Rees	01/05/06	11:20	**G044**	Osprey Ref	-22.2042	113.8273	45.5
CF4010	Grab	Max Rees	01/05/06	11:32	**G045**	Osprey Ref	-22.1908	113.8311	45.9
CF4010	Grab	Max Rees	01/05/06	15:55	**G046**	Osprey Ref	-22.2038	113.8229	65.1

SURVEY	TASK	LEADER	DATE	TIME	ID	LOCATION	LAT	LON	DEPTH
CF4010	Grab	Max Rees	01/05/06	16:23	**G047**	Osprey Ref	-22.1764	113.8159	73.5
CF4010	Grab	Max Rees	01/05/06	16:38	**G048**	Osprey Ref	-22.1646	113.819	74.1
CF4010	Grab	Max Rees	02/05/06	12:27	**G050**	Osprey Ref	-22.1671	113.8379	60.9
CF4010	Grab	Max Rees	02/05/06	13:56	**G051**	Mandu SZ	-22.1133	113.859	59.7
CF4010	Grab	Max Rees	02/05/06	14:08	**G052**	Mandu SZ	-22.1253	113.8556	58.2
CF4010	Grab	Max Rees	02/05/06	15:37	**G053**	Mandu SZ	-22.1268	113.8614	46.4
CF4010	Grab	Max Rees	02/05/06	15:49	**G054**	Mandu SZ	-22.1372	113.8507	58
CF4010	Grab	Max Rees	02/05/06	15:59	**G055**	Mandu SZ	-22.1376	113.8552	47.9
CF4010	Grab	Max Rees	03/05/06	11:40	**G056**	Mandu SZ	-22.0832	113.8299	82.6
CF4010	Grab	Max Rees	03/05/06	12:13	**G057**	Mandu SZ	-22.1188	113.8176	86.2
CF4011	Grab	Andrew Heyward	06/05/06	11:48	**G058**	Mandu SZ	-22.1168	113.8635	45.1
CF4011	Grab	Andrew Heyward	07/05/06	11:49	**G060**	Cloates SZ (Mid)	-22.7622	113.6752	38.8
CF4011	Grab	Andrew Heyward	07/05/06	12:01	**G061**	Cloates SZ (Mid)	-22.7498	113.6696	27
CF4011	Grab	Andrew Heyward	07/05/06	12:14	**G062**	Cloates SZ (Mid)	-22.7357	113.6588	28.4
CF4011	Grab	Andrew Heyward	07/05/06	4:53	**G065**	Cloates SZ (Mid)	-22.7724	113.6465	37.5
CF4011	Grab	Andrew Heyward	07/05/06	5:07	**G066**	Cloates SZ (Mid)	-22.7605	113.6366	41
CF4011	Grab	Andrew Heyward	08/05/06	8:50	**G068**	Cloates SZ (Mid)	-22.7441	113.6301	39.5
CF4011	Grab	Andrew Heyward	08/05/06	8:58	**G069**	Cloates SZ (Mid)	-22.7356	113.6182	38.5
CF4011	Grab	Andrew Heyward	08/05/06	9:03	**G070**	Cloates SZ (Mid)	-22.7484	113.6253	37
CF4011	Grab	Andrew Heyward	08/05/06	14:28	**G071**	Cloates SZ (Mid)	-22.7917	113.6434	63.1
CF4011	Grab	Andrew Heyward	08/05/06	14:45	**G072**	Cloates SZ (Mid)	-22.7811	113.6373	60.1
CF4011	Grab	Andrew Heyward	09/05/06	8:53	**G074**	Cloates SZ (Mid)	-22.7386	113.6072	64.7
CF4011	Grab	Andrew Heyward	09/05/06	9:07	**G075**	Cloates SZ (Mid)	-22.7522	113.6172	60.7
CF4011	Grab	Andrew Heyward	09/05/06	9:20	**G076**	Cloates SZ (Mid)	-22.7646	113.6243	60.7
CF4011	Grab	Andrew Heyward	09/05/06	10:42	**G078**	Cloates SZ (Mid)	-22.7843	113.6196	65.7
CF4011	Grab	Andrew Heyward	09/05/06	10:58	**G079**	Cloates SZ (Mid)	-22.7697	113.6122	66.5
CF4011	Grab	Andrew Heyward	09/05/06	11:15	**G080**	Cloates SZ (Mid)	-22.7574	113.6048	66
CF4011	Grab	Andrew Heyward	09/05/06	13:05	**G081**	Cloates SZ (Mid)	-22.7965	113.6278	65
CF4011	Grab	Andrew Heyward	10/05/06	9:44	**G083**	Cloates SZ (North)	-22.586	113.5845	130
CF4011	Grab	Andrew Heyward	10/05/06	12:23	**G086**	Cloates SZ (North)	-22.6118	113.5833	102.6
CF4011	Grab	Andrew Heyward	10/05/06	16:20	**G088**	Cloates SZ (North)	-22.588	113.5962	99
CF4011	Grab	Andrew Heyward	11/05/06	9:51	**G089**	Cloates SZ (North)	-22.6144	113.6003	72
CF4011	Grab	Andrew Heyward	11/05/06	10:07	**G090**	Cloates SZ (North)	-22.602	113.604	77.7
CF4011	Grab	Andrew Heyward	11/05/06	10:19	**G091**	Cloates SZ (North)	-22.588	113.6104	76
CF4011	Grab	Andrew Heyward	11/05/06	13:19	**G092**	Cloates SZ (North)	-22.6382	113.5729	94.1
CF4011	Grab	Andrew Heyward	11/05/06	13:34	**G093**	Cloates SZ (North)	-22.6405	113.5857	74.6
CF4011	Grab	Andrew Heyward	11/05/06	13:47	**G094**	Cloates SZ (North)	-22.6274	113.5932	73
CF4011	Grab	Andrew Heyward	12/05/06	14:28	**G095**	Cloates SZ (North)	-22.6152	113.6139	36.5

SURVEY	TASK	LEADER	DATE	TIME	ID	LOCATION	LAT	LON	DEPTH
CF4011	Grab	Andrew Heyward	12/05/06	14:51	**G096**	Cloates SZ (North)	-22.614	113.607	57.4
CF4011	Grab	Andrew Heyward	12/05/06	15:05	**G097**	Cloates SZ (North)	-22.6282	113.6029	52.8
CF4011	Grab	Andrew Heyward	12/05/06	16:48	**G099**	Cloates SZ (North)	-22.6417	113.6081	36
CF4011	Grab	Andrew Heyward	12/05/06	16:58	**G100**	Cloates SZ (North)	-22.64	113.5971	56
CF4011	Grab	Andrew Heyward	13/05/06	7:54	**G101**	Cloates SZ (North)	-22.5905	113.6275	35
CF4011	Grab	Andrew Heyward	13/05/06	8:28	**G102**	Cloates SZ (North)	-22.5904	113.6196	55
CF4011	Grab	Andrew Heyward	13/05/06	8:39	**G103**	Cloates SZ (North)	-22.6061	113.6175	37.8
CF4011	Grab	Andrew Heyward	13/05/06	8:46	**G104**	Cloates SZ (North)	-22.6037	113.6132	55.7
CF4011	Grab	Andrew Heyward	13/05/06	13:22	**G107**	Cloates SZ (Mid)	-22.7268	113.6365	34.7
CF4011	Grab	Andrew Heyward	13/05/06	13:56	**G109**	Cloates SZ (Mid)	-22.75	113.6577	35
CF4011	Grab	Andrew Heyward	13/05/06	14:11	**G110**	Cloates SZ (Mid)	-22.7673	113.6673	33
CF4011	Grab	Andrew Heyward	13/05/06	14:27	**G111**	Cloates SZ (Mid)	-22.7792	113.6749	28.9
CF4011	Grab	Andrew Heyward	13/05/06	15:38	**G112**	Cloates SZ (Mid)	-22.7413	113.5964	64.4
CF4011	Grab	Andrew Heyward	14/05/06	10:55	**G113**	Cloates Ref	-22.4393	113.6676	102.6
CF4011	Grab	Andrew Heyward	14/05/06	11:21	**G114**	Cloates Ref	-22.4524	113.6592	104
CF4011	Grab	Andrew Heyward	14/05/06	11:37	**G115**	Cloates Ref	-22.4642	113.6548	103
CF4011	Grab	Andrew Heyward	14/05/06	13:50	**G116**	Cloates Ref	-22.4792	113.6473	102
CF4011	Grab	Andrew Heyward	14/05/06	14:02	**G117**	Cloates Ref	-22.4915	113.6407	98.4
CF4011	Grab	Andrew Heyward	15/05/06	10:25	**G118**	Cloates Ref	-22.5115	113.6512	56
CF4011	Grab	Andrew Heyward	15/05/06	10:39	**G119**	Cloates Ref	-22.5071	113.6398	80
CF4011	Grab	Andrew Heyward	15/05/06	12:06	**G120**	Cloates Ref	-22.4703	113.6719	58.4
CF4011	Grab	Andrew Heyward	15/05/06	12:18	**G121**	Cloates Ref	-22.4672	113.6622	80
CF4011	Grab	Andrew Heyward	15/05/06	14:09	**G122**	Cloates Ref	-22.4824	113.6542	75.7
CF4011	Grab	Andrew Heyward	15/05/06	15:02	**G123**	Cloates Ref	-22.4929	113.6465	82
CF4011	Grab	Andrew Heyward	15/05/06	15:16	**G124**	Cloates Ref	-22.4946	113.6582	58
CF4011	Grab	Andrew Heyward	15/05/06	15:28	**G125**	Cloates Ref	-22.4843	113.6645	53
CF4011	Grab	Andrew Heyward	15/05/06	15:46	**G126**	Cloates Ref	-22.4575	113.6805	62
CF4011	Grab	Andrew Heyward	15/05/06	15:58	**G127**	Cloates Ref	-22.4548	113.668	82
CF4011	Grab	Andrew Heyward	15/05/06	16:23	**G128**	Cloates Ref	-22.4615	113.696	39
CF4011	Grab	Andrew Heyward	16/05/06	9:41	**G129**	Cloates Ref	-22.4603	113.6938	43
CF4011	Grab	Andrew Heyward	16/05/06	9:56	**G130**	Cloates Ref	-22.4625	113.6972	29.1
CF4011	Grab	Andrew Heyward	16/05/06	11:56	**G131**	Cloates Ref	-22.4979	113.662	39.7
CF4011	Grab	Andrew Heyward	16/05/06	12:14	**G132**	Cloates Ref	-22.5146	113.6537	41
CF4011	Grab	Andrew Heyward	16/05/06	12:20	**G133**	Cloates Ref	-22.4857	113.6673	45
CF4011	Grab	Andrew Heyward	17/05/06	7:30	**G134**	Norwegian Bay	-22.6104	113.6486	7
CF4011	Grab	Andrew Heyward	17/05/06	13:16	**G135**	Mandu SZ	-22.1461	113.8246	72
CF4011	Grab	Andrew Heyward	17/05/06	13:27	**G136**	Mandu SZ	-22.1344	113.8263	73.6
CF4011	Grab	Andrew Heyward	17/05/06	14:02	**G137**	Mandu SZ	-22.1088	113.8337	75

SURVEY	TASK	LEADER	DATE	TIME	ID	LOCATION	LAT	LON	DEPTH
CF4011	Grab	Andrew Heyward	17/05/06	14:12	**G138**	Mandu SZ	-22.0984	113.8361	73.8
CF4011	Grab	Andrew Heyward	17/05/06	14:25	**G139**	Mandu SZ	-22.0968	113.824	80.7
CF4011	Grab	Andrew Heyward	17/05/06	17:37	**G140**	Mandu SZ	-22.1457	113.8122	82.7
CF4011	Grab	Andrew Heyward	17/05/06	17:46	**G141**	Seaward Mandu SZ	-22.1404	113.8008	101
CF4011	Grab	Andrew Heyward	17/05/06	19:31	**G142**	Seaward Mandu SZ	-22.1285	113.805	100.4
CF4011	Grab	Andrew Heyward	17/05/06	20:13	**G143**	Seaward Mandu SZ	-22.1146	113.807	100.4
CF4011	Grab	Andrew Heyward	17/05/06	20:52	**G144**	Seaward Mandu SZ	-22.102	113.8087	98
CF4011	Grab	Andrew Heyward	18/05/06	10:05	**G145**	Mandu SZ	-22.1059	113.8208	98
CF4011	Grab	Andrew Heyward	18/05/06	10:25	**G146**	Mandu SZ	-22.1334	113.8136	80
CF4011	Grab	Andrew Heyward	18/05/06	11:27	**G147**	Mandu SZ	-22.1214	113.8301	75
CF4011	Grab	Andrew Heyward	18/05/06	13:29	**G149**	Mandu SZ	-22.1503	113.8467	56
CF4011	Grab	Andrew Heyward	18/05/06	13:38	**G150**	Mandu SZ	-22.1496	113.8513	40
CF4011	Grab	Andrew Heyward	18/05/06	14:01	**G152**	Mandu SZ	-22.1232	113.8453	70
CF4011	Grab	Andrew Heyward	18/05/06	14:16	**G153**	Mandu SZ	-22.1112	113.8487	70
CF4011	Grab	Andrew Heyward	18/05/06	14:35	**G154**	Mandu SZ	-22.1022	113.8618	58.7
CF4011	Grab	Andrew Heyward	19/05/06	7:50	**G156**	Lighthouse SZ	-22.7988	114.1243	13
CF4011	Grab	Andrew Heyward	19/05/06	14:57	**G157**	Muiron Islands	-21.6664	114.2667	32
CF4011	Grab	Andrew Heyward	19/05/06	16:03	**G158**	Muiron Islands	-21.6274	114.3246	26.6
CF4011	Grab	Andrew Heyward	19/05/06	16:35	**G159**	Muiron Islands	-21.6098	114.3475	27.5
CF4011	Grab	Andrew Heyward	19/05/06	17:07	**G160**	Muiron Islands	-21.6099	114.3737	30
CF4011	Grab	Andrew Heyward	20/05/06	7:14	**G161**	Muiron Islands	-21.6219	114.3817	21.4
CF4011	Grab	Andrew Heyward	20/05/06	8:15	**G162**	Muiron Islands	-21.6611	114.3297	21
CF4011	Grab	Andrew Heyward	20/05/06	9:15	**G163**	Muiron Islands	-21.6716	114.3164	19
CF4011	Grab	Andrew Heyward	20/05/06	9:35	**G164**	Muiron Islands	-21.6831	114.3030	19.6
CF4011	Grab	Andrew Heyward	20/05/06	14:00	**G165**	Muiron Islands	-21.6095	114.2692	57
CF4011	Grab	Andrew Heyward	20/05/06	14:25	**G166**	Muiron Islands	-21.6025	114.2903	53
CF4011	Grab	Andrew Heyward	20/05/06	14:49	**G167**	Muiron Islands	-21.5918	114.3051	62
CF4011	Grab	Andrew Heyward	20/05/06	15:45	**G169**	Muiron Islands	-21.5932	114.3456	63

Appendix 2.3: Grain size statistics

Table 1: Grain size scale for sediments from Udden (1914) and Wentworth (1922)

Grain Size phi	Grain Size mm	Descriptive term	
		Gravel	
-1	2		
		Very coarse	Sand
0	1		Sand
	microns	Coarse	Sand
1	00		Sand
		Medium	Sand
2	250		Sand
		Fine	Sand
3	125		Sand
		Very fine	Sand
4	63		
		Mud	

Table 2: Statistical formulae used in the calculation of grain size parameters. (Blott and Pye, 2001). Of is the frequency in percent; m is the mid-point of each class interval in metric (m_m) or phi ($m_\square$) units; P_x and $\square_x$ are grain diameters, in metric or phi units respectively, at the cumulative percentile value of x.

(a) Arithmetic Method of Moments

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{x}_a = \frac{\Sigma f m_m}{100}$	$\sigma_a = \sqrt{\frac{\Sigma f (m_m - \bar{x}_a)^2}{100}}$	$Sk_a = \frac{\Sigma f (m_m - \bar{x}_a)^3}{100 \sigma_a^3}$	$K_a = \frac{\Sigma f (m_m - \bar{x}_a)^4}{100 \sigma_a^4}$

(b) Geometric Method of Moments

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{x}_g = \exp \frac{\Sigma f \ln m_m}{100}$	$\sigma_g = \exp \sqrt{\frac{\Sigma f (\ln m_m - \ln \bar{x}_g)^2}{100}}$	$Sk_g = \frac{\Sigma f (\ln m_m - \ln \bar{x}_g)^3}{100 \ln \sigma_g^3}$	$K_g = \frac{\Sigma f (\ln m_m - \ln \bar{x}_g)^4}{100 \ln \sigma_g^4}$

Sorting (σ_g)		Skewness (Sk_g)		Kurtosis (K_g)	
Very well sorted	< 1.27				
Well sorted	1.27 – 1.41	Very fine skewed	< $^-$1.30	Very platykurtic	< 1.70
Moderately well sorted	1.41 – 1.62	Fine skewed	$^-$1.30 – $^-$0.43	Platykurtic	1.70 – 2.55
Moderately sorted	1.62 – 2.00	Symmetrical	$^-$0.43 – $^+$0.43	Mesokurtic	2.55 – 3.70
Poorly sorted	2.00 – 4.00	Coarse skewed	$^+$0.43 – $^+$1.30	Leptokurtic	3.70 – 7.40
Very poorly sorted	4.00 – 16.00	Very coarse skewed	> $^+$1.30	Very leptokurtic	> 7.40
Extremely poorly sorted	> 16.00				

(c) Logarithmic Method of Moments

Mean	Standard Deviation	Skewness	Kurtosis
$\bar{x}_\phi = \dfrac{\Sigma f m_\phi}{100}$	$\sigma_\phi = \sqrt{\dfrac{\Sigma f (m_\phi - \bar{x}_\phi)^2}{100}}$	$Sk_\phi = \dfrac{\Sigma f (m_\phi - \bar{x}_\phi)^3}{100 \sigma_\phi{}^3}$	$K_\phi = \dfrac{\Sigma f (m_\phi - \bar{x}_\phi)^4}{100 \sigma_\phi{}^4}$

Sorting ($\sigma_\square$)		Skewness ($Sk_\square$)		Kurtosis ($K_\square$)	
Very well sorted	< 0.35				
Well sorted	0.35 – 0.50	Very fine skewed	> $^+$1.30	Very platykurtic	< 1.70
Moderately well sorted	0.50 – 0.70	Fine skewed	$^+$0.43 – $^+$1.30	Platykurtic	1.70 – 2.55
Moderately sorted	0.70 – 1.00	Symmetrical	$^-$0.43 – $^+$0.43	Mesokurtic	2.55 – 3.70
Poorly sorted	1.00 – 2.00	Coarse skewed	$^-$0.43 – $^-$1.30	Leptokurtic	3.70 – 7.40
Very poorly sorted	2.00 – 4.00	Very coarse skewed	< $^-$1.30	Very leptokurtic	> 7.40
Extremely poorly sorted	> 4.00				

(d) Logarithmic (Original) Folk and Ward (1957) Graphical Measures

Mean	Standard Deviation	Skewness	Kurtosis
$M_Z = \dfrac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$	$\sigma_I = \dfrac{\phi_{84} - \phi_{16}}{4} + \dfrac{\phi_{95} - \phi_5}{6.6}$	$Sk_I = \dfrac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \dfrac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$	$K_G = \dfrac{\phi_{95} - \phi_5}{2.44(\phi_{75} - \phi_{25})}$

Sorting (σ_I)		Skewness (Sk_I)		Kurtosis (K_G)	
Very well sorted	< 0.35			Very platykurtic	< 0.67
Well sorted	0.35 – 0.50	Very fine skewed	$^+$0.3 to $^+$1.0	Platykurtic	0.67 – 0.90
Moderately well sorted	0.50 – 0.70	Fine skewed	$^+$0.1 to $^+$0.3	Mesokurtic	0.90 – 1.11
Moderately sorted	0.70 – 1.00	Symmetrical	$^+$0.1 to $^-$0.1	Leptokurtic	1.11 – 1.50
Poorly sorted	1.00 – 2.00	Coarse skewed	$^-$0.1 to $^-$0.3	Very leptokurtic	1.50 – 3.00
Very poorly sorted	2.00 – 4.00	Very coarse skewed	$^-$0.3 to $^-$1.0	Extremely leptokurtic	> 3.00
Extremely poorly sorted	> 4.00				

(e) Geometric Folk and Ward (1957) Graphical Measures

Mean	Standard Deviation
$M_G = \exp\dfrac{\ln P_{16} + \ln P_{50} + \ln P_{84}}{3}$	$\sigma_G = \exp\left(\dfrac{\ln P_{16} - \ln P_{84}}{4} + \dfrac{\ln P_5 - \ln P_{95}}{6.6}\right)$

Skewness	Kurtosis
$Sk_G = \dfrac{\ln P_{16} + \ln P_{84} - 2(\ln P_{50})}{2(\ln P_{84} - \ln P_{16})} + \dfrac{\ln P_5 + \ln P_{95} - 2(\ln P_{50})}{2(\ln P_{25} - \ln P_5)}$	$K_G = \dfrac{\ln P_5 - \ln P_{95}}{2.44(\ln P_{25} - \ln P_{75})}$

Sorting (σ_G)		Skewness (Sk_G)		Kurtosis (K_G)	
Very well sorted	< 1.27			Very platykurtic	< 0.67
Well sorted	1.27 – 1.41	Very fine skewed	$^-0.3$ to $^-1.0$	Platykurtic	0.67 – 0.90
Moderately well sorted	1.41 – 1.62	Fine skewed	$^-0.1$ to $^-0.3$	Mesokurtic	0.90 – 1.11
Moderately sorted	1.62 – 2.00	Symmetrical	$^-0.1$ to $^+0.1$	Leptokurtic	1.11 – 1.50
Poorly sorted	2.00 – 4.00	Coarse skewed	$^+0.1$ to $^+0.3$	Very leptokurtic	1.50 – 3.00
Very poorly sorted	4.00 – 16.00	Very coarse skewed	$^+0.3$ to $^+1.0$	Extremely leptokurtic	> 3.00
Extremely poorly sorted	> 16.00				

Appendix 2.4: Grain size percentages

GRAB	LOCATION	GRAVEL (%)	V COARSE SAND (%)	COARSE SAND (%)	MEDIUM SAND (%)	FINE SAND (%)	V FINE SAND (%)	MUD
G002	Osprey Ref	22	24.3	26.3	20.5	5.8	0.8	0.2
G003	Osprey Ref	52.4	20.1	12.6	7.7	3.6	2.2	1.4
G011	Osprey SZ	20.4	25.3	25.2	23.5	4.2	1	0.4
G012	Osprey SZ	32.1	26.2	20.9	12.3	4.9	3	0.5
G013	Osprey SZ	36.1	29.9	22.4	9.3	1.4	0.8	0.1
G014	Osprey SZ	1.6	2.8	7.5	15.1	44.4	24.7	3.9
G015	Osprey SZ	1.5	4.7	8.3	16.7	39.5	24.6	4.7
G016	Osprey SZ	3.4	4.7	9.6	19.7	30.3	26.1	6.2
G017	Osprey SZ	7.9	7.2	10.5	16	22.7	23	12.7
G018	Osprey SZ	11.4	9.1	13.7	15.3	12.2	18.8	19.4
G019	Osprey SZ	7.8	9	17.2	19	16.7	21.8	8.5
G020	Seaward Osprey SZ	7.4	7	13.4	17.7	18.6	25.8	10.1
G022	Osprey SZ	9	6.7	12.1	14.8	18.4	24.3	14.7
G023	Osprey SZ	4.4	5.6	11.2	15.5	23.9	27.1	12.2
G024	Osprey SZ	11.5	13.4	24.1	22.5	7.9	14.3	6.4
G025	Osprey SZ	14	14.3	20.4	33.4	15.6	2.1	0.1
G026	Osprey SZ	13.7	15.2	17.4	13.5	8	13.2	19.1
G027	Osprey Ref	18.2	12.4	12.2	15.4	19.3	17.6	4.8
G028	Osprey Ref	3	4.4	8.5	17.6	40.9	22.6	3
G029	Osprey Ref	10.1	10	18.5	20.2	23.5	15.3	2.4
G030	Osprey Ref	10.7	11.9	18.3	17.5	16.8	19.2	5.6
G031	Osprey Ref	18.7	22.1	26.1	23.6	8.6	0.9	0.1
G032	Osprey Ref	33.9	13.2	14.9	18.1	17.3	2.6	0.1
G033	Osprey Ref	100	0	0	0	0	0	0
G034	Seaward Osprey Ref	9.5	10.1	19.2	26.3	19.8	13.8	1.2
G035	Osprey Ref	3.9	5.8	11.2	23.7	31	17	7.5
G036	Osprey Ref	2	3.2	5.7	22.1	40.1	22.4	4.4
G037	Osprey Ref	10.5	10.6	20.6	41.2	14.1	2.8	0.3
G038	Osprey Ref	0.5	0.3	1.4	40	49.6	7.9	0.3
G039	Osprey Ref	1.7	6.8	20.9	31.5	28.4	9	1.6
G040	Osprey Ref	11.2	8.3	12.5	20	21.9	19.2	7
G041	Osprey Ref	1.7	4.5	10.9	23.2	39.6	17.3	2.7
G042	Osprey Ref	64.9	17.7	11.4	4	1.2	0.6	0.1
G043	Osprey Ref	24.9	25.2	26.7	14.9	7.1	0.9	0.2
G044	Osprey Ref	100	0	0	0	0	0	0
G045	Osprey Ref	1.8	5.9	12.3	39.5	40	0.6	0

GRAB	LOCATION	GRAVEL (%)	V COARSE SAND (%)	COARSE SAND (%)	MEDIUM SAND (%)	FINE SAND (%)	V FINE SAND (%)	MUD
G046	Osprey Ref	24.9	23	25	19.6	6.8	0.6	0.2
G047	Osprey Ref	0.6	1	4.8	33.8	46.3	12	1.4
G048	Osprey Ref	1.2	1.9	7.2	36.4	47.1	6	0.2
G050	Osprey Ref	36	25.4	17.8	15.5	4.4	0.8	0.2
G051	Mandu SZ	4.3	18.6	27	28.3	18.8	2.6	0.3
G052	Mandu SZ	33.4	15.5	26.9	17.8	5	1.1	0.3
G053	Mandu SZ	8.7	27.5	35.8	19.4	6.9	1.5	0.2
G054	Mandu SZ	40.2	22.6	20.5	13.1	2.9	0.5	0.2
G055	Mandu SZ	13	6.2	23.8	48	8.8	0.3	0
G056	Mandu SZ	9.5	11.5	15.1	14	16.8	27.1	6
G057	Mandu SZ	16.6	15.7	20.5	17.4	17.1	12	0.7
G058	Mandu SZ	0.6	1.2	4.3	23.6	61.9	8.2	0.1
G060	Cloates SZ (Mid)	63.4	2.9	13.6	18.4	1.3	0.3	0.1
G061	Cloates SZ (Mid)	0	0.1	0.8	28.1	69	1.9	0
G062	Cloates SZ (Mid)	0.1	0.3	1.2	7.4	55.6	35	0.3
G065	Cloates SZ (Mid)	3.5	14.3	42.7	37.9	1.5	0	0
G066	Cloates SZ (Mid)	22.1	24.1	49	4.8	0	0	0
G068	Cloates SZ (Mid)	23.8	21.9	39.7	14.3	0.4	0	0
G069	Cloates SZ (Mid)	100	0	0	0	0	0	0
G070	Cloates SZ (Mid)	100	0	0	0	0	0	0
G071	Cloates SZ (Mid)	2.3	5.4	28.6	54.3	9	0.4	0
G072	Cloates SZ (Mid)	0.1	0.5	3.6	40.6	52.6	2.6	0.1
G074	Cloates SZ (Mid)	0.1	0.4	1.3	14.3	76.1	7.8	0.1
G075	Cloates SZ (Mid)	9.9	21.1	31.9	30.8	5.6	0.5	0.1
G076	Cloates SZ (Mid)	0.2	0.3	4.5	54.1	38.6	2.2	0.1
G078	Cloates SZ (Mid)	38.5	15.4	18.5	17.5	6.8	2.6	0.6
G079	Cloates SZ (Mid)	23.4	30.6	21.8	15.8	5.8	2.3	0.3
G080	Cloates SZ (Mid)	0.3	1.2	6.1	21.8	54.8	15.7	0.2
G081	Cloates SZ (Mid)	18	12.6	15	25	20.3	8.8	0.3
G083	Cloates SZ (North)	18.3	15.6	26.1	15.9	3.1	5.5	15.6
G086	Cloates SZ (North)	8.7	10.2	29.1	25.7	10	15.3	0.9
G088	Cloates SZ (North)	10.4	17.9	34	25.6	3.3	6	2.9
G089	Cloates SZ (North)	10.5	11.4	19.5	23.6	14.4	17.8	2.6
G090	Cloates SZ (North)	3.1	4.2	17.5	51.3	17	5.8	1.1
G091	Cloates SZ (North)	1.6	3.9	13.3	56.9	20.7	3.2	0.6
G092	Cloates SZ (North)	18.8	23.1	35.3	12.3	2	5.3	3.3
G093	Cloates SZ (North)	25.3	25.5	31.8	15.4	1	0.8	0.3

GRAB	LOCATION	GRAVEL (%)	V COARSE SAND (%)	COARSE SAND (%)	MEDIUM SAND (%)	FINE SAND (%)	V FINE SAND (%)	MUD
G094	Cloates SZ (North)	8.7	37.9	34.5	14	4.2	0.7	0
G095	Cloates SZ (North)	100	0	0	0	0	0	0
G096	Cloates SZ (North)	2.3	6.8	31.8	51.7	6.5	0.8	0.2
G097	Cloates SZ (North)	41	4.4	5.3	31.1	11.1	6.6	0.4
G099	Cloates SZ (North)	100	0	0	0	0	0	0
G100	Cloates SZ (North)	46.5	10.2	7.6	15.9	6.7	11.7	1.5
G101	Cloates SZ (North)	0.3	0.6	10.8	85.3	2.7	0.3	0
G102	Cloates SZ (North)	9.8	3.3	13.3	55.9	15.9	1.7	0.2
G103	Cloates SZ (North)	42.1	8	9.8	27.5	10.8	1.6	0.2
G104	Cloates SZ (North)	13.8	23.8	62	0.4	0	0	0
G107	Cloates SZ (Mid)	75.4	13.8	5.9	1.9	1.3	1.4	0.3
G109	Cloates SZ (Mid)	58.5	17.8	16.3	6	1.2	0.1	0
G110	Cloates SZ (Mid)	0	0.1	0.4	2.6	56.6	39.8	0.4
G111	Cloates SZ (Mid)	0.3	0.3	0.6	1.4	36.8	57.5	3
G112	Cloates SZ (Mid)	0.1	0.2	0.9	63.1	34.4	1.3	0
G113	Cloates Ref	22.4	21.3	30	13.5	8.5	4.2	0.2
G114	Cloates Ref	33.2	23.8	21.5	10	2.8	4.8	3.9
G115	Cloates Ref	14.7	20.3	28.7	20.4	7.3	5.3	3.3
G116	Cloates Ref	19.7	9.7	24.7	29.9	8.4	4.2	3.3
G117	Cloates Ref	14.4	14.9	24	22.1	6.6	11.2	6.8
G118	Cloates Ref	24.7	19	32.9	20.9	2.4	0.1	0.1
G119	Cloates Ref	18.5	12.8	17.7	19.5	8.8	14.9	7.8
G120	Cloates Ref	54.2	14.5	8.8	11.8	7.8	2.4	0.5
G121	Cloates Ref	5.7	9.9	21	39.1	17.7	4.7	1.9
G122	Cloates Ref	10	14.2	33.3	36.6	5.1	0.7	0.1
G123	Cloates Ref	14.5	20	33.9	26.8	3.7	0.8	0.4
G124	Cloates Ref	86.6	7.1	2.5	1.2	0.8	1.1	0.7
G125	Cloates Ref	59.6	22.3	11.7	4.1	1.3	0.7	0.4
G126	Cloates Ref	17.7	29	25.1	20	7.1	0.9	0.2
G127	Cloates Ref	2.7	6.8	17.2	35.6	23.4	8.6	5.8
G128	Cloates Ref	100	0	0	0	0	0	0
G129	Cloates Ref	82.8	9.4	2.1	0.9	1.6	2.8	0.5
G130	Cloates Ref	100	0	0	0	0	0	0
G131	Cloates Ref	91.1	5.7	1.7	0.7	0.4	0.3	0.2
G132	Cloates Ref	1.1	4.4	19.5	55.7	19	0.3	0
G133	Cloates Ref	100	0	0	0	0	0	0
G134	Norwegian Bay	1.1	0.8	2.4	9.3	36.1	49.2	1.1

GRAB	LOCATION	GRAVEL (%)	V COARSE SAND (%)	COARSE SAND (%)	MEDIUM SAND (%)	FINE SAND (%)	V FINE SAND (%)	MUD
G135	Mandu SZ	6	5.4	9.7	15.2	31.1	28	4.6
G136	Mandu SZ	32.8	17.5	23.2	19.3	5.6	1.3	0.4
G137	Mandu SZ	29.8	23.2	19.9	18.9	6	1.9	0.4
G138	Mandu SZ	41	20.4	21.1	14.3	2.2	0.7	0.3
G139	Mandu SZ	23	15.7	19	18.6	7.2	13	3.5
G140	Mandu SZ	15.3	10.8	14.3	19.7	20.8	16.1	3
G141	Seaward Mandu SZ	7.2	6.2	15.5	26	23.7	16.8	4.6
G142	Seaward Mandu SZ	6	9.2	15.1	26.8	21.6	16.3	5.1
G143	Seaward Mandu SZ	2.5	3.7	10	24.4	50.2	8.8	0.3
G144	Seaward Mandu SZ	1.1	2.5	7.3	16.8	28.7	29.8	13.7
G145	Mandu SZ	17.4	13.4	18.4	19.9	9.6	13.3	8.1
G146	Mandu SZ	16.7	18.9	23.2	17.4	7.8	12.3	3.8
G147	Mandu SZ	28.1	28.3	25.1	14.5	3.4	0.5	0.1
G149	Mandu SZ	26.7	24.6	24.7	15.4	4.4	3	1.3
G150	Mandu SZ	51.3	15.8	14.9	10.7	4.1	2.4	0.8
G152	Mandu SZ	1.1	1.4	3	12.3	55.9	24.5	1.8
G153	Mandu SZ	4.6	32.8	27.1	23.4	9.9	2	0.2
G154	Mandu SZ	71.1	14.1	8.5	4.2	1.1	0.7	0.3

Appendix 2.5: Grain size descriptive statistics

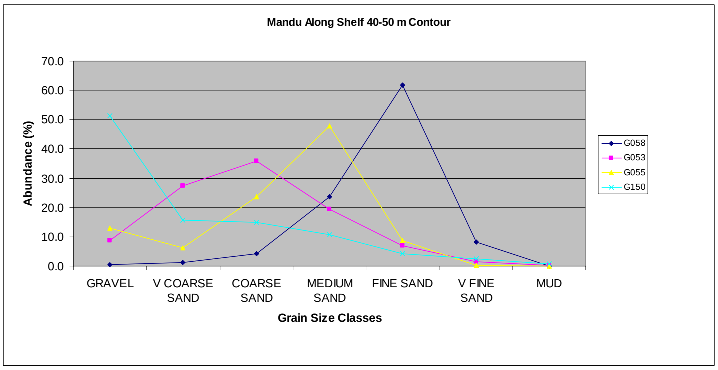
GRAB	LOCATION	SEDIMENT NAME	MODE	MEAN	SORTING	SKEWNESS	KURTOSIS
G002	Osprey Ref	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G003	Osprey Ref	Sandy Gravel	Unimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Leptokurtic
G011	Osprey SZ	Gravelly Very Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G012	Osprey SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G013	Osprey SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Moderately Sorted	Fine Skewed	Platykurtic
G014	Osprey SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Very Coarse Skewed	Leptokurtic
G015	Osprey SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Very Coarse Skewed	Leptokurtic
G016	Osprey SZ	Slightly Gravelly Fine Sand	Trimodal	Fine Sand	Poorly Sorted	Coarse Skewed	Leptokurtic
G017	Osprey SZ	Gravelly Muddy Very Fine Sand	Trimodal	Fine Sand	Very Poorly Sorted	Coarse Skewed	Leptokurtic
G018	Osprey SZ	Gravelly Muddy Very Fine Sand	Trimodal	Fine Sand	Very Poorly Sorted	Fine Skewed	Mesokurtic
G019	Osprey SZ	Gravelly Very Fine Sand	Polymodal	Medium Sand	Poorly Sorted	Symmetrical	Mesokurtic
G020	Seaward Osprey SZ	Gravelly Muddy Very Fine Sand	Polymodal	Fine Sand	Poorly Sorted	Symmetrical	Leptokurtic
G022	Osprey SZ	Gravelly Muddy Very Fine Sand	Polymodal	Fine Sand	Very Poorly Sorted	Coarse Skewed	Leptokurtic
G023	Osprey SZ	Slightly Gravelly Muddy Very Fine Sand	Bimodal	Fine Sand	Poorly Sorted	Coarse Skewed	Leptokurtic
G024	Osprey SZ	Gravelly Coarse Sand	Trimodal	Medium Sand	Poorly Sorted	Fine Skewed	Mesokurtic
G025	Osprey SZ	Gravelly Medium Sand	Trimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G026	Osprey SZ	Gravelly Muddy Coarse Sand	Trimodal	Medium Sand	Very Poorly Sorted	Very Fine Skewed	Platykurtic
G027	Osprey Ref	Gravelly Fine Sand	Trimodal	Medium Sand	Poorly Sorted	Coarse Skewed	Very Platykurtic
G028	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Very Coarse Skewed	Leptokurtic
G029	Osprey Ref	Gravelly Fine Sand	Polymodal	Medium Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G030	Osprey Ref	Gravelly Very Fine Sand	Polymodal	Medium Sand	Poorly Sorted	Symmetrical	Platykurtic
G031	Osprey Ref	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G032	Osprey Ref	Sandy Gravel	Polymodal	Coarse Sand	Poorly Sorted	Fine Skewed	Very Platykurtic
G033	Osprey Ref	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G034	Seaward Osprey Ref	Gravelly Medium Sand	Bimodal	Medium Sand	Poorly Sorted	Symmetrical	Mesokurtic
G035	Osprey Ref	Slightly Gravelly Fine Sand	Bimodal	Fine Sand	Poorly Sorted	Symmetrical	Leptokurtic
G036	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Coarse Skewed	Leptokurtic
G037	Osprey Ref	Gravelly Medium Sand	Bimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Mesokurtic
G038	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Well Sorted	Fine Skewed	Mesokurtic
G039	Osprey Ref	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Poorly Sorted	Symmetrical	Mesokurtic
G040	Osprey Ref	Gravelly Fine Sand	Trimodal	Medium Sand	Poorly Sorted	Symmetrical	Mesokurtic
G041	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Coarse Skewed	Leptokurtic
G042	Osprey Ref	Sandy Gravel	Unimodal	Very Coarse Sand	Moderately Sorted	Very Fine Skewed	Leptokurtic
G043	Osprey Ref	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G044	Osprey Ref	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G045	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Medium Sand	Moderately Sorted	Very Coarse Skewed	Leptokurtic

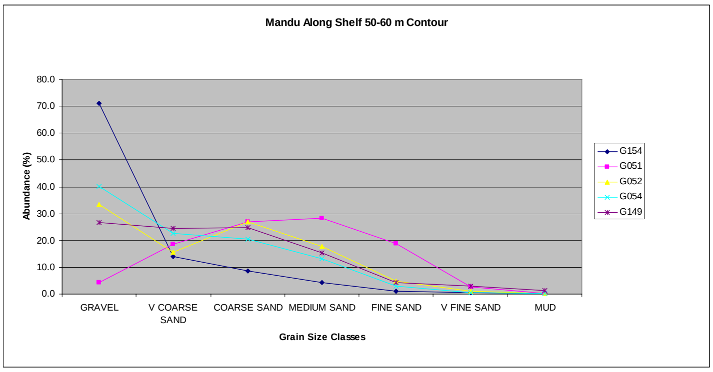
GRAB	LOCATION	SEDIMENT NAME	MODE	MEAN	SORTING	SKEWNESS	KURTOSIS
G046	Osprey Ref	Gravelly Coarse Sand	Polymodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G047	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Sorted	Symmetrical	Mesokurtic
G048	Osprey Ref	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Sorted	Coarse Skewed	Leptokurtic
G050	Osprey Ref	Sandy Gravel	Trimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G051	Mandu SZ	Slightly Gravelly Medium Sand	Bimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G052	Mandu SZ	Sandy Gravel	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G053	Mandu SZ	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Symmetrical	Mesokurtic
G054	Mandu SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G055	Mandu SZ	Gravelly Medium Sand	Bimodal	Coarse Sand	Poorly Sorted	Very Coarse Skewed	Mesokurtic
G056	Mandu SZ	Gravelly Very Fine Sand	Trimodal	Medium Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G057	Mandu SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G058	Mandu SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Well Sorted	Coarse Skewed	Leptokurtic
G060	N Cloates SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Very Platykurtic
G061	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Very Well Sorted	Coarse Skewed	Leptokurtic
G062	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Well Sorted	Coarse Skewed	Leptokurtic
G065	M Cloates SZ	Slightly Gravelly Coarse Sand	Unimodal	Coarse Sand	Moderately Sorted	Coarse Skewed	Mesokurtic
G066	M Cloates SZ	Gravelly Coarse Sand	Bimodal	Very Coarse Sand	Moderately Sorted	Coarse Skewed	Platykurtic
G068	M Cloates SZ	Gravelly Coarse Sand	Bimodal	Very Coarse Sand	Moderately Sorted	Coarse Skewed	Platykurtic
G069	M Cloates SZ	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G070	M Cloates SZ	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G071	M Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Sorted	Coarse Skewed	Mesokurtic
G072	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Well Sorted	Symmetrical	Mesokurtic
G074	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Well Sorted	Fine Skewed	Very Leptokurtic
G075	M Cloates SZ	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G076	M Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Well Sorted	Symmetrical	Mesokurtic
G078	M Cloates SZ	Sandy Gravel	Bimodal	Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G079	M Cloates SZ	Gravelly Very Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G080	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Sorted	Very Coarse Skewed	Mesokurtic
G081	M Cloates SZ	Gravelly Medium Sand	Trimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G083	N Cloates SZ	Gravelly Muddy Coarse Sand	Trimodal	Medium Sand	Very Poorly Sorted	Very Fine Skewed	Leptokurtic
G086	N Cloates SZ	Gravelly Coarse Sand	Trimodal	Medium Sand	Poorly Sorted	Fine Skewed	Mesokurtic
G088	N Cloates SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Symmetrical	Leptokurtic
G089	N Cloates SZ	Gravelly Medium Sand	Polymodal	Medium Sand	Poorly Sorted	Symmetrical	Platykurtic
G090	N Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Sorted	Symmetrical	Very Leptokurtic
G091	N Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Sorted	Coarse Skewed	Leptokurtic
G092	N Cloates SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Leptokurtic
G093	N Cloates SZ	Gravelly Coarse Sand	Bimodal	Very Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G094	N Cloates SZ	Gravelly Very Coarse Sand	Bimodal	Coarse Sand	Moderately Sorted	Fine Skewed	Leptokurtic

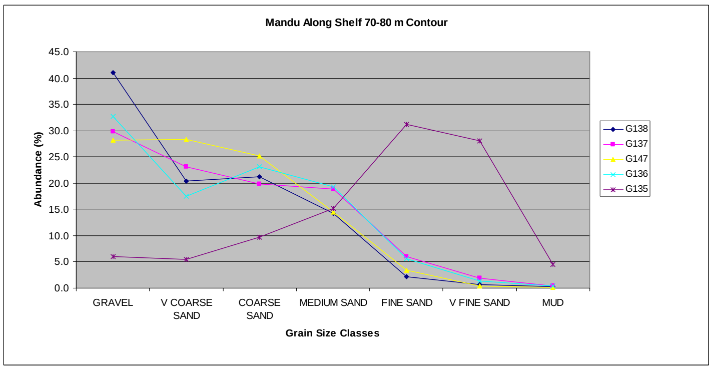
GRAB	LOCATION	SEDIMENT NAME	MODE	MEAN	SORTING	SKEWNESS	KURTOSIS
G095	N Cloates SZ	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G096	N Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Sorted	Coarse Skewed	Leptokurtic
G097	N Cloates SZ	Sandy Gravel	Bimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Very Platykurtic
G099	N Cloates SZ	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G100	N Cloates SZ	Sandy Gravel	Trimodal	Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G101	N Cloates SZ	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Well Sorted	Symmetrical	Mesokurtic
G102	N Cloates SZ	Gravelly Medium Sand	Bimodal	Medium Sand	Moderately Sorted	Coarse Skewed	Very Leptokurtic
G103	N Cloates SZ	Sandy Gravel	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Very Platykurtic
G104	N Cloates SZ	Gravelly Coarse Sand	Bimodal	Very Coarse Sand	Moderately Well Sorted	Very Coarse Skewed	Mesokurtic
G107	M Cloates SZ	Sandy Gravel	Unimodal	Very Fine Gravel	Moderately Well Sorted	Very Fine Skewed	Extremely Leptokurtic
G109	M Cloates SZ	Sandy Gravel	Unimodal	Very Coarse Sand	Moderately Sorted	Very Fine Skewed	Mesokurtic
G110	M Cloates SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Well Sorted	Symmetrical	Mesokurtic
G111	M Cloates SZ	Slightly Gravelly Very Fine Sand	Unimodal	Very Fine Sand	Well Sorted	Symmetrical	Mesokurtic
G112	M Cloates SZ	Slightly Gravelly Medium Sand	Bimodal	Medium Sand	Moderately Well Sorted	Very Fine Skewed	Very Platykurtic
G113	Cloates Ref	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G114	Cloates Ref	Sandy Gravel	Unimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Mesokurtic
G115	Cloates Ref	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Mesokurtic
G116	Cloates Ref	Gravelly Medium Sand	Bimodal	Coarse Sand	Poorly Sorted	Symmetrical	Mesokurtic
G117	Cloates Ref	Gravelly Coarse Sand	Trimodal	Medium Sand	Very Poorly Sorted	Fine Skewed	Leptokurtic
G118	Cloates Ref	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Symmetrical	Platykurtic
G119	Cloates Ref	Gravelly Medium Sand	Trimodal	Medium Sand	Very Poorly Sorted	Fine Skewed	Platykurtic
G120	Cloates Ref	Sandy Gravel	Unimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G121	Cloates Ref	Gravelly Medium Sand	Bimodal	Medium Sand	Poorly Sorted	Coarse Skewed	Leptokurtic
G122	Cloates Ref	Gravelly Medium Sand	Bimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Mesokurtic
G123	Cloates Ref	Gravelly Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G124	Cloates Ref	Gravel	Unimodal	Very Fine Gravel	Well Sorted	Very Fine Skewed	Very Leptokurtic
G125	Cloates Ref	Sandy Gravel	Unimodal	Very Coarse Sand	Moderately Sorted	Very Fine Skewed	Leptokurtic
G126	Cloates Ref	Gravelly Very Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G127	Cloates Ref	Slightly Gravelly Medium Sand	Bimodal	Medium Sand	Poorly Sorted	Symmetrical	Leptokurtic
G128	Cloates Ref	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G129	Cloates Ref	Gravel	Unimodal	Very Fine Gravel	Moderately Well Sorted	Very Fine Skewed	Extremely Leptokurtic
G130	Cloates Ref	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G131	Cloates Ref	Gravel	Unimodal	Very Fine Gravel	Very Well Sorted	Fine Skewed	Very Leptokurtic
G132	Cloates Ref	Slightly Gravelly Medium Sand	Unimodal	Medium Sand	Moderately Sorted	Coarse Skewed	Leptokurtic
G133	Cloates Ref	Very Coarse Rhodolith Gravel		V Coarse Gravel			
G134	Norwegian Bay	Slightly Gravelly Very Fine Sand	Unimodal	Fine Sand	Moderately Sorted	Very Coarse Skewed	Leptokurtic
G135	Mandu SZ	Gravelly Fine Sand	Trimodal	Fine Sand	Poorly Sorted	Very Coarse Skewed	Leptokurtic
G136	Mandu SZ	Sandy Gravel	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic

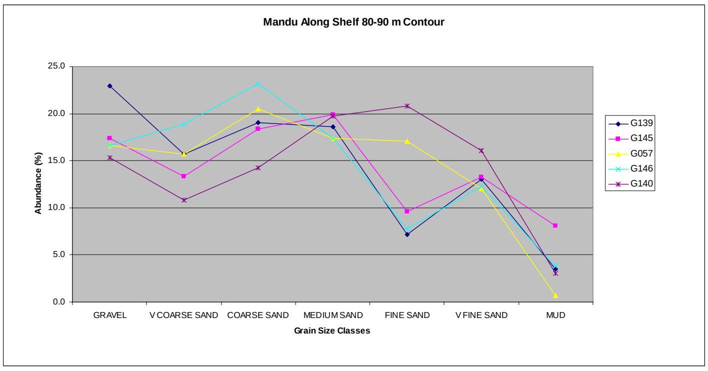
GRAB	LOCATION	SEDIMENT NAME	MODE	MEAN	SORTING	SKEWNESS	KURTOSIS
G137	Mandu SZ	Gravelly Very Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G138	Mandu SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Platykurtic
G139	Mandu SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G140	Mandu SZ	Gravelly Fine Sand	Trimodal	Medium Sand	Poorly Sorted	Coarse Skewed	Platykurtic
G141	Seaward Mandu SZ	Gravelly Medium Sand	Bimodal	Medium Sand	Poorly Sorted	Coarse Skewed	Mesokurtic
G142	Seaward Mandu SZ	Gravelly Medium Sand	Bimodal	Medium Sand	Poorly Sorted	Symmetrical	Mesokurtic
G143	Seaward Mandu SZ	Slightly Gravelly Fine Sand	Unimodal	Medium Sand	Poorly Sorted	Very Coarse Skewed	Leptokurtic
G144	Seaward Mandu SZ	Slightly Gravelly Muddy Very Fine Sand	Unimodal	Fine Sand	Poorly Sorted	Symmetrical	Very Leptokurtic
G145	Mandu SZ	Gravelly Medium Sand	Trimodal	Medium Sand	Very Poorly Sorted	Fine Skewed	Mesokurtic
G146	Mandu SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G147	Mandu SZ	Gravelly Very Coarse Sand	Bimodal	Very Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G149	Mandu SZ	Gravelly Coarse Sand	Trimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G150	Mandu SZ	Sandy Gravel	Bimodal	Very Coarse Sand	Poorly Sorted	Very Fine Skewed	Mesokurtic
G152	Mandu SZ	Slightly Gravelly Fine Sand	Unimodal	Fine Sand	Moderately Sorted	Coarse Skewed	Leptokurtic
G153	Mandu SZ	Slightly Very Gravelly Very Coarse Sand	Bimodal	Coarse Sand	Poorly Sorted	Fine Skewed	Platykurtic
G154	Mandu SZ	Sandy Gravel	Unimodal	Very Coarse Sand	Moderately Sorted	Very Fine Skewed	Very Leptokurtic

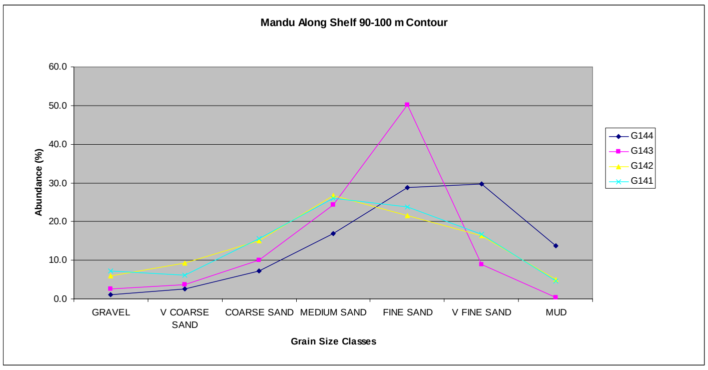
Appendix 2.6: Cross shelf profiles of grain size percentages for all sampling sites

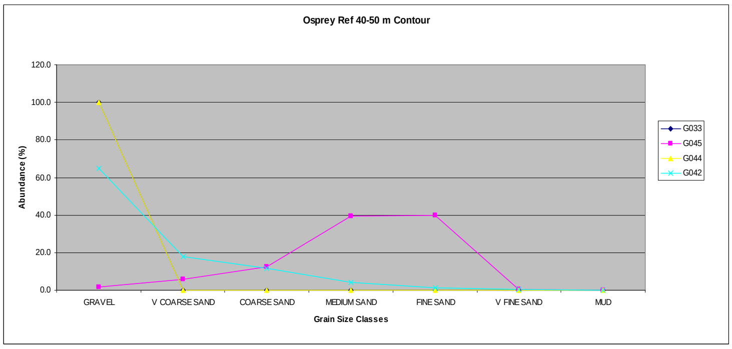


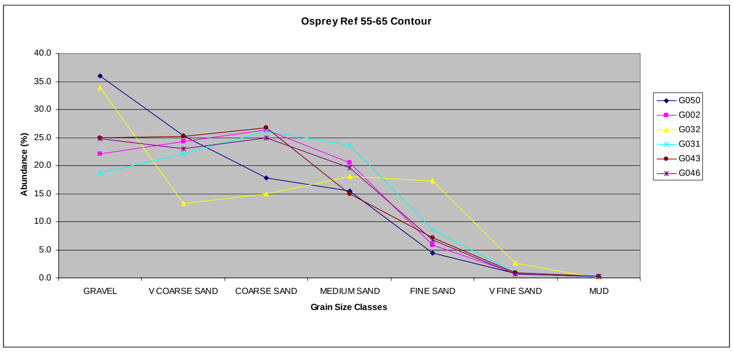


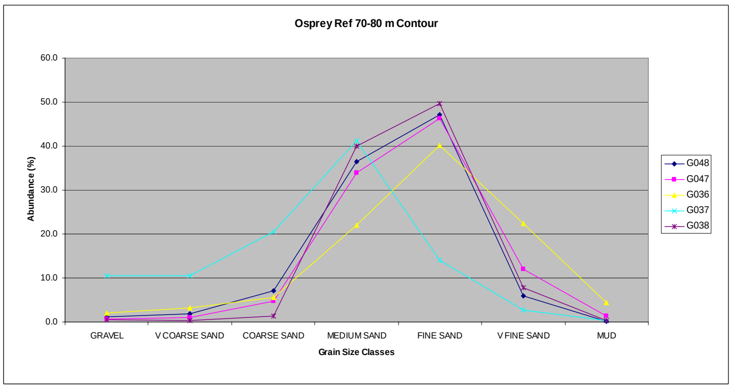


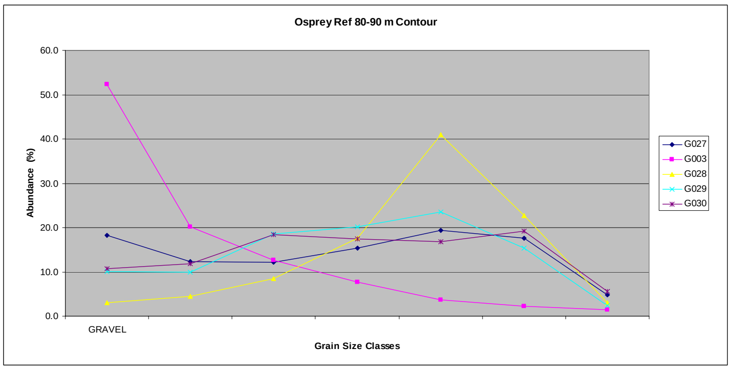


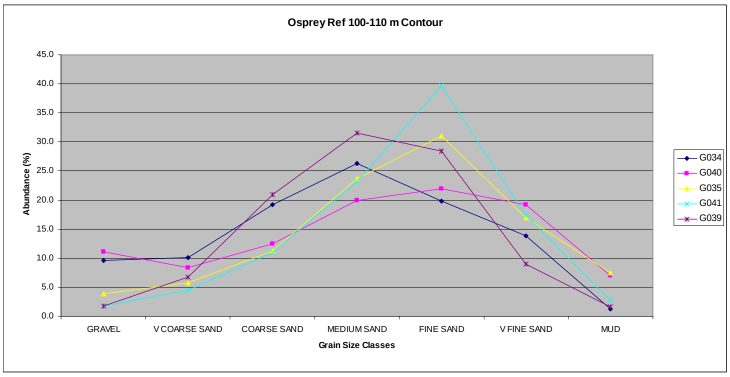

Mandu Along Shelf 90-100 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G144
G143
G142
G141

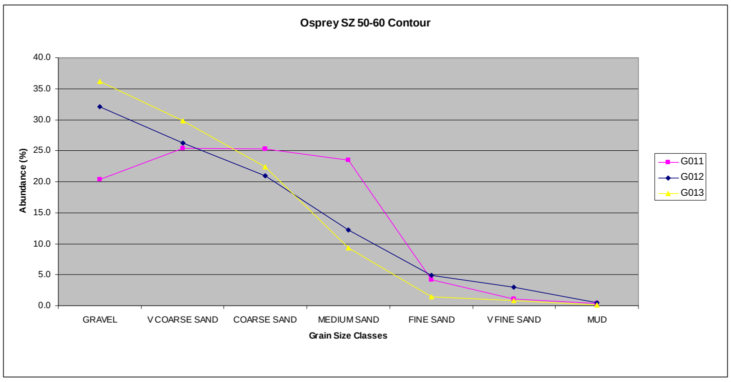

Osprey Ref 40-50 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G033
G045
G044
G042

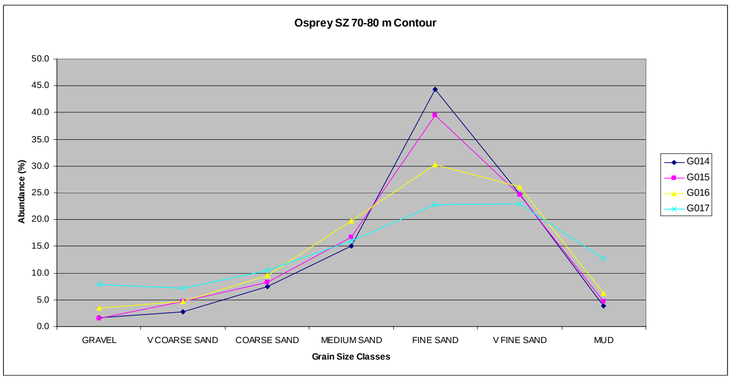

Osprey Ref 55-65 Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G050
G002
G032
G031
G043
G046

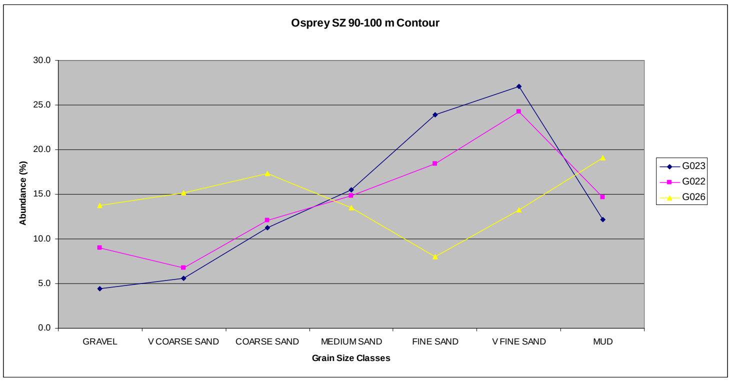

Osprey Ref 70-80 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G048
G047
G036
G037
G038

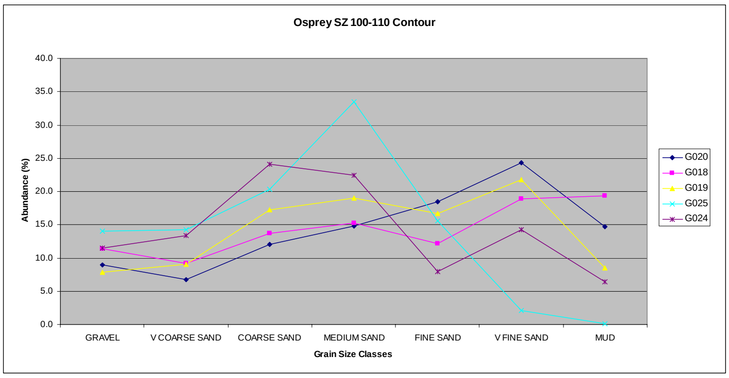

Osprey Ref 80-90 m Contour
Abundance (%)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
GRAVEL
Grain Size Classes
G027
G003
G028
G029
G030

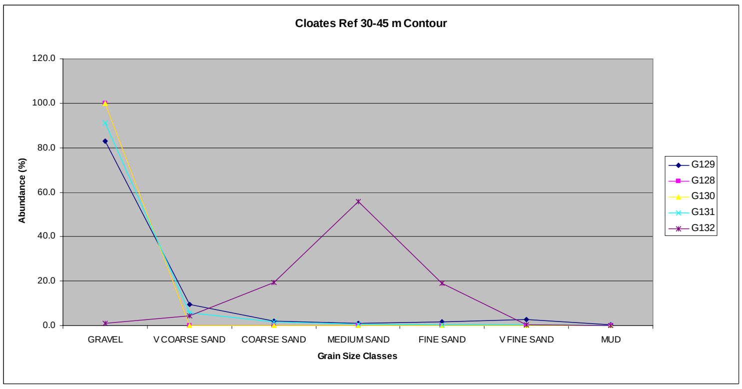

Osprey Ref 100-110 m Contour
Abundance (%)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G034
G040
G035
G041
G039

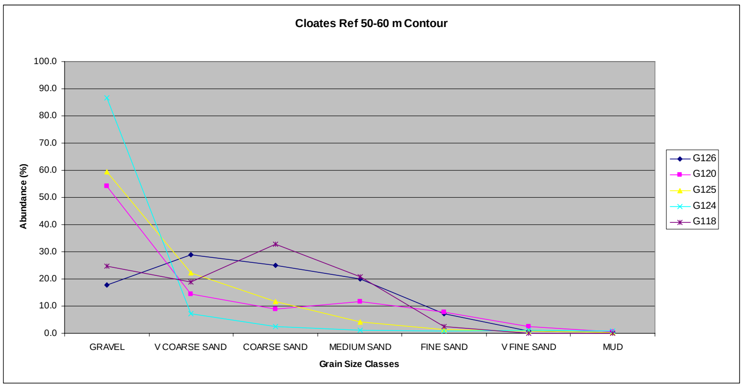

Osprey SZ 50-60 Contour
Abundance (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G011
G012
G013

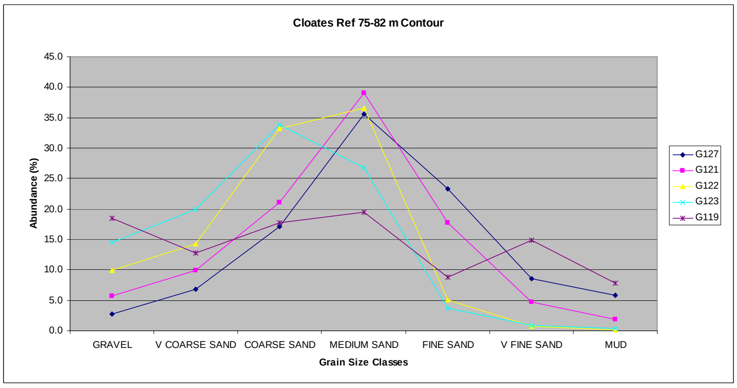

Osprey SZ 70-80 m Contour
Abundance (%)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G014
G015
G016
G017

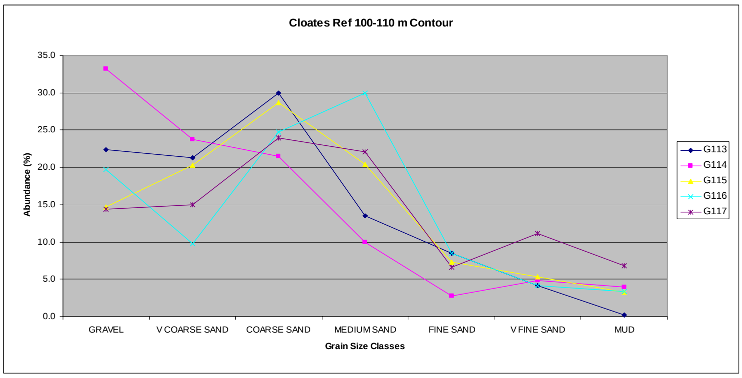

Osprey SZ 90-100 m Contour
Abundance (%)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G023
G022
G026

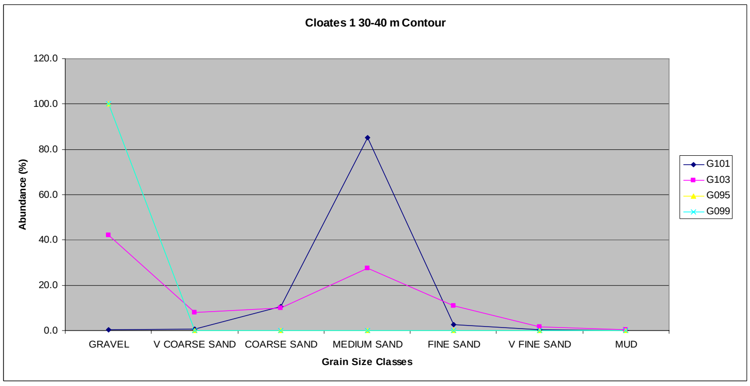

Osprey SZ 100-110 Contour
Abundance (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G020
G018
G019
G025
G024

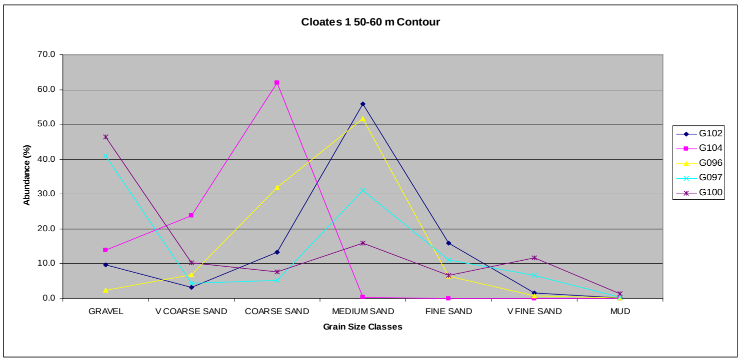

Cloates Ref 30-45 m Contour
Abundance (%)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G129
G128
G130
G131
G132

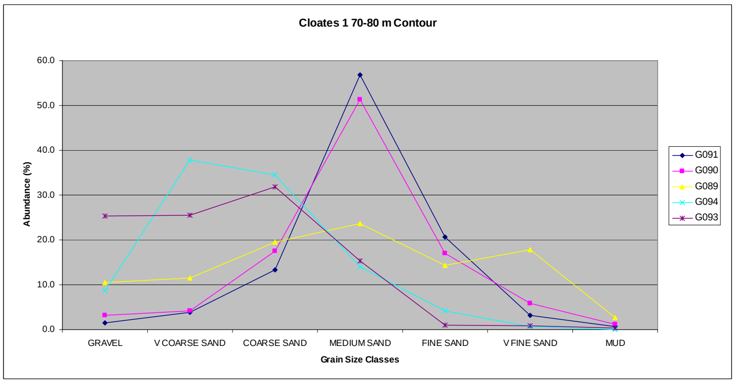

Cloates Ref 50-60 m Contour
Abundance (%)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G126
G120
G125
G124
G118


Cloates Ref 75-82 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G127
G121
G122
G123
G119

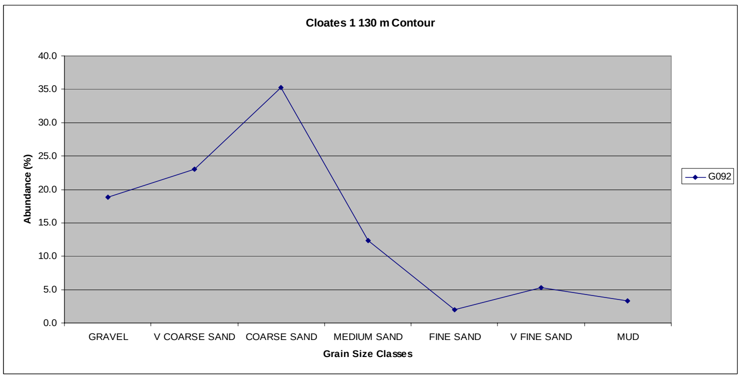

Cloates Ref 100-110 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G113
G114
G115
G116
G117

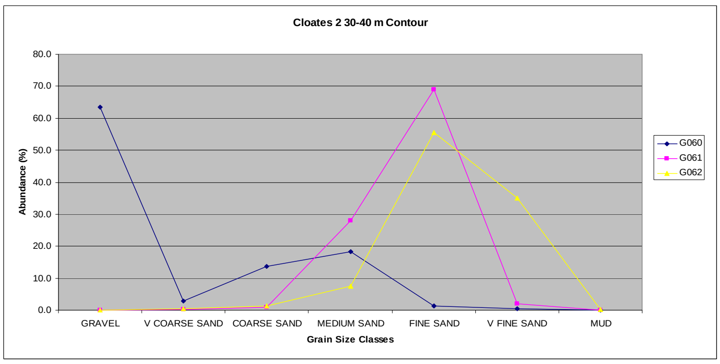

Cloates 1 30-40 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G101
G103
G095
G099

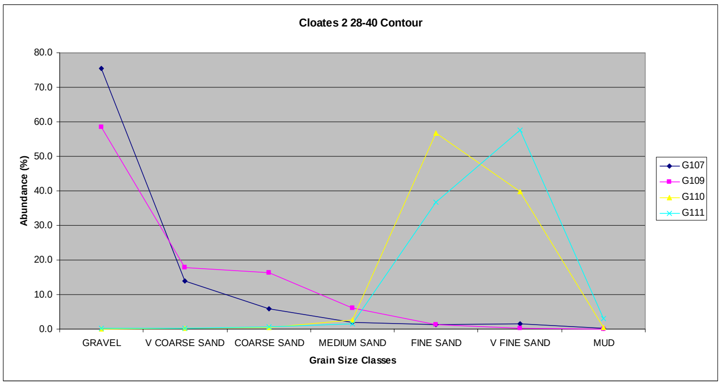

Cloates 1 50-60 m Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G102
G104
G096
G097
G100

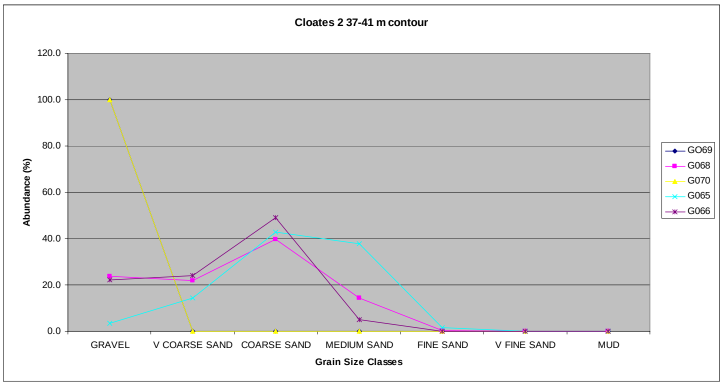

Cloates 1 70-80 m Contour
Abundance (%)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G091
G090
G089
G094
G093

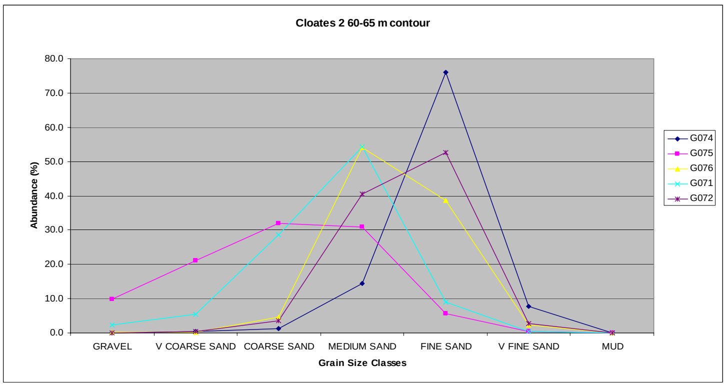

Cloates 1 90-100 m Contour
Abundance (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G088
G086
G092


Cloates 1 130 m Contour
Abundance (%)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G092


Cloates 2 30-40 m Contour
Abundance (%)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
Grain Size Classes
G060
G061
G062


Cloates 2 28-40 Contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G107
G109
G110
G111


Cloates 2 37-41 m contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
GO69
G068
G070
G065
G066


Cloates 2 60-65 m contour
Abundance (%)
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G074
G075
G076
G071
G072


Cloates 2 65-70 m contour
Abundance
Grain Size Classes
GRAVEL
V COARSE SAND
COARSE SAND
MEDIUM SAND
FINE SAND
V FINE SAND
MUD
G112
G078
G079
G080
G081

Appendix 3: Towed Video

Appendix 3.1: Towed Video operations data

Date	Leader	Cruise	Tow ID	Tow	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Depth	End Depth	Start Time	Finish Time
22/04/2006	Rees	CF4010	A1	1	1	Mandu SZ	-22.156	113.8453	-22.16	113.8444	55	52.6	1400	1406
22/04/2006	Rees	CF4010	A2	2	1	Osprey Ref/Mandu SZ	-22.1575	113.839	-22.1626	113.8395	65	65	1422	1444
22/04/2006	Rees	CF4010	A3	3	1	Osprey Ref/Mandu SZ	-22.1582	113.8082	-22.1638	113.8058	85	85	1504	1524
23/04/2006	Rees	CF4010	A4	4	1	Osprey SZ	-22.256	113.8084	-22.2592	113.806	42	44.6	0840	0850
23/04/2006	Rees	CF4010	A5	5	1	Osprey SZ	-22.2684	113.8025	-22.2724	113.801	40	40	0903	0913
23/04/2006	Rees	CF4010	A6	6	2	Osprey SZ	-22.2809	113.7974	-22.2846	113.7952	40.5	38.2	0924	0934
23/04/2006	Rees	CF4010	A7	7	2	Osprey SZ	-22.2921	113.7899	-22.2959	113.7873	40.7	40.8	0944	0954
23/04/2006	Rees	CF4010	A8	8	2	Osprey SZ	-22.3069	113.7777	-22.3104	113.7748	43.8	32.7	1007	1019
23/04/2006	Rees	CF4010	A9	9	2	Osprey SZ	-22.2559	113.8047	-22.2604	113.8021	56.8	57.9	1518	1534
23/04/2006	Rees	CF4010	A10	10	2	Osprey SZ	-22.2679	113.7976	-22.2714	113.7954	57	56.8	1547	1558
23/04/2006	Rees	CF4010	A11	11	3	Osprey SZ	-22.2799	113.7919	-22.2841	113.7896	55.6	55.6	1612	1621
25/04/2006	Rees	CF4010	A12	12	3	Osprey SZ	-22.2912	113.7837	-22.2993	113.7785	58.6	56.5	0802	0827
25/04/2006	Rees	CF4010	A13	13	3	Osprey SZ	-22.3046	113.7756	-22.3075	113.7715	52.8	50	0839	0857
25/04/2006	Rees	CF4010	A14	14	3	Osprey SZ	-22.2526	113.7896	-22.2567	113.7876	74	73	1239	1256
25/04/2006	Rees	CF4010	A15	15	3	Osprey SZ	-22.2639	113.7849	-22.2678	113.7828	75.1	76.5	1315	1329
25/04/2006	Rees	CF4010	A16	16	4	Osprey SZ	-22.2758	113.7798	-22.2812	113.7764	76.7	74.8	1358	1420
25/04/2006	Rees	CF4010	A17	17	4	Osprey SZ	-22.2869	113.773	-22.2901	113.7704	75	77	1430	1443
25/04/2006	Rees	CF4010	A18	18	4	Osprey SZ	-22.296	113.7663	-22.299	113.7634	77.2	74	1455	1509
26/04/2006	Rees	CF4010	A19	19	4	Osprey SZ	-22.2408	113.7664	-22.2436	113.7656	105	102	0920	1007
26/04/2006	Rees	CF4010	A20	20	5	Osprey SZ	-22.2541	113.7623	-22.2576	113.7605	103	103.2	1029	1056
26/04/2006	Rees	CF4010	A21	21	5	Osprey SZ	-22.2656	113.7575	-22.2694	113.7555	101	100.9	1129	1200
26/04/2006	Rees	CF4010	A22	22	6	Osprey SZ	-22.2471	113.7789	-22.248	113.7782	87	88.9	1639	1646
26/04/2006	Rees	CF4010	A23	23	6	Osprey SZ	-22.2636	113.7704	-22.2663	113.7686	88.3	88	1712	1728
26/04/2006	Rees	CF4010	A24	24	6	Osprey SZ	-22.2749	113.7635	-22.275	113.7623	91.5	92.8	1743	1753
26/04/2006	Rees	CF4010	A25	25	6	Osprey SZ	-22.2808	113.7607	-22.2812	113.7611	90	88.7	1605	1616
27/04/2006	Rees	CF4010	A27	27	6	Osprey SZ	-22.2806	113.7608	-22.2817	113.7602	86.6	79.7	0810	0820
27/04/2006	Rees	CF4010	A28	28	6	Osprey SZ	-22.2903	113.7549	-22.291	113.7542	89	89	0839	0845
27/04/2006	Rees	CF4010	A29	29	6	Osprey SZ	-22.2751	113.7527	-22.2754	113.7511	102	105	0931	0944
27/04/2006	Rees	CF4010	A30	30	6	Osprey SZ	-22.2863	113.7452	-22.2869	113.7439	103.3	103	1001	1010
27/04/2006	Rees	CF4010	A31	31	7	Seaward Osprey SZ	-22.2417	113.761	-22.2437	113.7612	112	111.6	1630	1640
27/04/2006	Rees	CF4010	A32	32	7	Seaward Osprey SZ	-22.2386	113.7566	-22.2373	113.7572	127.8	129	1700	1706
28/04/2006	Rees	CF4010	A33	33	7	Osprey Ref	-22.1748	113.7933	-22.176	113.7935	99	98	0823	0831

Date	Leader	Cruise	Tow ID	To w	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Dept h	End Depth	Start Time	Finish Time
28/04/2006	Rees	CF4010	A34	34	7	Osprey Ref	-22.1673	113.8044	-22.1691	113.802	85.9	91.3	0927	0948
28/04/2006	Rees	CF4010	A35	35	7	Osprey Ref	-22.1731	113.8035	-22.176	113.8029	83.1	79	0959	1019
28/04/2006	Rees	CF4010	A36	36	7	Osprey Ref	-22.1875	113.7996	-22.1905	113.7992	86.5	84.7	1033	1051
28/04/2006	Rees	CF4010	A37	37	8	Osprey Ref	-22.2004	113.7952	-22.2032	113.7944	83.1	83.9	1107	1125
28/04/2006	Rees	CF4010	A38	38	8	Osprey Ref	-22.214	113.7898	-22.2182	113.7895	83.4	81.9	1859	1912
29/04/2006	Rees	CF4010	A39	39	8	Osprey Ref	-22.1688	113.8014	-22.1733	113.8003	91.4	91.2	0854	0918
29/04/2006	Rees	CF4010	A40	40	8	Osprey Ref	-22.1672	113.8012	-22.1702	113.8018	92.9	88.2	0942	1016
29/04/2006	Rees	CF4010	A41	41	9	Osprey Ref	-22.184473	113.807054	-22.185298	113.806845	75.7	77.5	1402	1425
29/04/2006	Rees	CF4010	A42	42	9	Osprey Ref	-22.1929	113.8053	-22.196	113.8041	77.5	77.7	1435	1447
29/04/2006	Rees	CF4010	A43	43	9	Osprey Ref	-22.2026	113.805	-22.2048	113.805	71	72.4	1536	1546
29/04/2006	Rees	CF4010	A44	44	9	Osprey Ref	-22.2123	113.8029	-22.2152	113.8026	72.6	70.4	1557	1607
30/04/2006	Rees	CF4010	A45	45	9	Osprey Ref	-22.1678	113.823	-22.1712	113.8213	73	72.6	0851	0900
30/04/2006	Rees	CF4010	A46	46	9	Osprey Ref	-22.1781	113.8193	-22.1806	113.8186	72.1	72.1	0937	0943
30/04/2006	Rees	CF4010	A47	47	9	Osprey Ref	-22.1888	113.8167	-22.1903	113.8162	71.3	71.5	0955	1000
30/04/2006	Rees	CF4010	A48	48	9	Osprey Ref	-22.198	113.8138	-22.1997	113.8134	71.3	70.6	1009	1013
30/04/2006	Rees	CF4010	A49	49	9	Osprey Ref	-22.2055	113.8099	-22.208	113.8094	71.2	70.9	1022	1028
30/04/2006	Rees	CF4010	A50	50	9	Osprey Ref/Osprey SZ	-22.2213	113.803	-22.2248	113.802	72.7	70.9	1004	1049
30/04/2006	Rees	CF4010	A51	51	9	Osprey Ref	-22.2083	113.7821	-22.2105	113.7813	100.9	101.2	1255	1300
30/04/2006	Rees	CF4010	A52	52	10	Seaward Osprey Ref	-22.2171	113.7741	-22.2203	113.7729	105.8	107.1	1314	1323
30/04/2006	Rees	CF4010	A53	53	10	Seaward Osprey Ref	-22.1955	113.7818	-22.1984	113.7812	107	105	1457	1402
30/04/2006	Rees	CF4010	A54	54	10	Osprey Ref	-22.2156	113.8202	-22.2187	113.8199	57.9	54.7	1616	1629
30/04/2006	Rees	CF4010	A55	55	10	Osprey Ref	-22.1998	113.8239	-22.2039	113.8234	59.7	59.3	1648	1658
30/04/2006	Rees	CF4010	A56	56	10	Osprey Ref	-22.1891	113.8283	-22.1922	113.8282	59.9	54.9	1712	1720
30/04/2006	Rees	CF4010	A57	57	10	Osprey Ref	-22.1773	113.834	-22.1812	113.834	57	51.6	1734	1746
30/04/2006	Rees	CF4010	A58	58	10	Osprey Ref	-22.1663	113.8391	-22.1691	113.8396	58.4	54	1759	1810
30/04/2006	Rees	CF4010	A59	59	10	Osprey Ref	-22.1663	113.8444	-22.169	113.8442	40	37.1	1820	1832
01/05/2006	Rees	CF4010	A60	60	11	Osprey Ref	-22.1779	113.8381	-22.192	113.8296	44.5	46.9	0847	0857
01/05/2006	Rees	CF4010	A61	61	11	Osprey Ref	-22.1898	113.8321	-22.2035	113.8273	44.2	49.6	0906	0917
01/05/2006	Rees	CF4010	A62	62	11	Osprey Ref	-22.2006	113.8282	-22.2035	113.8273	44.2	45.5	0925	0933
01/05/2006	Rees	CF4010	A63	63	11	Osprey Ref	-22.2127	113.8257	-22.215	113.8233	42.6	45.6	0945	1000
02/05/2006	Rees	CF4010	A64	64	11	Osprey Ref	-22.1779	113.8157	-22.1848	113.8143	73.1	73.1	0900	0924
02/05/2006	Rees	CF4010	A65	65	11	Mandu SZ	-22.135	113.8521	-22.1383	113.8518	56.3	55	1705	1718
02/05/2006	Rees	CF4010	A66	66	12	Mandu SZ	-22.1594	113.8442	-22.156	113.8464	53.5	49.4	1741	1752
02/05/2006	Rees	CF4010	A67	67	12	Mandu SZ	-22.1496	113.8476	-22.1459	113.8495	53	50.9	1801	1812
02/05/2006	Rees	CF4010	A68	68	12	Mandu SZ	-22.1275	113.8542	-22.1241	113.855	42.7	58.6	1827	1838
02/05/2006	Rees	CF4010	A69	69	12	Mandu SZ	-22.1166	113.8581	-22.1139	113.8581	57.8	59.7	1851	1859

Date	Leader	Cruise	Tow ID	Tow	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Depth	End Depth	Start Time	Finish Time
03/05/2006	Rees	CF4010	A70	70	12	Mandu SZ	-22.092	113.8253	-22.0964	113.8234	81	82.6	0844	0856
03/05/2006	Rees	CF4010	A71	71	12	Mandu SZ	-22.107	113.8211	-22.1107	113.8224	82.5	78	0909	0923
03/05/2006	Rees	CF4010	A72	72	13	Mandu SZ	-22.1178	113.8185	-22.1236	113.8172	84.3	82.8	0936	0956
03/05/2006	Rees	CF4010	A73	73	13	Mandu SZ	-22.1292	113.8147	-22.1318	113.8145	84.3	83.2	1007	1015
03/05/2006	Rees	CF4010	A74	74	13	Mandu SZ	-22.1427	113.8135	-22.1472	113.814	80.9	81	1027	1046
03/05/2006	Rees	CF4010	A75	75	13	Mandu SZ	-22.1529	113.8364	-22.1501	113.8376	69.8	62.2	1502	1512
03/05/2006	Rees	CF4010	A76	76	13	Mandu SZ	-22.1404	113.8405	-22.1394	113.842	69.9	64	1524	1531
03/05/2006	Rees	CF4010	A77	77	13	Mandu SZ	-22.1262	113.8447	-22.1241	113.8463	71.6	70	1548	1559
03/05/2006	Rees	CF4010	A79	79	14	Mandu SZ	-22.1161	113.8487	-22.1129	113.8511	68.9	68	1614	1628
06/05/2006	Heyward	CF4011	A80	80	14	Mandu SZ	-22.100798	113.866428	-22.105091	113.865122	45.4	43	0920	0930
06/05/2006	Heyward	CF4011	A81	81	14	Mandu SZ	-22.114086	113.863643	-22.11897	113.863353	45	45	0941	0951
06/05/2006	Heyward	CF4011	A82	82	14	Mandu SZ	-22.126656	113.862806	-22.130656	113.86031	43	40	1002	10.10
06/05/2006	Heyward	CF4011	A83	83	14	Mandu SZ	-22.136615	113.856788	-22.140756	113.854855	43	44	1021	1030
06/05/2006	Heyward	CF4011	A84	84	14	Mandu SZ	-22.14744	113.851192	-22.151758	113.849623	42	42	1040	1050
06/05/2006	Heyward	CF4011	A85	85	14	Seaward Mandu SZ	-22.094201	113.810963	-22.09774	113.807879	100.4	101.9	1403	1414
07/05/2006	Heyward	CF4011	A86	86	14	Cloates SZ (Mid)	-22.720451	113.646417	-22.723411	113.648015	29	32	0910	0920
07/05/2006	Heyward	CF4011	A87	87	15	Cloates SZ (Mid)	-22.733198	113.655742	-22.735881	113.6579	32	32	0933	0941
07/05/2006	Heyward	CF4011	A88	88	15	Cloates SZ (Mid)	-22.745609	113.667592	-22.748262	113.669944	26	24.6	0952	0959
07/05/2006	Heyward	CF4011	A89	89	15	Cloates SZ (Mid)	-22.760523	113.677331	-22.762551	113.678155	28.6	30.6	1007	1018
07/05/2006	Heyward	CF4011	A90	90	15	Cloates SZ (Mid)	-22.772294	113.678844	-22.775713	113.679278	29.8	31	1032	1040
07/05/2006	Heyward	CF4011	A91	91	15	Cloates SZ (Mid)	-22.729882	113.626175	-22.733356	113.629168	36	34	1352	1401
07/05/2006	Heyward	CF4011	A92	92	15	Cloates SZ (Mid)	-22.744841	113.632039	-22.747724	113.634301	34	30	1411	1423
07/05/2006	Heyward	CF4011	A93	93	15	Cloates SZ (Mid)	-22.758311	113.638582	-22.761902	113.640716	35	31	1435	1445
07/05/2006	Heyward	CF4011	A94	94	15	Cloates SZ (Mid)	-22.771414	113.646108	-22.774212	113.648774	30.4	40.1	1453	1505
07/05/2006	Heyward	CF4011	A95	95	15	Cloates SZ (Mid)	-22.783152	113.655121	-22.784955	113.657811	36	35	1515	1524
07/05/2006	Heyward	CF4011	A96	96	16	Cloates SZ (Mid)	-22.784187	113.649326	-22.782959	113.647886	38	45	1842	1848
07/05/2006	Heyward	CF4011	A97	97	16	Cloates SZ (Mid)	-22.773725	113.640957	-22.77202	113.639153	41	42	1925	1938
07/05/2006	Heyward	CF4011	A98	98	16	Cloates SZ (Mid)	-22.763865	113.633636	-22.761792	113.630895	37	41	1947	1957
07/05/2006	Heyward	CF4011	A99	99	16	Cloates SZ (Mid)	-22.750544	113.626773	-22.748242	113.625375	43	41.5	2012	2022
07/05/2006	Heyward	CF4011	A100	100	16	Cloates SZ (Mid)	-22.735901	113.61921	-22.73386	113.617145	44	40	2034	2042
08/05/2006	Heyward	CF4011	A101	101	16	Cloates SZ (Mid)	-22.796427	113.651861	-22.794164	113.650547	54	52.5	1103	1114
08/05/2006	Heyward	CF4011	A102	102	16	Cloates SZ (Mid)	-22.775027	113.637231	-22.777275	113.637593	57	60.3	1154	1213
08/05/2006	Heyward	CF4011	A103	103	16	Cloates SZ (Mid)	-22.78729	113.649478	-22.787728	113.645362	41	44	1412	1435
08/05/2006	Heyward	CF4011	A104	104	17	Cloates SZ (Mid)	-22.763081	113.628004	-22.766374	113.630979	55	53	1652	1701
08/05/2006	Heyward	CF4011	A105	105	17	Cloates SZ (Mid)	-22.750581	113.620633	-22.746311	113.621446	41	45.1	1721	1736
09/05/2006	Heyward	CF4011	A106	106	17	Cloates SZ (Mid)	-22.79407	113.628892	-22.789854	113.628333	65	64.9	1320	1335

Date	Leader	Cruise	Tow ID	To w	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Dept h	End Depth	Start Time	Finish Time
09/05/2006	Heyward	CF4011	A107	107	17	Cloates SZ (Mid)	-22.781737	113.618618	-22.77732	113.618618	65.1	62	1350	1406
09/05/2006	Heyward	CF4011	A108	108	17	Cloates SZ (Mid)	-22.76919	113.613767	-22.764987	113.612707	65.6	63	1420	1434
09/05/2006	Heyward	CF4011	A109	109	17	Cloates SZ (Mid)	-22.756053	113.605573	-22.75197	113.603841	65.5	63.7	1445	1457
09/05/2006	Heyward	CF4011	A110	110	18	Cloates SZ (Mid)	-22.741812	113.600057	-22.737927	113.598419	65.2	63.6	1508	1523
10/05/2006	Heyward	CF4011	A111	111	18	Cloates SZ (North)	-22.586605	113.593336	-22.590379	113.59093	106	108	1100	1112
10/05/2006	Heyward	CF4011	A112	112	18	Cloates SZ (North)	-22.61462	113.582095	-22.617603	113.578493	101	107	1133	1146
10/05/2006	Heyward	CF4011	A113	113	18	Cloates SZ (North)	-22.601289	113.589944	-22.602332	113.58759	98.5	102	1630	1642
10/05/2006	Heyward	CF4011	A114	114	18	Cloates SZ (North)	-22.625361	113.578157	-22.622207	113.578506	97	99	1712	1731
10/05/2006	Heyward	CF4011	A115	115	19	Cloates SZ (North)	-22.640552	113.570486	-22.637029	113.570531	100	102	1751	1812
10/05/2006	Heyward	CF4011	A116	116	19	Cloates SZ (North)	-22.643935	113.585406	-22.639742	113.584268	74.5	76.3	2002	2019
10/05/2006	Heyward	CF4011	A117	117	19	Cloates SZ (North)	-22.62868	113.592822	-22.624606	113.59341	73	73	2032	2045
11/05/2006	Heyward	CF4011	A118	118	19	Cloates SZ (North)	-22.61448	113.601243	-22.609823	113.604647	70.6	67.7	0814	0830
11/05/2006	Heyward	CF4011	A119	119	19	Cloates SZ (North)	-22.603933	113.604915	-22.599703	113.607593	73	72	0840	0855
11/05/2006	Heyward	CF4011	A120	120	20	Cloates SZ (North)	-22.590578	113.606817	-22.586582	113.607521	79	80.1	0906	0921
11/05/2006	Heyward	CF4011	A121	121	20	Cloates SZ (North)	-22.644554	113.59437	-22.640199	113.595548	58	58.2	1542	1554
11/05/2006	Heyward	CF4011	A122	122	20	Cloates SZ (North)	-22.630289	113.599404	-22.625752	113.600685	61	60	1604	1617
11/05/2006	Heyward	CF4011	A123	123	20	Cloates SZ (North)	-22.616456	113.607528	-22.612519	113.60988	50	49	1626	1638
11/05/2006	Heyward	CF4011	A124	124	20	Cloates SZ (North)	-22.604658	113.612092	-22.601045	113.614989	57.2	53	1810	1822
11/05/2006	Heyward	CF4011	A125	125	20	Cloates SZ (North)	-22.59139	113.618453	-22.587491	113.620451	55.53	59.1	1832	1845
12/05/2006	Heyward	CF4011	A126	126	21	Cloates SZ (North)	-22.614356	113.620442	-22.618317	113.620566	21.7	21.7	1811	1821
13/05/2006	Heyward	CF4011	A127	127	21	Cloates SZ (North)	-22.646	113.607533	-22.641833	113.607583	38	36.3	1932	1942
14/05/2006	Heyward	CF4011	A128	128	21	Cloates Ref	-22.455983	113.667833	-22.460117	113.666467	81	80	1527	1538
14/05/2006	Heyward	CF4011	A129	129	21	Cloates Ref	-22.4695	113.6621	-22.473017	113.659383	76	76	1618	1627
14/05/2006	Heyward	CF4011	A130	130	21	Cloates Ref	-22.48305	113.650883	-22.487233	113.6498	85	81	1640	16.49
14/05/2006	Heyward	CF4011	A131	131	21	Cloates Ref	-22.4934	113.644267	-22.4978	113.643567	86	80	1701	1713
14/05/2006	Heyward	CF4011	A132	132	21	Cloates Ref	-22.502167	113.63935	-22.50645	113.638433	87	85	1724	1734
14/05/2006	Heyward	CF4011	A133	133	21	Cloates Ref	-22.50495	113.63215	-22.504833	113.633267	100	98	1753	1804
14/05/2006	Heyward	CF4011	A134	134	22	Cloates Ref	-22.4518	113.66285	-22.45535	113.660367	99	96.2	1922	1934
14/05/2006	Heyward	CF4011	A135	135	22	Cloates Ref	-22.468867	113.651733	-22.472867	113.648867	104	104	1953	2008
14/05/2006	Heyward	CF4011	A136	136	22	Cloates Ref	-22.480717	113.645817	-22.484583	113.643467	101.4	101	2017	2029
14/05/2006	Heyward	CF4011	A137	137	22	Cloates Ref	-22.494917	113.63745	-22.498783	113.6356	101.4	102	2042	2054
15/05/2006	Heyward	CF4011	A138	138	22	Cloates Ref	-22.457917	113.68055	-22.461683	113.67845	63	60.7	0753	0805
15/05/2006	Heyward	CF4011	A139	139	22	Cloates Ref	-22.4708	113.670867	-22.474717	113.669333	60	55	0813	0826
15/05/2006	Heyward	CF4011	A140	140	23	Cloates Ref	-22.484467	113.664283	-22.488133	113.6618	54.9	58.3	0837	0849
15/05/2006	Heyward	CF4011	A141	141	23	Cloates Ref	-22.496217	113.658917	-22.499083	113.65585	54.4	58.3	0859	0910
15/05/2006	Heyward	CF4011	A142	142	23	Cloates Ref	-22.51175	113.6507	-22.5147	113.647283	56.4	58.7	0920	0932

Date	Leader	Cruise	Tow ID	Tow	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Depth	End Depth	Start Time	Finish Time
15/05/2006	Heyward	CF4011	A143	143	23	Cloates Ref	-22.462433	113.6937	-22.466267	113.691933	40	38.3	1632	1646
15/05/2006	Heyward	CF4011	A144	144	23	Cloates Ref	-22.47375	113.6873	-22.477233	113.684633	38.2	32.4	1653	1608
15/05/2006	Heyward	CF4011	A145	145	23	Cloates Ref	-22.485617	113.66715	-22.489717	113.66705	42.6	37.2	1726	174
15/05/2006	Heyward	CF4011	A146	146	24	Cloates Ref	-22.496367	113.66265	-22.499483	113.660217	40.4	41.1	1747	1800
15/05/2006	Heyward	CF4011	A147	147	24	Cloates Ref	-22.513183	113.655517	-22.515883	113.6532	38	38.9	1812	1823
16/05/2006	Heyward	CF4011	A148	148	24	Cloates Ref	-22.46375	113.696983	-22.466867	113.69555	28.7	28.1	1001	1020
16/05/2006	Heyward	CF4011	A149	149	24	Cloates Ref	-22.476767	113.689317	-22.4787	113.687083	23.8	22.4	1403	1420
16/05/2006	Heyward	CF4011	A150	150	24	Cloates Ref	-22.489433	113.676167	-22.4914	113.674933	35	33	1432	1447
16/05/2006	Heyward	CF4011	A151	151	25	Cloates Ref	-22.496883	113.666333	-22.49765	113.665433	32.8	33	1458	1516
16/05/2006	Heyward	CF4011	A152	152	25	Cloates Ref	-22.513683	113.659267	-22.51555	113.65775	36	37	1526	1545
16/05/2006	Heyward	CF4011	A153	153	25	Cloates SZ (North)	-22.591317	113.6265	-22.594317	113.624367	36	37	1623	1639
16/05/2006	Heyward	CF4011	A154	154	25	Cloates SZ (North)	-22.603267	113.619217	-22.6061	113.616633	33.6	40.1	1647	1702
16/05/2006	Heyward	CF4011	A155	155	25	Cloates SZ (North)	-22.615883	113.614417	-22.618517	113.6129	32.2	31.3	1708	1727
16/05/2006	Heyward	CF4011	A156	156	26	Cloates SZ (North)	-22.62945	113.610883	-22.632283	113.6088	30.9	38	1736	1753
16/05/2006	Heyward	CF4011	A157	157	26	Cloates SZ (North)	-22.64685	113.606117	-22.646883	113.610183	39.9	36.5	18.08	1821
17/05/2006	Heyward	CF4011	A158	158	27	Cloates SZ (North)	-22.646117	113.597067	-22.643933	113.599867	50.8	46	0757	8.12
17/05/2006	Heyward	CF4011	A159	159	27	Cloates SZ (North)	-22.630833	113.605717	-22.626933	113.60505	46	50	0823	0838
17/05/2006	Heyward	CF4011	A160	160	27	Cloates SZ (North)	-22.616433	113.610267	-22.6126	113.60965	46	52	0847	0905
17/05/2006	Heyward	CF4011	A161	161	27	Cloates SZ (North)	-22.603967	113.6174	-22.60065	113.61985	42	38.4	0916	0931
17/05/2006	Heyward	CF4011	A162	162	27	Cloates SZ (North)	-22.591217	113.624183	-22.587217	113.6259	46.9	49.6	0941	0957
17/05/2006	Heyward	CF4011	A163	163	28	Mandu SZ	-22.1019	113.834983	-22.10585	113.8338	74.6	73	1536	1551
17/05/2006	Heyward	CF4011	A164	164	28	Mandu SZ	-22.112283	113.83085	-22.1162	113.830117	72	72	1558	1613
17/05/2006	Heyward	CF4011	A165	165	28	Mandu SZ	-22.122017	113.825367	-22.12425	113.821717	73	76	1629	1642
17/05/2006	Heyward	CF4011	A166	166	28	Mandu SZ	-22.134167	113.823067	-22.138083	113.821533	75	74	1655	1706
17/05/2006	Heyward	CF4011	A167	167	28	Mandu SZ	-22.145283	113.820733	-22.148633	113.81815	73	72	1714	1730
17/05/2006	Heyward	CF4011	A168	168	28	Seaward Mandu SZ	-22.140933	113.801083	-22.144783	113.801367	99.3	101	1828	1841
17/05/2006	Heyward	CF4011	A169	169	29	Seaward Mandu SZ	-22.128367	113.804083	-22.1322	113.8035	100.3	101.2	1946	2001
17/05/2006	Heyward	CF4011	A170	170	29	Seaward Mandu SZ	-22.114583	113.806767	-22.1185	113.8063	100	99	2025	2042
17/05/2006	Heyward	CF4011	A171	171	29	Seaward Mandu SZ	-22.102417	113.80825	-22.106367	113.807767	98	99	2105	2118
18/05/2006	Heyward	CF4011	A172	172	29	Adjacent Lighthouse SZ	-21.790367	114.122333	-21.787933	114.125633	22	35	1157	1205
19/05/2006	Heyward	CF4011	A173	173	29	Seaward Lighthouse SZ	-21.709583	114.110833	-21.706217	114.113133	53.3	53.2	1313	1328
19/05/2006	Heyward	CF4011	A174	174	29	Muiron Islands	-21.6709	114.262717	-21.66875	114.26635	28.2	28.6	1437	1449
19/05/2006	Heyward	CF4011	A175	175	30	Muiron Islands	-21.664267	114.308117	-21.661583	114.312083	27.2	26.1	1522	1533
19/05/2006	Heyward	CF4011	A176	176	30	Muiron Islands	-21.6313	114.32195	-21.628133	114.3247	27.2	25.5	1549	1601
19/05/2006	Heyward	CF4011	A177	177	30	Muiron Islands	-21.61265	114.3442	-21.6097	114.346717	26.1	27.8	1620	1631
19/05/2006	Heyward	CF4011	A178	178	30	Muiron Islands	-21.6093	114.368783	-21.61	114.373317	31.5	30.8	1650	1706

Date	Leader	Cruise	Tow ID	To w	Tape	Zoning	Start Latitute	Start Longitude	End Latitude	End Longitude	Start Dept h	End Depth	Start Time	Finish Time
20/05/2006	Heyward	CF4011	A179	179	30	Muiron Islands	-21.623533	114.376717	-21.62595	114.37225	20	22	0750	0803
20/05/2006	Heyward	CF4011	A180	180	30	Muiron Islands	-21.635883	114.359983	-21.63775	114.35575	22	22	0812	0821
20/05/2006	Heyward	CF4011	A181	181	31	Muiron Islands	-21.659117	114.3334	-21.660917	114.329767	19	19	0839	0852
20/05/2006	Heyward	CF4011	A182	182	31	Muiron Islands	-21.6695	114.320867	-21.671417	114.316883	19	19	0901	0914
20/05/2006	Heyward	CF4011	A183	183	31	Muiron Islands	-21.680633	114.308233	-21.682833	114.303733	20	18.4	0924	0935
20/05/2006	Heyward	CF4011	A184	184	31	Muiron Islands	-21.693	114.296433	-21.6947	114.292067	17.2	19.5	0948	0959
20/05/2006	Heyward	CF4011	A185	185	31	Muiron Islands	-21.680367	114.313783	-21.674983	114.306033	15.8	20	1130	1156
20/05/2006	Heyward	CF4011	A186	186	32	Muiron Islands	-21.61025	114.263267	-21.60895	114.2676	54	54.7	1338	1354
20/05/2006	Heyward	CF4011	A187	187	32	Muiron Islands	-21.6063	114.2843	-21.603817	114.287983	51.9	52.5	1408	1421
20/05/2006	Heyward	CF4011	A188	188	32	Muiron Islands	-21.594117	114.300933	-21.59215	114.305	57	61	1436	1448
20/05/2006	Heyward	CF4011	A189	189	32	Muiron Islands	-21.593067	114.322783	-21.594283	114.327083	57	58	1506	1519
20/05/2006	Heyward	CF4011	A190	190	32	Muiron Islands	-21.597833	114.343967	-21.5941	114.345467	56	61.1	1533	1544
20/05/2006	Heyward	CF4011	A191	191	32	Muiron Islands	-21.60695	114.26005	-21.611933	114.25775	51	52.4	2033	2102
21/05/2006	Heyward	CF4011	A192	192	33	Muiron Islands	-21.58515	114.233033	-21.58565	114.22775	70	70	0820	0833
21/05/2006	Heyward	CF4011	A193	193	33	Muiron Islands	-21.579317	114.242017	-21.5804	114.234617	60	70	0850	0906

Appendix 4. Benthic Sled

Table 3: Benthic sled operations data

Date	Leader	Cruise	ID	Zoning	Start Lat	Start Lon	End Latitude	End	Start	End	Star	End
22/04/2006	Rees	CF4010	D001	Mandu SZ	22 09.4980S	113 50.5230E	22 09.8230S	113 50.2520E	58.4	62.9	908	922
22/04/2006	Rees	CF4010	D002	Mandu SZ	22 09.4320S	113 48.5250E	22 10.1110S	113 48.3120E	87.9	81.8	1742	1755
23/04/2006	Rees	CF4010	D003a	Osprey SZ	22 18.4250S	113 46.6580E			44	43	1348	
23/04/2006	Rees	CF4010	D003b	Osprey SZ	22 18.2850S	113 46.7770E	22 18.5310S	113 46.5620E	44	43	1417	
23/04/2006	Rees	CF4010	D004	Osprey SZ	22 15.6780S	113 48.0710E	22 14.7430S	113 48.4900E	57	57	628	
25/04/2006	Rees	CF4010	D005	Osprey SZ	22 18.2633S	113 46.5440E	22 18.5048S	113.46.1573E	55	54.6	1134	1145
25/04/2006	Rees	CF4010	D006	Osprey SZ	22 15.5882S	113 47.1899E	22 15.1408S	113 47.3980E	75.5	74.5	1806	1816
26/04/2006	Rees	CF4010	D007	Osprey SZ	22 14.9244S	113 45.4285E	22 16.3370S	113 45.1809E	104	99.7	1516	1529
27/04/2006	Rees	CF4010	D008	Osprey SZ	22 17.4550S	113 45.2370E	22 16.9880S	113 45.4190E	91	88	904	912
27/04/2006	Rees	CF4010	D009	Seaward Osprey SZ	22 15.7663S	113 44.9683E	22 15.6201S	113 45.0250E	114.9	114.5	1554	1559
28/04/2006	Rees	CF4010	D010	Osprey Ref	22 10.6970S	113 47.5540E	22 10.2880S	113 47.5850E	101.5	99	848	857
28/04/2006	Rees	CF4010	D011	Osprey Ref	22 11.4711S	113 47.8975E	22 11.7468S	113 47.8364E	84.5	84.5	1353	1359
28/04/2006	Rees	CF4010	D012	Osprey Ref	22 11.8760S	113 47.8400E	22 11.2954S	113 47.9540E	81	85.3	1536	1548
28/04/2006	Rees	CF4010	D013	Osprey Ref	22 10.2790S	113 49.1636E	22 10.4685S	113 49.1035E	73	71.4	1832	1837
29/04/2006	Rees	CF4010	D014	Osprey Ref	22 10.1290S	113 48.3470E	22 10.6970S	113 48.1370E	82.2	81.6	800	815
29/04/2006	Rees	CF4010	D015	Osprey Ref	22 12.2130S	113 48.0810E	22 11.5328S	113 48.3439E	78.2	78.2	1401	
30/04/2006	Rees	CF4010	D016	Osprey Ref	22 10.5907S	113 49.2044E	22 10.3204S	113 49.2994E	72	73.1	916	922
30/04/2006	Rees	CF4010	D017	Seaward Osprey Ref/Osprey SZ	22 13.1900S	113 46.3520E	22 13.4611S	113 46.1814E	110	110	1526	
01/05/2006	Rees	CF4010	D018	Osprey Ref	22 10.1560S	113 50.2820E	22 10.3274S	113 50.2284E	58.6	57.8	820	823
01/052006	Rees	CF4010	D019	Osprey Ref	22 12.8808S	113 49.4104E	22 13.1569S	113 49.2902E	174	177	1751	1758
02/05/2006	Rees	CF4010	D020	Osprey Ref	22 10.9100S	113 48.8900E	22 10.6610S	113 48.9373E	73-72	72	948	950
02/05/2006	Rees	CF4010	D021	Osprey Ref	22 10.1140S	113 50.4146E	22 10.1990S	113 50.3385E	53.6	57	1122	1125
02/05/2006	Rees	CF4010	D022	Osprey Ref	22 10.0690S	113 50.6570E	22 10.0100S	113 50.6690E	40.5	40.5	1151	1152
03/05/2006	Rees	CF4010	D023	Mandu SZ	22 06.5431S	113 51.5003E	22 07.3150S	113 51.3630E	58.2	58.2	810	
03/05/2006	Rees	CF4010	D024	Mandu SZ	22 05.6910S	113 49.4170E	22 05.6800S	113 49.4201E	81	81	1400	1407
06/05/2006	Heyward	CF4011	D025	Mandu SZ	22 08.8030S	113 51.0960E	22 08.6520S	113 51.1240E	42.8	46.8	1312	1314
08/05/2006	Heyward	CF4011	D026	Cloates SZ (Mid)	22 44.2879S	113 37.2728E	22 44.1800S	113 37.1940E	42-44.5	44.5	815	819
08/05/2006	Heyward	CF4011	D027	Cloates SZ (Mid)	22 45.7340S	113 37.6310E			56	56	1804	1806
09/05/2006	Heyward	CF4011	D028	Cloates SZ (Mid)	22 47.2401S	113 37.2233E	22 47.1120S	113 37.1130E	65.8	65.6	1021	1026
09/05/2006	Heyward	CF4011	D029	Cloates SZ (Mid)	22 47.2840S	113 38.7330E	22 47.2181S	113 38.7043E	55	56	1803	1805
10/05/2006	Heyward	CF4011	D030	Cloates SZ (North)	22 36.8530S	113 34.8401E	22 37.2659S	113 34.6735E	106.5	103.9	1305	
11/05/2006	Heyward	CF4011	D031	Cloates SZ (North)	22 36.1170S	113 36.3360E	22 35.5680S	113 36.8100E	74	75	1118	1132
11/05/2006	Heyward	CF4011	D032	Cloates SZ (North)	22 38.2040S	113 34.1390E	22 38.0440S	113 34.0740E	106.6	113.3	1213	1219
11/05/2006	Heyward	CF4011	D033	Cloates SZ (North)	22 36.9746S	113 36.5029E	22 37.1110S	113 36.3881E	50.3	50.3	1745	
12/05/2006	Heyward	CF4011	D034	Cloates SZ (North)	22 38.1631S	113 36.6303E	22 38.0520S	113 36.5730E	32	35.8	1627	1630
12/05/2006	Heyward	CF4011	D035	Cloates SZ (North)	22 37.6600S	113 35.6000E	22 37.9660S	113 34.8454E	82	80.3	1152	1157
13/05/2006	Heyward	CF4011	D036	Cloates SZ (Mid)	22 46.3586S	113 38.7088E	22 46.4055S	113 38.7578E	30.8	30.8	1459	
14/05/2006	Heyward	CF4011	D037	Cloates SZ (North)	22 36.6680S	113 36.9310S	22 36.7608S	113 36.8779E	36	36	754	
14/05/2006	Heyward	CF4011	D038	Cloates SZ (North)	22 36.6478S	113 36.6530E	22 36.5950S	113 36.9620E	51.1	47	907	913
14/05/2006	Heyward	CF4011	D039	Cloates Ref	22 27.5260S	113 39.9950E	22 27.3960S	113 40.0740E	81	79	1553	1559
15/05/2006	Heyward	CF4011	D040	Cloates Ref	22 29.9953S	113 39.3071E	22 29.8503S	113 39.3459E	61	61.7	1102	1106
15/05/2006	Heyward	CF4011	D041	Cloates Ref	22 28.0280S	113 39.1780E	22 27.8090S	113 39.2600E	103	105	1331	1343
16/05/2006	Heyward	CF4011	D042	Cloates Ref	22 29.2980S	113 40.0200E	22 29.1260S	113 40.0230E	40	44	908	912
18/05/2006	Heyward	CF4011	D043	Mandu SZ	22 07.5780S	113 50.8140E			69	69	759	
18/05/2006	Heyward	CF4011	D044	Seaward Mandu SZ	22 06.1510S	113 48.4850E	22 06.4910S	113 48.2510E	99	99	842	853
18/05/2006	Heyward	CF4011	D045	Seaward Mandu SZ	22 06.7090S	113 47.7100E	22 06.8710S	113 47.5350E	134	153	920	923
19/05/2006	Heyward	CF4011	D046	Tantabiddi	21 54.4891S	113 53.7342E	21 54.5651S	113 53.6661E	82	82	940	944
20/05/2006	Heyward	CF4011	D047	Muiron Islands	21 40.1188S	114 19.1620E	21 40.1999S	114 19.0788E	20	19.7	1053	1057
20/05/2006	Heyward	CF4011	D048	Muiron Islands	21 40.9548S	114 18.2962E	21 41.0250S	114 18.2204E	19.7	19.7	1115	

Appendix 4.1: WA Museum summary report

WESTERN AUSTRALIAN museum

PRELIMINARY IDENTIFICATION OF SPECIMENS FROM THE NINGALOO DEEPWATER SURVEY – 2006 EXPEDITION

for

THE AUSTRALIAN INSTITUTE OF MARINE SCIENCE

by

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March 2007

Summary

This report presents preliminary identifications of marine faunal specimens collected in deeper water off Ningaloo reef, Western Australia. The research is part of a collaborative study with the Australian Institute of Marine Science (AIMS) and the Western Australian Marine Science Institution (WAMSI).

The WA Museum was requested to identify the dominant filter feeders collected in the study. Specimens of other taxa collected are held in the Museum and some of this material has been identified. The collection was dominated by sponges.

Specimens were collected with an epibenthic sled at depths between 20 to 154m. The Western Australian Museum provided guidance to establish protocols used in the field for preservation of representative specimens of each species collected. All species of all phyla were collected.

This report also makes recommendations for standardising future fieldwork methodology for the two remaining surveys in 2007 and 2008.

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1.0 Background.

The AIMS vessel 'R.V. Cape Ferguson' conducted a survey of the deeper water habitats off Ningaloo Reef in May 2006. Two further expeditions are planned for the region. Sampling stations were determined by reference to an acoustic generated map and video footage that indicated different habitat types in the area. Collection of organisms within these areas would indicate whether the fauna or bottom type differed in accordance with the acoustic maps.

The primary aims of this aspect of the study were to address the following management questions:

1. What is the distribution of the major benthic communities in the deeper (non lagoonal) waters of the Ningaloo Marine Park (NMP)?
2. What are the major species/functional groups in the major benthic communities?
3. What is the abundance/biomass/size composition of the major species?
4. What are the causes of these distributions?
5. What is the significance of the biodiversity of the deeper waters globally?
6. Are the deep water sanctuary zones appropriately situated (conservation and representativeness)?
7. What species/functional groups and sites should be used to measure temporal changes in these communities in the long-term?

2.0 Procedures.

The expedition, undertaken as two 14 day cruises, aboard the RV Cape Ferguson mobilised from Exmouth, and focussed on acoustic mapping, video imagery, sediment characterisation, and collection of biodiversity. Biological specimens were collected from each of the different habitats encountered using an epibenthic sled, and incidental collections were obtained during sediment collections with a Van Veen grab.

Sampling using the sled was not quantitative, and focussed on collecting a representative subset of biota from the different habitats. It was difficult to sample highly consolidated outcropping reef, which occurred in some areas.

Mark Salotti, from the WA Museum, participated in the first cruise and established protocols for the handling and preservation of the specimens collected. Preservation of specimens was in 75% ethanol, formalin, or material was frozen. Protocols for preserving specimens are provided in Appendix 1.

All phyla collected were preserved. The priority taxa were the filter feeders and these were mostly weighed (there were some initial problems with the scales) before preservation.

Specimens are to be accessioned into the WA Museum collections.

3.0 Results

At many of the sled stations sponges were found to be the dominant filter feeding group present (Appendix 2). For the first 19 stations where substrate type was recorded, 6 stations had a dominant sponge component, although at some localities they were part of a mixed substrate type (Appendix 2).

Appendix 1 documents the major cnidarian species collected on the expedition. Cnidaria were occasionally present in very high numbers or biomass, but diversity of species appeared to be low.

Appendix 2 documents the major sponge species considered to be dominant by the field team. Dominance was determined by the number of times a species was repetitively collected during the fieldwork.

These preliminary results begin to address the primary aims of the project.

3. What is the abundance/biomass/size composition of the major species?

Either a total catch weight (3 stations) or a total sponge weight (45 stations) was recorded at the stations sampled (Appendix 2). Weight of sponge per sled station varied from 0 (3 stations) to 461.5kg at station 30. These weights can be used as surrogates for biomass, and be related to the substratum type and depth characteristics of each station. Individual species weights were not attempted, except at 1 station, and it is recommended that these should be included in a revised fieldwork methodology (see 5.0 below). This will be trialled during the 2007 fieldwork program.

5. What is the biogeographical significance of the biodiversity of the deeper Ningaloo waters?

This question has still to be addressed. Many of the sponge species of WA are poorly known and described so determination of distributions of these species will be problematic (see Appendix 2 for the proportion of the 39 dominant species without known species names at this time). Of the eight known species five have distributions restricted to Western Australia, and three are more widespread within Australia. This is the first record for these eight species from the Ningaloo region, and this result is a consequence of the lack of any prior work on sponges at these depths in this region.

To give species names to the remaining sponge taxa would require a taxonomic revision of each family, and this is an enormous task that is beyond the scope of this project. However comparison of these specimens to those collected during other expeditions (eg CSIRO Voyage of Discovery) will provide a Western Australian distribution for those species that were found in both studies. This will provide excellent distribution knowledge of these taxa, and will assist with determining the uniqueness of the Ningaloo deeper water fauna. It is hoped this work will be achieved in 2007.

Assessing better known phyla, such as echinoderms and molluscs will assist with answering questions about biogeographic affinities of the Ningaloo deepwater fauna. Fieldwork protocols have been developed that aim to target taxa associated with the dominant filter feeders (see 5.0 below) and these will be trialled during the 2007 fieldwork.

4.0 Overview of the fauna.

Information on Porifera (sponges) and Cnidaria (with the exception of hard corals) in the region is restricted to previous AIMS surveys 2001, 2002 to the north, some collections in Exmouth Gulf as a consequence of a FRDC trawling study by Fisheries WA and the WA Museum, and work undertaken by the Southern Surveyor in deeper water (>100 metres) to the west of this study by CSIRO in 2005. No work has been undertaken on these taxa in shallow waters on Ningaloo Reef apart from the Scleractinia.

Two CSIRO expeditions on the “Diamantina” had a few collecting stations northward of the area examined in this expedition. One station on the 6/63 cruise and three stations on the 1/64 cruise were greater than 200 metres depth. These stations were reported to consist of fine mud or soft ooze. CSIRO may hold information about the fauna collected from these sites.

Extensive trawl surveys were conducted by CSIRO in the early 1980s on the North West Shelf between the Montebello Islands and Cape Leveque between 30-200m depth but very few stations were sampled between 200-600 metres. The WA Museum holds a large collection of the by-catch of these surveys, ie. cnidaria, sponges, echinoderms and some crustaceans. CSIRO targeted fishes and prawns.

Parts of these collections have been identified and some published e.g. azooxanthellate corals (Cairns, 1998) but much of the other taxa collected have not had additional taxonomic work done on them.

4.1 **Cnidaria**

The octocorals collected in this study included only three species of gorgonian. These were identified by Dr. Phil Alderslade from images taken on the 2006 expedition, so no further information is available regarding these species.

4.2 **Porifera**

1. No species of glass sponges (Class Hexactinellida) were collected in this study. These exclusively deepwater sponges are known to occur in soft sediments worldwide.
2. All sponges collected belonged to the Class Demospongiae.
3. In a previous AIMS survey to the north of Ningaloo 22 species of Demosponges were collected from greater than 200 metres depth compared to 75 species collected at less than 200 metres depth (Fromont, 2001). In a second AIMS survey 24 species of Demosponges were collected from depths greater than 200 metres. Twelve of the species collected on this latter expedition (50%) had not been collected on the previous expedition (Fromont et al. 2002).
4. In this survey 39 species were selected as the dominant sponges seen in the 2006 expedition. All of these sponges belonged to the Class Demospongiae and were collected from depths between 20-154 metres. Many additional species were collected but have not been identified.

4.3 Molluscs.

Some of the mollusc material has been identified, however this phylum was not prioritised as a group to be identified in this study. Since the completion of the 2006 fieldwork it has been recognised that identification of the abundant or major mollusc species found in the region would assist with interpretation of the results, particularly those relating to interpretation of the biogeography of the region. Consequently a revised field methodology has been outlined below for trialling in 2007.

4.4 Fishes.

Fishes are being studied separately by UWA. A few fish species were collected in 2006 and are being identified by staff of the WA Museum. These will be incorporated into a future checklist of species of the region.

4.5 Echinodermata

The echinoderms have not yet been examined. This phylum was not prioritised as a group to be identified in this study. Since the completion of the 2006 fieldwork it has been recognised that identification of the abundant or major echinoderm species found in the region would assist with a biogeographic interpretation of the results. Consequently a revised field methodology has been outlined below for trialling in 2007. Identification of echinoderms will occur when the agreements are finalised between WAMSI and AIMS and funds are available to the Museum to contract these identifications.

5.0 Recommendations for future fieldwork

Examination of the methods of collection and priority of taxa from the first expedition in 2006 has identified gaps that additional sampling criteria could address. These revised methods would enable better interpretation of the fauna particularly in terms of dominance but also for interpretation of the biogeography of the Ningaloo area. These methods and anticipated results are outlined below.

5.1 Methods:

1. Replicate sled tows per habitat depending on size/extent of the habitat.
2. Sled tow times to be standardized as much as possible, ie from time tow touches bottom for 5 or 10 minutes. Actual tow time to be trialled in 2007.
3. Lat/long and depth recorded at start and end of tow.

5.2 Weights (as surrogates for biomass/dominance):

1. Overall weight of sled biomass
2. Overall sponge weight in sled
3. If the net is full then subsample the catch. For example subsample and sort 2 large nally tubs of a full net, subsample and sort 1 large nally tub for a half full net, if less than half full sort all material. Method to be trialled in 2007.
4. Weight of ‘other’ sessile organisms in sled (if dominated by another phyla, eg cnidaria, rhodoliths, bryozoa etc)
5. Sponge weights for 10 most dominant species per station
6. Weights for 10 most dominant sessile species if not sponge
7. Weight of top 5 dominant mobile taxa, eg molluscs, crustaceans, echinoderms, fish.

5.3 Voucher Specimens:

8. Voucher top 10 sponge species ie photograph with ruler and preserve
9. Voucher top 10 most dominant sessile species if not sponge
10. Voucher top 5 mobile taxa – photograph
11. Voucher all other species found both sessile and mobile. If too busy leave mobile specimens with sponge in station bags, freeze, and split in the lab post fieldwork.

5.4 Anticipated results:

1. Determination of habitats with characterisation of the dominant taxa for each habitat by biomass
2. Identification of dominant biota ranked by weight
3. Comparison of deeper water habitats by dominant sessile phyla eg Porifera, Cnidaria etc
4. Comparison of habitats by dominant sessile species
5. Comparison of habitats by dominant mobile species
6. Distribution in park of dominant species
7. Images of dominant species with associated identification
8. Determine if all habitats are represented in marine reserves
9. Comparison with AIMS Vincent-Enfield collections
10. Comparison of species results with deepwater (100+metres) survey results from CSIRO ‘Voyage of Discovery’ offshore from this study.
11. Comparison of species with shallow water surveys, both historical (WA Museum) or recent studies.

6.0 Literature cited.

Cairns, S.D. 1998. Azooxanthellate Scleractinia (Cnidaria: Anthozoa) of Western Australia. *Records of the Western Australian Museum* 18(4): 361-417.

Fromont, J. 2001. Porifera. Pp 32-38 in: Dept. of Aquatic Zoology, WA Museum, unpublished report “*Identification of specimens from the North West Shelf and Slope*”.

Fromont, J. Marsh, L.M. and Alderslade, P. (2002). Preliminary identification of specimens from the north west slope – 2nd expedition. Unpublished report, WA Museum, 62pgs.

7.0 Collection results.

Appendix 1: Protocols for specimen preservation.

SPONGES:-

- Place small and medium-sized specimens in freezer bag with label and 75% ethanol.
- Freeze large specimens, duplicate labels and voucher a representative piece in 75% ethanol.
- Section very large specimens and ethanol-fix/preserve or freeze. The section vouchered should be representative of the body shape and size.

CNIDARIA:-

Hard Corals:

- Place in container with label and a dilute solution of bleach;
- When 'bleached', wash in water, then air-dry.
- Place duplicate specimens in 75% ethanol.

Other Cnidaria:

- Place small and medium-sized specimens in bag with label and 75% ethanol.
- Freeze large specimens.

ASCIDIANS:-

- Place in zip-lock bag with label;
- Refrigerate to relax;
- Place small and medium-sized specimen in 75% ethanol.
- Freeze large specimens.

ECHINODERMS:-

Crinoids:

- Place in ice-cream container on paper-towel with label;
- Add 75% ethanol carefully;
- Add another layer of paper-towel;
- Press down carefully until animal relaxes;
- Lift off paper-towel and adjust animal evenly so it preserves in a flat position;
- Return paper-towel;
- Add next specimen.

Where there are duplicate specimens formalin can be used instead of ethanol so that some specimens retain their colour.

Ophiuroids:

- Relax in $MgCl_2$ solution (72g [$^2/_3$ of a 12-dram vial] of $MgCl_2$ in 1 litre of <u>fresh</u> water) by adding $MgCl_2$ solution to animal in seawater until half (isotonic) $MgCl_2$ solution and half seawater;
- Place in zip-lock bag with label;
- Freeze flat (or preserve flat as in crinoid technique).

Where there are duplicate specimens some specimens can be formalin-fixed.

Asteroids:

- Place in zip-lock bag with label;
- Freeze flat;
- Remove from freezer and place in ethanol.

Formalin-fix duplicate specimens to preserve colour and freeze any additional specimens.

Echinoids:

- Place in plastic/calico bag or field jar with label;
- Add/place in 75% ethanol.

Formalin-fix duplicate specimens to preserve colour and freeze any additional specimens.

Holothurians:

- Relax in shade in seawater;
- Place in plastic/calico bag with label;
- Add/place in 75% ethanol.

For particularly large, solid specimens of echinoids and holothurians ethanol can be injected with a syringe to ensure penetration of all internal tissues. Specimens are then replaced into ethanol.

Crinoids and ophiuroids (especially basket-stars) clinging onto sponges etc., will release their hold when placed in fresh water.

Molluscs:-

Bivalves/**Gastropods**:

- Place in dish of seawater and allow to rest;
- Relax in $MgCl_2$ solution (72g [$^2/_3$ of a 12-dram vial] of $MgCl_2$ in 1 litre of fresh water) by adding $MgCl_2$ solution to animal in seawater until half (isotonic) $MgCl_2$ solution and half seawater;
- Place in zip-lock bag with label and freeze.

Cephalopods:

- Place in zip-lock bag with label;
- Freeze flat.

Nudibranchs:

- Place in a plastic vial with label
- Refrigerate for several hours;
- Freeze.

This method retains colour and prevents the specimen from ‘cracking’. All other groups, including Crustacea and Fish should be labelled and frozen.

Table 1: Dominant Cnidaria found in the study (identified from images by Dr P. Alderslade, NT Museum)

Identification	Station/Details
Nephtheidae: *Umbellulifera* sp.	D009-021
Nephtheidae: *Umbellulifera* sp.	D010-015
Nephtheidae: *Umbellulifera* sp.	D011-010
Subergorgiidae: *Subergorgia mollis* Nutting, 1911	G1-11506, G3-11506, Gorg-11506
Primnoidae	G2-11506

Table 2: Preliminary identification of the dominant Porifera (sponges) collected in the 2006 Ningaloo Deepwater Biodiversity Survey

						Station Number										
Order	Family	Genus	Subgenus	Species	Authority	1	2	3	4	5	6	7	8	9	10	11
	Desmacididae	Desmacidon		sp.ng1							1					
	Geodiidae	Geodia		sp.ng1												
	Geodiidae	Isops		sp.ng1										1		
	Desmacellidae	Sigmaxinella		soelae	Hooper, 1984											
	Suberitidae	Caulospongia		amplexa	Fromont, 1998											
	Suberitidae	Caulospongia		plicata	Saville-Kent 1871					1						
	Chondropsidae	Phoriospongia		sp.ng1												
	Phloeodictyidae	Oceanapia		macrotoxa cf	(Hooper, 1984)	1				1						
	Phloeodictyidae	Oceanapia		ramsayi cf	(Lendenfeld, 1888)					1						
	Phloeodictyidae	Oceanapia		sp.ng1												
	Phloeodictyidae	Oceanapia		sp.ng2												
	Coelosphaeridae	Coelosphaera	(Coelosphaera)	sp.ng1												
	Irciniidae	Sarcotragus		sp.ng1												
	Petrosiidae	Xestospongia		sp.ng1												
	Petrosiidae	Xestospongia		sp.ng2												
	Petrosiidae	Xestospongia		sp.ng3		1										
	Petrosiidae	Petrosia	(Petrosia)	sp.ng1												
	Acorinidae	Jaspis		sp.ng1												
	Tetillidae	Cinachyra		isis cf		1										
	Ancorinidae	Tethyopsis		sp.ng1								1				
	Pseudoceratinidae	Pseudoceratina		sp.ng1								1				
	Crambeidae	Monanchora		sp.ng1				1								
	Callyspongiidae	Callyspongia		sp.ng1												
	Microcionidae	Clathria	(Thalysias)	cactiformis	Hooper, 1996					2						
	Chalinidae	Haliclona	(Haliclona)	sp.ng1												
	Axinellidae	Axinella		sp.ng1												
	Axinellidae	Axinella		sp.ng2												
	Axinellidae	Axinella		sp.ng3												
	Axinellidae	Phakellia		sp.ng1												
	Axinellidae	Phakellia		sp.ng2												
	Axinellidae	Phakellia		sp.ng3												
	Raspailidae	Raspailia	(Parasyringella)	sp.ng1												
	Raspailidae	Raspailia		wardi	Hooper 1991											
	Dictyonellidae	Acanthella		sp.ng1												
	Dictyonellidae	Acanthella		sp.ng2												
	Dictyonellidae	Acanthella		sp.ng3												
Lithistida				sp.ng1												
Lithistida				sp.ng2												
Lithistida				sp.ng3												
					No. Sp Collected	18	14	12	11	64	1	4	13	10	5	10
					Total Sp Wt (Kg)	23.1	12.50	29.50	35.00	13.00	0.00	14.0	0.1	1.47	3.60	0.15
					Depth from (m)	58.4	87.9	43	58	55	75.5	99.7	88	114.	99	84.5
					Depth to (m)	62.9	81.8	43	57	54.6	74.5	104	91	114.	101.	85

Table 2 cont…

Order	Family	Genus	Subgenus	Species	Authority	12	13	14	15	16	17	18	19	20	21	22	23
						Station Number											
	Desmacididae	Desmacidon		sp.ng1				1									
	Geodiidae	Geodia		sp.ng1				2			1						
	Geodiidae	Isops		sp.ng1													
	Desmacellidae	Sigmaxinella		soelae	Hooper, 1984								1				
	Suberitidae	Caulospongia		amplexa	Fromont, 1998			1					1				
	Suberitidae	Caulospongia		plicata	Saville-Kent 1871						1						
	Chondropsidae	Phoriospongia		sp.ng1						1							
	Phloeodictyidae	Oceanapia		macrotoxa cf	(Hooper, 1984)												
	Phloeodictyidae	Oceanapia		ramsayi cf	(Lendenfeld, 1888)												
	Phloeodictyidae	Oceanapia		sp.ng1							1						
	Phloeodictyidae	Oceanapia		sp.ng2													
	Coelosphaeridae	Coelosphaera	(Coelosphaera)	sp.ng1								1					
	Irciniidae	Sarcotragus		sp.ng1													
	Petrosiidae	Xestospongia		sp.ng1													
	Petrosiidae	Xestospongia		sp.ng2				1									
	Petrosiidae	Xestospongia		sp.ng3													
	Petrosiidae	Petrosia	(Petrosia)	sp.ng1							1						
	Acorinidae	Jaspis		sp.ng1				1									
	Tetillidae	Cinachyra		isis cf							1	1					
	Ancorinidae	Tethyopsis		sp.ng1													
	Pseudoceratinidae	Pseudoceratina		sp.ng1													
	Crambeidae	Monanchora		sp.ng1						1			1				
	Callyspongiidae	Callyspongia		sp.ng1													
	Microcionidae	Clathria	(Thalysias)	cactiformis	Hooper, 1996												
	Chalinidae	Haliclona	(Haliclona)	sp.ng1											1		
	Axinellidae	Axinella		sp.ng1											1		
	Axinellidae	Axinella		sp.ng2									1				
	Axinellidae	Axinella		sp.ng3									4				
	Axinellidae	Phakellia		sp.ng1											2		
	Axinellidae	Phakellia		sp.ng2				1									
	Axinellidae	Phakellia		sp.ng3													
	Raspailidae	Raspailia	(Parasyringella)	sp.ng1				1					2		1		
	Raspailidae	Raspailia		wardi	Hooper 1991												
	Dictyonellidae	Acanthella		sp.ng1									1				
	Dictyonellidae	Acanthella		sp.ng2													
	Dictyonellidae	Acanthella		sp.ng3													
Lithistida				sp.ng1													
Lithistida				sp.ng2				1									
Lithistida				sp.ng3							1						
					No. Sp Collected	11	7	15	6	7	13	16	26	0	28	21	0
					Total Sp Wt (Kg)	1.70	0.00	27.50	2.00	3.20	99.50	4.30	53.00	0.00	3.40	0.80	0.15
					Depth from (m)	81	73	81.6	78.6	72	110	58.6	44.5	72	53.6	40.5	57
					Depth to (m)	85.3	71.4	82.2	77	73.1	112	57.8	49.8	73	57	40	58.2

Table 2 cont…

Order	Family	Genus	Subgenus	Species	Authority	Station Number										
						24	25	26	27	28	29	30	31	32	33	34
	Desmacididae	Desmacidon		sp.ng1						1						
	Geodiidae	Geodia		sp.ng1												
	Geodiidae	Isops		sp.ng1								1				
	Desmacellidae	Sigmaxinella		soelae	Hooper, 1984								1			
	Suberitidae	Caulospongia		amplexa	Fromont, 1998					1						
	Suberitidae	Caulospongia		plicata	Saville-Kent 1871											
	Chondropsidae	Phoriospongia		sp.ng1												
	Phloeodictyidae	Oceanapia		macrotoxa cf	(Hooper, 1984)											
	Phloeodictyidae	Oceanapia		ramsayi cf	(Lendenfeld, 1888)											
	Phloeodictyidae	Oceanapia		sp.ng1												
	Phloeodictyidae	Oceanapia		sp.ng2					1							
	Coelosphaeridae	Coelosphaera	(Coelosphaera)	sp.ng1												
	Irciniidae	Sarcotragus		sp.ng1												
	Petrosiidae	Xestospongia		sp.ng1					1							
	Petrosiidae	Xestospongia		sp.ng2												
	Petrosiidae	Xestospongia		sp.ng3												
	Petrosiidae	Petrosia	(Petrosia)	sp.ng1												
	Acorinidae	Jaspis		sp.ng1												
	Tetillidae	Cinachyra		isis cf												
	Ancorinidae	Tethyopsis		sp.ng1												
	Pseudoceratinidae	Pseudoceratina		sp.ng1												
	Crambeidae	Monanchora		sp.ng1					1							1
	Callyspongiidae	Callyspongia		sp.ng1												
	Microcionidae	Clathria	(Thalysias)	cactiformis	Hooper, 1996											
	Chalinidae	Haliclona	(Haliclona)	sp.ng1								1				
	Axinellidae	Axinella		sp.ng1												
	Axinellidae	Axinella		sp.ng2												
	Axinellidae	Axinella		sp.ng3						1		2				
	Axinellidae	Phakellia		sp.ng1									1			
	Axinellidae	Phakellia		sp.ng2								1				
	Axinellidae	Phakellia		sp.ng3											1	
	Raspailidae	Raspailia	(Parasyringella)	sp.ng1											1	
	Raspailidae	Raspailia		wardi	Hooper 1991							1		1		
	Dictyonellidae	Acanthella		sp.ng1												
	Dictyonellidae	Acanthella		sp.ng2								1				
	Dictyonellidae	Acanthella		sp.ng3											1	
Lithistida				sp.ng1												
Lithistida				sp.ng2						1						
Lithistida				sp.ng3												
					No. Sp Collected	28	3	12	16	10	8	56	3	4	26	5
					Total Sp Wt (Kg)	106.00	0.25	1.00	8.00	5.00	0.20	461.5	0.4	84.00	6.00	1.40
					Depth from (m)	81	42.8	42	56	65.8	55	106.5	74	107	50.3	32
					Depth to (m)	81	46.8	44.5	53	65.6	56	103.9	75	113	47	35.8

Table 2 cont…

			Station Number												
Order	Family	Genus	Subgenus	Species	Authority	35	36	37	38	39	40	41	42	43	44
	Desmacididae	Desmacidon		sp.ng1						1					
	Geodiidae	Geodia		sp.ng1		1									
	Geodiidae	Isops		sp.ng1											
	Desmacellidae	Sigmaxinella		soelae	Hooper, 1984										
	Suberitidae	Caulospongia		amplexa	Fromont, 1998										
	Suberitidae	Caulospongia		plicata	Saville-Kent 1871										
	Chondropsidae	Phoriospongia		sp.ng1											
	Phloeodictyidae	Oceanapia		macrotoxa cf	(Hooper, 1984)										
	Phloeodictyidae	Oceanapia		ramsayi cf	(Lendenfeld, 1888)										
	Phloeodictyidae	Oceanapia		sp.ng1											
	Phloeodictyidae	Oceanapia		sp.ng2											
	Coelosphaeridae	Coelosphaera	(Coelosphaera)	sp.ng1											
	Irciniidae	Sarcotragus		sp.ng1											
	Petrosiidae	Xestospongia		sp.ng1											
	Petrosiidae	Xestospongia		sp.ng2											
	Petrosiidae	Xestospongia		sp.ng3											
	Petrosiidae	Petrosia	(Petrosia)	sp.ng1											
	Acorinidae	Jaspis		sp.ng1											
	Tetillidae	Cinachyra		isis cf											
	Ancorinidae	Tethyopsis		sp.ng1											
	Pseudoceratinidae	Pseudoceratina		sp.ng1											
	Crambeidae	Monanchora		sp.ng1											
	Callyspongiidae	Callyspongia		sp.ng1		1									
	Microcionidae	Clathria	(Thalysias)	cactiformis	Hooper, 1996										
	Chalinidae	Haliclona	(Haliclona)	sp.ng1		1									
	Axinellidae	Axinella		sp.ng1											
	Axinellidae	Axinella		sp.ng2											
	Axinellidae	Axinella		sp.ng3											
	Axinellidae	Phakellia		sp.ng1		1									
	Axinellidae	Phakellia		sp.ng2											
	Axinellidae	Phakellia		sp.ng3											
	Raspailidae	Raspailia	(Parasyringella)	sp.ng1		1									
	Raspailidae	Raspailia		wardi	Hooper 1991										
	Dictyonellidae	Acanthella		sp.ng1											
	Dictyonellidae	Acanthella		sp.ng2											
	Dictyonellidae	Acanthella		sp.ng3											
Lithistida				sp.ng1											
Lithistida				sp.ng2											
Lithistida				sp.ng3											
					No. Sp Collected	10	9	12	7	12	8	3	6	2	1
					Total Sp Wt (Kg)	375.00	4.50	17.00	36.00	24.00	4.00	120.00	0.40	0.20	0.10
					Depth from (m)	82	30.8	36	51.1	81	61	103	40	68	99
					Depth to (m)	80.3	31	36	47	79	61.7	105	44	69	99

Table 2 cont…

Order	Family	Genus	Subgenus	Species	Authority	45	46	47	48	49
					Station Number					
	Desmacididae	Desmacidon		sp.ng1						
	Geodiidae	Geodia		sp.ng1						
	Geodiidae	Isops		sp.ng1						
	Desmacellidae	Sigmaxinella		soelae	Hooper, 1984					
	Suberitidae	Caulospongia		amplexa	Fromont, 1998					
	Suberitidae	Caulospongia		plicata	Saville-Kent 1871					
	Chondropsidae	Phoriospongia		sp.ng1						
	Phloeodictyidae	Oceanapia		macrotoxa cf	(Hooper, 1984)					
	Phloeodictyidae	Oceanapia		ramsayi cf	(Lendenfeld, 1888)					
	Phloeodictyidae	Oceanapia		sp.ng1						1
	Phloeodictyidae	Oceanapia		sp.ng2						
	Coelosphaeridae	Coelosphaera	(Coelosphaera)	sp.ng1						
	Irciniidae	Sarcotragus		sp.ng1		1				
	Petrosiidae	Xestospongia		sp.ng1						
	Petrosiidae	Xestospongia		sp.ng2						
	Petrosiidae	Xestospongia		sp.ng3						
	Petrosiidae	Petrosia	(Petrosia)	sp.ng1						
	Acorinidae	Jaspis		sp.ng1						
	Tetillidae	Cinachyra		isis cf						
	Ancorinidae	Tethyopsis		sp.ng1						
	Pseudoceratinidae	Pseudoceratina		sp.ng1						
	Crambeidae	Monanchora		sp.ng1						1
	Callyspongiidae	Callyspongia		sp.ng1						
	Microcionidae	Clathria	(Thalysias)	cactiformis	Hooper, 1996					
	Chalinidae	Haliclona	(Haliclona)	sp.ng1						
	Axinellidae	Axinella		sp.ng1						
	Axinellidae	Axinella		sp.ng2						
	Axinellidae	Axinella		sp.ng3						13
	Axinellidae	Phakellia		sp.ng1						
	Axinellidae	Phakellia		sp.ng2						
	Axinellidae	Phakellia		sp.ng3						
	Raspailidae	Raspailia	(Parasyringella)	sp.ng1						
	Raspailidae	Raspailia		wardi	Hooper 1991					
	Dictyonellidae	Acanthella		sp.ng1						
	Dictyonellidae	Acanthella		sp.ng2						
	Dictyonellidae	Acanthella		sp.ng3						
Lithistida				sp.ng1		1				
Lithistida				sp.ng2						
Lithistida				sp.ng3						
					No. Sp Collected	21	1	2	11	42
					Total Sp Wt (Kg)	60.00	0.001	0.001	17.00	115.00
					Depth from (m)	134	82	20	19.7	57
					Depth to (m)	154	82	20	19.7	55.3

Appendix 5: Stereo-Baited Remote Underwater Video System

Appendix 5.1: Demersal reef fish species list

	Family	Species
1	Acanthuridae	*Acanthurid sp*
2		*Acanthurus albipectoralis*
3		*Acanthurus blochii*
4		*Acanthurus dussumieri*
5		*Acanthurus grammoptilus*
6		*Acanthurus mata*
7		*Acanthurus nigricauda*
8		*Acanthurus olivaceus*
9		*Acanthurus sp*
10		*Acanthurus thompsoni*
11		*Acanthurus triostegus*
12		*Ctenochaetus striatus*
13		*Naso annulatus*
14		*Naso brevirostis*
15		*Naso brevirostris*
16		*Naso hexacanthus*
17		*Naso lituratus*
18		*Naso mcdadei*
19		*Naso sp*
20		*Naso tuberosus*
21		*Naso unicornis*
22		*Naso white tailed spp Ningaloo*
23		*Zebrasoma scopas*
24	Apogonidae	*Apogon aureus*
25		*Apogon bandanensis*
26		*Apogon fraenatus*
27		*Apogon fragilis*
28		*Apogon sp*
29		*Cheliodipterus parazonatus*
30		*Rhabdamia gracilis*
31	Ariidae	*Arius sp*
32	Aulostomidae	*Aulostomus chinensis*
33	Balistidae	*Abalistes sp*
34		*Abalistes stellatus*
35		*Balistoides viridescens*
36		*Melichthys vidua*
37		*Pseudobalistes flavimarginatus*
38		*Pseudobalistes fuscus*
39		*Sufflamen bursa*
40		*Sufflamen chrysopterus*
41		*Sufflamen fraenatum*
42		*Sufflamen frenatus*
43		*Xanthichthys auromarginatus*
44	Blenniidae	*Meiacanthus grammistes*
45		*Meiacanthus sp*

46	Caesionidae	*Caesio cuning*
47		*Caesio sp*
48		*Caesio teres*
49		*Pterocaesio*
50		*Pterocaesio digramma*
51		*Pterocaesio marri*
52		*Pterocaesio sp*
53	Carangidae	*Atule mate*
54		*Carangoides caeruleopinnatus*
55		*Carangoides chrysophrys*
56		*Carangoides deep_banded_sp*
57		*Carangoides ferdau*
58		*Carangoides fulvoguttatus*
59		*Carangoides gymnostethus*
60		*Carangoides hedlandensis*
61		*Caranx ignobilis*
62		*Caranx melampygus*
63		*Decapterus russelli*
64		*Decapterus sp*
65		*Gnathanodon speciosus*
66		*Parastromateus niger*
67		*Pseudocaranx dentex*
68		*Seriola hippos*
69		*Seriola rivoliana*
70		*Seriolina nigrofasciata*
71	Carcharhinidae	*Carcharhinus albimarginatus*
72		*Carcharhinus amblyrhynchos*
73		*Carcharhinus elongate*
74		*Carcharhinus macloti*
75		*Carcharhinus plumbeus*
76		*Carcharhinus sp*
77		*Galeocerdo cuvier*
78		*Rhizoprionodon taylori*
79		*Triaenodon obesus*
80	Chaetodontidae	*Chaetodon assarius*
81		*Chaetodon auriga*
82		*Chaetodon citrinellus*
83		*Chaetodon guentheri*
84		*Chaetodon guttatissimus*
85		*Chaetodon kleinii*
86		*Chaetodon lineolatus*
87		*Chaetodon lunula*
88		*Chaetodon melannotus*
89		*Chaetodon meyeri*
90		*Chaetodon ocellicaudus*
91		*Chaetodon ornatissimus*
92		*Chaetodon plebeius*
93		*Chaetodon punctatofasciatus*
94		*Chaetodon selene*
95		*Chaetodon sp*

96		*Chaetodon speculum*
97		*Chaetodon trifascialis*
98		*Chaetodon unimaculatus*
99		*Chaetodon vagabundus*
100		*Coradion altivelis*
101		*Coradion chrysozonus*
102		*Forcipiger flavissimus*
103		*Forcipiger longirostris*
104		*Heniochus acuminatus*
105		*Heniochus singularius*
106	Chanidae	*Chanos chanos*
107	cirrhitidae	*paracirrhites forsteri*
108	Dasyatidae	*Himantura sp*
109		*Pastinachus sephen*
110		*Taeniura meyeni*
111	Diodontidae	*Chilomycterus reticulatus*
112	Echeneidae	*Echeneis naucrates*
113	Elopidae	*Elops hawaiiensis*
114	Ephippidae	*Platax batavianus*
115		*Platax pinnatus*
116		*Platax sp*
117		*Platax teira*
118	Fistulariidae	*Fistularia commersonii*
119		*Fistularia petimba*
120		*Fistularia sp*
121	Ginglymostomatidae	*Nebrius ferrugineus*
122	Glaucosomatidae	*Glaucosoma burgeri*
123	Haemulidae	*Diagramma pictum*
124		*Plectorhinchus flavomaculatus*
125	Hemigaleidae	*Hemigaleus microstoma*
126	Holocentridae	*Sargocentron rubrum*
127	Kyphosidae	*Kyphosus biggibus*
128		*Kyphosus bigibbus*
129		*Kyphosus sydneyanus*
130	Labridae	*Bodianus axillaris*
131		*Bodianus bilunulatus*
132		*Bodianus mesothorax*
133		*Bodianus perditio*
134		*Bodianus perdito*
135		*Bodianus sp*
136		*Cheilinus fasciatus*
137		*Cheilinus trilobatus*
138		*Cheilinus unifasciatus*
139		*Choerodon cauteroma*
140		*Choerodon jordani*
141		*Choerodon monostigma*
142		*Choerodon rubescens*
143		*Choerodon schoenleinii*
144		*Choerodon zamboangae*
145		*Cirrhilabrus punctatus*

146		*Cirrhilabrus sp*
147		*Cirrhilabrus temminckii*
148		*Coris auricularis*
149		*Coris aygula*
150		*Coris caudimacula*
151		*Coris dorsomacula*
152		*Coris pictoides*
153		*Coris sp*
154		*Epibulus insidiator*
155		*Gomphosus varius*
156		*Halichoeres chrysus*
157		*Hemigymnus fasciatus*
158		*Hemigymnus melapterus*
159		*Hologymnosus annulatus*
160		*Hologymnosus doliatus*
161		*Labroides bicolor*
162		*Labroides dimidiatus*
163		*Labroides sp*
164		*Oxycheilinus digrammus*
165		*Oxycheilinus unifasciatus*
166		*Pseudocoris sp*
167		*Thalassoma hardwicke*
168		*Thalassoma lunare*
169		*Thalassoma lutescens*
170		*Thalassoma quinquevittatum*
171		*Xyrichtys pavo*
172	Lethrinidae	*Gymnocranius audleyi*
173		*Gymnocranius elongatus*
174		*Gymnocranius euanus*
175		*Gymnocranius grandoculis*
176		*Gymnocranius scissortail*
177		*Gymnocranius sp*
178		*Lethrinus atkinsoni*
179		*Lethrinus laticaudis*
180		*Lethrinus miniatus*
181		*Lethrinus nebulosus*
182		*Lethrinus olivaceus*
183		*Lethrinus plain*
184		*Lethrinus ravus*
185		*Lethrinus rubrioperculatus*
186	Lutjanidae	*Lutjanus bohar*
187		*Lutjanus carponotatus*
188		*Lutjanus fulviflamma*
189		*Lutjanus lutjanus*
190		*Lutjanus quinquelineatus*
191		*Lutjanus sebae*
192		*Lutjanus vitta*
193		*Pristipomoides multidens*
194		*Pristipomoides sp*
195		*Pristipomoides typus*

196		*Symphorus nematophorus*
197	Malacanthidae	*Malacanthus brevirostris*
198		*Malacanthus latovittatus*
199	Monacanthidae	*Aluterus scriptus*
200		*Monacanthid sp*
201	Mullidae	*Mulloides heptacanthus*
202		*Parupeneus barberinoides*
203		*Parupeneus cyclostomus*
204		*Parupeneus heptacanthus*
205		*Parupeneus indicus*
206		*Parupeneus multifasciatus*
207		*Parupeneus pleurostigma*
208		*Parupeneus spilurus*
209		*Upeneus moluccensis*
210		*Upeneus sulphureus*
211	Muraenidae	*Gymnothorax dark_sp*
212		*Gymnothorax favagineus*
213		*Gymnothorax javanicus*
214		*Gymnothorax pseudothyrsoideus*
215	Nemipteridae	*Nemipterus sp*
216		*Pentapodus emeryii*
217		*Pentapodus nagasakiensis*
218		*Scolopsis bilineatus*
219		*Scolopsis monogramma*
220	Odontaspididae	*Odontaspis ferox*
221	Ostraciidae	*Ostracion meleagris*
222		*Ostracion sp*
223	Pinguipedidae	*Parapercis sp*
224		*Parapercis clathrata*
225		*Parapercis nebulosa*
226	Plotosidae	*Euristhmus sp*
227	Pomacanthidae	*Apolemichthys trimaculatus*
228		*Centropyge tibicen*
229		*Centropyge vroliki*
230		*Chaetodontoplus duboulayi*
231		*Chaetodontoplus personifer*
232		*Genicanthus sp*
233		*Pomacanthus imperator*
234		*Pomacanthus semicirculatus*
235		*Pomacanthus sexstriatus*
236	Pomacentridae	*Amblyglyphidodon aureus*
237		*Chromis margaritifer*
238		*Chromis sp*
239		*Chromis weberi*
240		*Chrysiptera rollandi*
241		*Chrysiptera sp*
242		*Dascyllus reticulatus*
243		*Dascyllus trimaculatus*
244		*Dischistodus sp*
245		*Plectroglyphidodon johnstonianus*

246		*pomacentrus auriventris*
247		*Pomacentrus chrysurus*
248		*Pomacentrus coelestis*
249		*Pomacentrus Dark sp Ningaloo*
250		*Pomacentrus milleri*
251		*Pomacentrus sp*
252		*Pomacentrus vaiuli*
253		*Pomachromis richardsoni*
254		*Pristosis obtusirostris*
255		*Pristotis jerdoni*
256		*Stegastes albifasciatus*
257		*Stegastes fasciolatus*
258		*Stegastes nigricans*
259		*Stegastes obreptus*
260	Priacanthidae	*Priacanthus sp*
261	Rachycentridae	*Rachycentron canadus*
262	Rhynchobatidae	*Rhynchobatus djiddensis*
263	Scaridae	*Chlorurus bleekeri*
264		*Chlorurus microrhinos*
265		*Chlorurus sordidus*
266		*Scarus frenatus*
267		*Scarus ghobban*
268		*Scarus microhinos*
269		*Scarus prasiognathos*
270		*Scarus rubroviolaceus*
271		*Scarus schlegeli*
272		*Scarus sordidus*
273		*Scarus sp*
274	Scombridae	*Scomberomorus commerson*
275		*Scomberomorus queenslandicus*
276		*Scomberomorus sp*
277		*Thunnus sp*
278	Scorpaenidae	*Pterois volitans*
279	Serranidae	*Anthias cooperi*
280		*Anthias sp*
281		*Cephalopholis miniata*
282		*Cephalopholis sp Ningaloo*
283		*Cephalopholis urodeta*
284		*Epinephelus amblycephalus*
285		*Epinephelus areolatus*
286		*Epinephelus bilobatus*
287		*Epinephelus coioides*
288		*Epinephelus fasciatus*
289		*Epinephelus longispinis*
290		*Epinephelus malabaricus*
291		*Epinephelus multinotatus*
292		*Epinephelus Ning sp. Juvenile*
293		*Epinephelus polyphekadion*
294		*Epinephelus rivulatus*
295		*Epinephelus tukula*

296		*Gracila albomarginata*
297		*Plectropomus laevis*
298		*Plectropomus leopardus*
299		*Pseudanthias rubrizonatus*
300		*Pseudanthias sp*
301		*Variola louti*
302	Siganidae	*Siganus argenteus*
303		*Siganus fuscescens*
304		*Siganus punctatus*
305		*Siganus sp*
306		*Siganus trispilos*
307	Sparidae	*Argyrops spinifer*
308		*Pagrus auratus*
309	Sphyraenidae	*Sphyraena barracuda*
310		*Sphyraena forsteri*
311	Sphyrnidae	*Sphyrna mokarran*
312	Stegastomatidae	*Stegostoma fasciatum*
313	Synodontidae	*Synodus sageneus*
314		*Synodus sp*
315	Tetraodontidae	*Lagocephalus lunaris*
316		*Lagocephalus sceleratus*
317	Triakidae	*Hemitriakis falcata*
318		*Hemitriakis sp*
319	Zanclidae	*Zanclus cornutus*

Appendix 5.2: Stereo-BRUVS operations data

Cruise	Date	ID	Location	Latitude	Longitude	Depth	Time in	Time out
CF4010	22/04/2006	MZ001	Mandu SZ	-22.1624	113.8398	63	1550	1650
CF4010	22/04/2006	MZ002	Mandu SZ	-22.1590	113.8388	65	1555	1700
CF4010	22/04/2006	MZ003	Mandu SZ	-22.1558	113.8385	67	1600	1710
CF4010	22/04/2006	MZ004	Mandu SZ	-22.1515	113.8393	68	1605	1715
CF4010	22/04/2006	MZ005	Mandu SZ	-22.1482	113.8397	65	1610	1730
CF4010	02/05/2006	MZ006	Mandu SZ	-22.1517	113.8468	55	1319	1420
CF4010	02/05/2006	MZ007	Mandu SZ	-22.1472	113.8468	55	1322	1425
CF4010	02/05/2006	MZ008	Mandu SZ	-22.1444	113.8492	56	1325	1435
CF4010	02/05/2006	MZ009	Mandu SZ	-22.1407	113.8514	57	1328	1445
CF4010	02/05/2006	MZ010	Mandu SZ	-22.1359	113.8518	57	1332	1455
CF4010	02/05/2006	MZ011	Mandu SZ	-22.1524	113.8529	24	1512	1620
CF4010	02/05/2006	MZ012	Mandu SZ	-22.1486	113.8550	22	1517	1625
CF4010	02/05/2006	MZ013	Mandu SZ	-22.1449	113.8566	20	1520	1630
CF4010	02/05/2006	MZ014	Mandu SZ	-22.1406	113.8577	30	1526	1635
CF4010	02/05/2006	MZ015	Mandu SZ	-22.1367	113.8597	32	1528	1640
CF4010	03/05/2006	MZ016	Mandu SZ	-22.1050	113.8217	82	1122	1235
CF4010	03/05/2006	MZ017	Mandu SZ	-22.1006	113.8229	82	1127	1240
CF4010	03/05/2006	MZ018	Mandu SZ	-22.0966	113.8242	81	1130	1250
CF4010	03/05/2006	MZ019	Mandu SZ	-22.0921	113.8249	83	1133	1300
CF4010	03/05/2006	MZ020	Mandu SZ	-22.0886	113.8270	83	1136	1305
CF4010	22/04/2006	OR001	Osprey Ref	-22.1863	113.8389	17	1013	1150
CF4010	22/04/2006	OR002	Osprey Ref	-22.1819	113.8404	16	1025	1155
CF4010	22/04/2006	OR003	Osprey Ref	-22.1775	113.8419	20	1040	1205
CF4010	22/04/2006	OR004	Osprey Ref	-22.1729	113.8446	26	1100	1215
CF4010	22/04/2006	OR005	Osprey Ref	-22.1642	113.8479	32	1105	1225
CF4010	28/04/2006	OR006	Osprey Ref	-22.1812	113.8011	84	1142	1250
CF4010	28/04/2006	OR007	Osprey Ref	-22.1783	113.8018	83	1144	1255
CF4010	28/04/2006	OR008	Osprey Ref	-22.1738	113.8034	82	1148	1300
CF4010	28/04/2006	OR009	Osprey Ref	-22.1710	113.8041	83	1156	1305
CF4010	28/04/2006	OR010	Osprey Ref	-22.1677	113.8041	85	1159	1310
CF4010	28/04/2006	OR011	Osprey Ref	-22.1866	113.8332	41	1611	1720
CF4010	28/04/2006	OR012	Osprey Ref	-22.1892	113.8355	34	1613	1730
CF4010	28/04/2006	OR013	Osprey Ref	-22.1926	113.8341	35	1616	1740
CF4010	28/04/2006	OR014	Osprey Ref	-22.1935	113.8308	43	1619	1750
CF4010	28/04/2006	OR015	Osprey Ref	-22.1894	113.8318	44	1624	1800
CF4010	29/04/2006	OR016	Osprey Ref	-22.1750	113.8005	86	1031	1150
CF4010	29/04/2006	OR017	Osprey Ref	-22.1726	113.8014	87	1034	1200
CF4010	29/04/2006	OR018	Osprey Ref	-22.1708	113.8014	90	1036	1210
CF4010	29/04/2006	OR019	Osprey Ref	-22.1686	113.8018	91	1039	1220
CF4010	29/04/2006	OR020	Osprey Ref	-22.1674	113.8014	92	1041	1230
CF4010	29/04/2006	OR021	Osprey Ref	-22.2137	113.8029	73	1527	1630
CF4010	29/04/2006	OR022	Osprey Ref	-22.2074	113.8041	72	1530	1635
CF4010	29/04/2006	OR023	Osprey Ref	-22.2069	113.8041	73	1532	1640
CF4010	29/04/2006	OR024	Osprey Ref	-22.2038	113.8048	71	1538	1645
CF4010	29/04/2006	OR025	Osprey Ref	-22.2006	113.8053	71	1540	1650
CF4010	01/05/2006	OR031	Osprey Ref	-22.2006	113.8332	20	1035	1150
CF4010	01/05/2006	OR032	Osprey Ref	-22.2048	113.8318	23	1040	1200
CF4010	01/05/2006	OR033	Osprey Ref	-22.2085	113.8311	20	1043	1205
CF4010	01/05/2006	OR034	Osprey Ref	-22.2130	113.8304	20	1229	1350
CF4010	01/05/2006	OR036	Osprey Ref	-22.1793	113.8192	71	1233	1355
CF4010	01/05/2006	OR037	Osprey Ref	-22.1753	113.8205	72	1234	1400
CF4010	01/05/2006	OR038	Osprey Ref	-22.1723	113.8214	72	1238	1405
CF4010	01/05/2006	OR039	Osprey Ref	-22.1690	113.8224	73	1246	1415
CF4010	01/05/2006	OR040	Osprey Ref	-22.1834	113.8180	71	1500	1600
CF4010	01/05/2006	OR041	Osprey Ref	-22.1921	113.8269	60	1505	1605
CF4010	01/05/2006	OR042	Osprey Ref	-22.2012	113.8235	60	1510	1610
CF4010	01/05/2006	OR043	Osprey Ref	-22.2122	113.8206	60	1515	1615
CF4010	01/05/2006	OR044	Osprey Ref	-22.2149	113.8238	43	1520	1620

Cruise	Date	ID	Location	Latitude	Longitude	Depth	Time in	Time out
CF4010	01/05/2006	OR045	Osprey Ref	-22.2155	113.8234	47	1047	1200
CF4010	23/04/2006	OZ001	Osprey SZ	-22.2946	113.7884	44	1051	1210
CF4010	23/04/2006	OZ002	Osprey SZ	-22.2892	113.7918	42	1056	1220
CF4010	23/04/2006	OZ003	Osprey SZ	-22.2827	113.7960	40	1059	1230
CF4010	23/04/2006	OZ004	Osprey SZ	-22.2782	113.7992	41	1105	1235
CF4010	23/04/2006	OZ005	Osprey SZ	-22.2704	113.8020	41	1652	1800
CF4010	24/04/2006	OZ006	Osprey SZ	-22.2906	113.7963	21	1657	1805
CF4010	24/04/2006	OZ007	Osprey SZ	-22.2839	113.7990	32	1704	1810
CF4010	24/04/2006	OZ008	Osprey SZ	-22.2751	113.8046	19	1707	1815
CF4010	24/04/2006	OZ009	Osprey SZ	-22.2715	113.8052	33	1713	1825
CF4010	24/04/2006	OZ010	Osprey SZ	-22.2643	113.8083	30	913	1030
CF4010	24/04/2006	OZ011	Osprey SZ	-22.3029	113.7723	60	919	1040
CF4010	24/04/2006	OZ012	Osprey SZ	-22.2981	113.7798	56	923	1050
CF4010	24/04/2006	OZ013	Osprey SZ	-22.2919	113.7830	58	928	1100
CF4010	24/04/2006	OZ014	Osprey SZ	-22.2861	113.7880	57	932	1110
CF4010	24/04/2006	OZ015	Osprey SZ	-22.2803	113.7915	58	1531	1743
CF4010	25/04/2006	OZ016	Osprey SZ	-22.2975	113.7651	76	1546	1754
CF4010	25/04/2006	OZ017	Osprey SZ	-22.2886	113.7717	77	1549	1723
CF4010	25/04/2006	OZ018	Osprey SZ	-22.2844	113.7743	75	1555	1715
CF4010	25/04/2006	OZ019	Osprey SZ	-22.2798	113.7773	76	1600	1702
CF4010	25/04/2006	OZ020	Osprey SZ	-22.2757	113.7799	76	1238	1434
CF4010	25/04/2006	OZ021	Osprey SZ	-22.2409	113.7674	101	1244	1423
CF4010	25/04/2006	OZ022	Osprey SZ	-22.2420	113.7669	100	1251	1417
CF4010	25/04/2006	OZ023	Osprey SZ	-22.2435	113.7667	100	1254	1407
CF4010	25/04/2006	OZ024	Osprey SZ	-22.2456	113.7657	100	1300	1357
CF4010	25/04/2006	OZ025	Osprey SZ	-22.2510	113.7644	100	1044	1209
CF4010	26/04/2006	OZ026	Osprey SZ	-22.2577	113.7727	91	1049	1214
CF4010	26/04/2006	OZ027	Osprey SZ	-22.2628	113.7701	91	1053	1225
CF4010	26/04/2006	OZ028	Osprey SZ	-22.2674	113.7676	90	1057	1230
CF4010	26/04/2006	OZ029	Osprey SZ	-22.2724	113.7651	92	1101	1235
CF4010	26/04/2006	OZ030	Osprey SZ	-22.2772	113.7624	91	1346	1540
CF4010	26/04/2006	OZ031	Osprey SZ	-22.2692	113.7551	103	1350	1530
CF4010	26/04/2006	OZ032	Osprey SZ	-22.2737	113.7534	102	1353	1520
CF4010	26/04/2006	OZ033	Osprey SZ	-22.2781	113.7513	101	1358	1510
CF4010	26/04/2006	OZ034	Osprey SZ	-22.2823	113.7473	102	1401	1500
CF4010	26/04/2006	OZ035	Osprey SZ	-22.2857	113.7455	102	1046	1208
CF4011	14/05/2006	CR001	Cloates Ref	-22.4755	113.6504	97	1032	1200
CF4011	14/05/2006	CR002	Cloates Ref	-22.4706	113.6530	97	1036	1205
CF4011	14/05/2006	CR003	Cloates Ref	-22.4663	113.6553	97	1039	1210
CF4011	14/05/2006	CR004	Cloates Ref	-22.4614	113.6574	100	1042	1230
CF4011	14/05/2006	CR005	Cloates Ref	-22.4562	113.6589	101	1046	1240
CF4011	14/05/2006	CR006	Cloates Ref	-22.4511	113.6617	99	1050	1250
CF4011	14/05/2006	CR007	Cloates Ref	-22.4520	113.6685	84	1321	1520
CF4011	14/05/2006	CR008	Cloates Ref	-22.4585	113.6659	84	1326	1515
CF4011	14/05/2006	CR009	Cloates Ref	-22.4622	113.6648	79	1329	1500
CF4011	14/05/2006	CR010	Cloates Ref	-22.4678	113.6633	76	1332	1447
CF4011	14/05/2006	CR011	Cloates Ref	-22.4725	113.6584	80	1336	1440
CF4011	14/05/2006	CR012	Cloates Ref	-22.4766	113.6545	83	1340	1435
CF4011	15/05/2006	CR013	Cloates Ref	-22.4762	113.6680	55	1002	1125
CF4011	15/05/2006	CR014	Cloates Ref	-22.4804	113.6653	57	1005	1135
CF4011	15/05/2006	CR015	Cloates Ref	-22.4855	113.6631	57	1010	1140
CF4011	15/05/2006	CR016	Cloates Ref	-22.4891	113.6611	60	1012	1150
CF4011	15/05/2006	CR017	Cloates Ref	-22.4934	113.6595	57	1015	1155
CF4011	15/05/2006	CR018	Cloates Ref	-22.4988	113.6560	60	1019	1200
CF4011	15/05/2006	CR019	Cloates Ref	-22.4862	113.6427	101	1317	1430
CF4011	15/05/2006	CR020	Cloates Ref	-22.4788	113.6465	103	1318	1435
CF4011	15/05/2006	CR021	Cloates Ref	-22.4704	113.6493	109	1330	1440
CF4011	16/05/2006	CR022	Cloates Ref	-22.4819	113.6866	15	844	1041
CF4011	16/05/2006	CR023	Cloates Ref	-22.4845	113.6839	20	846	1045
CF4011	16/05/2006	CR024	Cloates Ref	-22.4876	113.6798	33	849	1050
CF4011	16/05/2006	CR025	Cloates Ref	-22.4904	113.6776	22	851	1055

Cruise	Date	ID	Location	Latitude	Longitude	Depth	Time in	Time out
CF4011	16/05/2006	CR026	Cloates Ref	-22.4937	113.6741	19	853	1100
CF4011	16/05/2006	CR027	Cloates Ref	-22.4974	113.6707	14	856	1105
CF4011	16/05/2006	CR028	Cloates Ref	-22.4740	113.6872	37	1128	1323
CF4011	16/05/2006	CR029	Cloates Ref	-22.4754	113.6858	36	1129	1327
CF4011	16/05/2006	CR030	Cloates Ref	-22.4785	113.6829	31	1132	1330
CF4011	16/05/2006	CR031	Cloates Ref	-22.4820	113.6797	36	1135	1335
CF4011	16/05/2006	CR032	Cloates Ref	-22.4846	113.6774	30	1137	1340
CF4011	16/05/2006	CR033	Cloates Ref	-22.4917	113.6715	35	1142	1345
CF4011	07/05/2006	CZ001	Cloates SZ	-22.7214	113.6468	32	1114	1246
CF4011	07/05/2006	CZ002	Cloates SZ	-22.7233	113.6476	33	1116	1250
CF4011	07/05/2006	CZ003	Cloates SZ	-22.7457	113.6670	30	1130	1302
CF4011	07/05/2006	CZ004	Cloates SZ	-22.7588	113.6764	31	1137	1311
CF4011	07/05/2006	CZ005	Cloates SZ	-22.7620	113.6779	31	1140	1314
CF4011	07/05/2006	CZ006	Cloates SZ	-22.7637	113.6784	30	1142	1316
CF4011	07/05/2006	CZ007	Cloates SZ	-22.7381	113.6309	39	1558	1725
CF4011	07/05/2006	CZ008	Cloates SZ	-22.7453	113.6327	34	1603	1734
CF4011	07/05/2006	CZ009	Cloates SZ	-22.7483	113.6343	32	1604	1742
CF4011	07/05/2006	CZ010	Cloates SZ	-22.7535	113.6362	33	1607	1748
CF4011	07/05/2006	CZ011	Cloates SZ	-22.7571	113.6380	34	1609	1753
CF4011	07/05/2006	CZ012	Cloates SZ	-22.7625	113.6396	38	1611	1801
CF4011	08/05/2006	CZ013	Cloates SZ	-22.7605	113.6296	44	1025	1232
CF4011	08/05/2006	CZ014	Cloates SZ	-22.7653	113.6329	53	1026	1240
CF4011	08/05/2006	CZ015	Cloates SZ	-22.7685	113.6342	51	1027	1245
CF4011	08/05/2006	CZ016	Cloates SZ	-22.7729	113.6371	48	1030	1250
CF4011	08/05/2006	CZ017	Cloates SZ	-22.7762	113.6392	54	1031	1255
CF4011	08/05/2006	CZ018	Cloates SZ	-22.7788	113.6416	50	1037	1305
CF4011	08/05/2006	CZ019	Cloates SZ	-22.7881	113.6456	56	1515	1620
CF4011	08/05/2006	CZ020	Cloates SZ	-22.7901	113.6473	55	1520	1625
CF4011	08/05/2006	CZ021	Cloates SZ	-22.7916	113.6477	52	1530	1635
CF4011	08/05/2006	CZ022	Cloates SZ	-22.7933	113.6488	55	1532	1402
CF4011	08/05/2006	CZ023	Cloates SZ	-22.7946	113.6501	59	1540	1407
CF4011	08/05/2006	CZ024	Cloates SZ	-22.7958	113.6512	56	1550	1410
CF4011	09/05/2006	CZ025	Cloates SZ	-22.7775	113.6186	63	958	1133
CF4011	09/05/2006	CZ026	Cloates SZ	-22.7811	113.6210	65	1001	1137
CF4011	09/05/2006	CZ027	Cloates SZ	-22.7849	113.6233	65	1003	1145
CF4011	09/05/2006	CZ028	Cloates SZ	-22.7878	113.6252	65	1005	1151
CF4011	09/05/2006	CZ029	Cloates SZ	-22.7916	113.6280	65	1007	1159
CF4011	09/05/2006	CZ030	Cloates SZ	-22.7944	113.6300	65	1010	1205
CF4011	09/05/2006	CZ031	Cloates SZ	-22.7624	113.6573	32	1601	1706
CF4011	09/05/2006	CZ032	Cloates SZ	-22.7692	113.6598	34	1607	1712
CF4011	09/05/2006	CZ033	Cloates SZ	-22.7721	113.6643	38	1610	1717
CF4011	09/05/2006	CZ034	Cloates SZ	-22.7748	113.6677	31	1612	1723
CF4011	09/05/2006	CZ035	Cloates SZ	-22.7768	113.6688	37	1615	1728
CF4011	09/05/2006	CZ036	Cloates SZ	-22.7773	113.6711	35	1619	1733
CF4011	10/05/2006	CZ037	Cloates SZ	-22.5929	113.5921	109	1208	1500
CF4011	10/05/2006	CZ038	Cloates SZ	-22.5965	113.5906	109	1211	1505
CF4011	10/05/2006	CZ039	Cloates SZ	-22.5999	113.5898	109	1214	1510
CF4011	10/05/2006	CZ040	Cloates SZ	-22.6051	113.5857	105	1217	1515
CF4011	10/05/2006	CZ041	Cloates SZ	-22.6068	113.5858	102	1218	1520
CF4011	10/05/2006	CZ042	Cloates SZ	-22.6112	113.5834	103	1221	1525
CF4011	11/05/2006	CZ043	Cloates SZ	-22.5856	113.6105	78	935	1035
CF4011	11/05/2006	CZ044	Cloates SZ	-22.5868	113.6098	79	937	1045
CF4011	11/05/2006	CZ045	Cloates SZ	-22.5882	113.6077	79	939	1050
CF4011	11/05/2006	CZ046	Cloates SZ	-22.5911	113.6062	80	941	1056
CF4011	11/05/2006	CZ047	Cloates SZ	-22.5951	113.6048	80	942	1105
CF4011	11/05/2006	CZ048	Cloates SZ	-22.6026	113.6021	78	944	1110
CF4011	11/05/2006	CZ049	Cloates SZ	-22.6316	113.5701	109	1159	1300
CF4011	11/05/2006	CZ050	Cloates SZ	-22.6364	113.5700	104	1200	1305
CF4011	11/05/2006	CZ051	Cloates SZ	-22.6448	113.5701	105	1203	1310
CF4011	11/05/2006	CZ052	Cloates SZ	-22.6325	113.5999	54	1446	1700
CF4011	11/05/2006	CZ053	Cloates SZ	-22.6291	113.6022	52	1410	1710

Cruise	Date	ID	Location	Latitude	Longitude	Depth	Time in	Time out
CF4011	11/05/2006	CZ054	Cloates SZ	-22.6268	113.6019	55	1453	1715
CF4011	11/05/2006	CZ055	Cloates SZ	-22.6214	113.6029	58	1458	1720
CF4011	11/05/2006	CZ056	Cloates SZ	-22.6151	113.6071	55	1502	1727
CF4011	11/05/2006	CZ057	Cloates SZ	-22.6108	113.6087	57	1507	1735
CF4011	12/05/2006	CZ058	Cloates SZ	-22.6364	113.6096	34	1412	1535
CF4011	12/05/2006	CZ059	Cloates SZ	-22.6341	113.6100	34	1413	1540
CF4011	12/05/2006	CZ060	Cloates SZ	-22.6303	113.6108	36	1415	1545
CF4011	12/05/2006	CZ061	Cloates SZ	-22.6252	113.6114	38	1420	1550
CF4011	12/05/2006	CZ062	Cloates SZ	-22.6215	113.6120	37	1423	1553
CF4011	12/05/2006	CZ063	Cloates SZ	-22.6175	113.6134	34	1425	1600
CF4011	12/05/2006	CZ064	Cloates SZ	-22.6164	113.6210	11	1605	1710
CF4011	12/05/2006	CZ067	Cloates SZ	-22.6223	113.6181	12	1608	1720
CF4011	12/05/2006	CZ068	Cloates SZ	-22.6255	113.6178	13	1610	1725
CF4011	12/05/2006	CZ069	Cloates SZ	-22.6297	113.6157	12	1615	1730
CF4011	12/05/2006	CZ070	Cloates SZ	-22.6342	113.6139	21	1617	1735
CF4011	13/05/2006	CZ071	Cloates SZ	-22.6393	113.6136	15	1619	1740
CF4011	13/05/2006	CZ072	Cloates SZ	-22.6352	113.5790	82	935	1040
CF4011	13/05/2006	CZ073	Cloates SZ	-22.6316	113.5804	84	940	1045
CF4011	13/05/2006	CZ074	Cloates SZ	-22.6287	113.5820	85	942	1050
CF4011	13/05/2006	CZ075	Cloates SZ	-22.6255	113.5842	86	946	1055
CF4011	13/05/2006	CZ076	Cloates SZ	-22.6228	113.5865	86	949	1100
CF4011	13/05/2006	CZ077	Cloates SZ	-22.6198	113.5889	84	952	1105
CF4011	06/05/2006	MZ021	Mandu SZ	-22.1553	113.8486	41	1111	1215
CF4011	06/05/2006	MZ022	Mandu SZ	-22.1518	113.8498	43	1114	1220
CF4011	06/05/2006	MZ023	Mandu SZ	-22.1477	113.8514	42	1118	1225
CF4011	06/05/2006	MZ024	Mandu SZ	-22.1465	113.8531	42	1121	1230
CF4011	06/05/2006	MZ025	Mandu SZ	-22.1408	113.8540	48	1125	1235
CF4011	06/05/2006	MZ026	Mandu SZ	-22.1387	113.8544	49	1128	1240
CF4011	17/05/2006	MZ027	Mandu SZ	-22.1240	113.8290	74	1339	1455
CF4011	17/05/2006	MZ028	Mandu SZ	-22.1191	113.8316	74	1341	1500
CF4011	17/05/2006	MZ029	Mandu SZ	-22.1136	113.8319	73	1345	1505
CF4011	17/05/2006	MZ030	Mandu SZ	-22.1037	113.8349	75	1350	1520
CF4011	17/05/2006	MZ031	Mandu SZ	-22.0998	113.8373	74	1353	1525
CF4011	17/05/2006	MZ032	Mandu SZ	-22.1094	113.8369	74	1359	1510
CF4011	18/05/2006	MZ033	Mandu SZ	-22.1250	113.8039	102	1055	1230
CF4011	18/05/2006	MZ034	Mandu SZ	-22.1281	113.8034	103	1058	1237
CF4011	18/05/2006	MZ035	Mandu SZ	-22.1324	113.8029	101	1101	1245
CF4011	18/05/2006	MZ036	Mandu SZ	-22.1367	113.8024	101	1103	1250
CF4011	18/05/2006	MZ037	Mandu SZ	-22.1407	113.8008	102	1106	1300
CF4011	18/05/2006	MZ038	Mandu SZ	-22.1447	113.8003	102	1108	1305
CF4011	30/04/2006	OR026	Osprey Ref	-22.1899	113.7867	102	1154	1300
CF4011	30/04/2006	OR027	Osprey Ref	-22.1844	113.7884	101	1158	1305
CF4011	30/04/2006	OR028	Osprey Ref	-22.1783	113.7905	101	1202	1315
CF4011	30/04/2006	OR029	Osprey Ref	-22.1734	113.7915	103	1205	1325
CF4011	30/04/2006	OR030	Osprey Ref	-22.1688	113.7941	101	1208	1335