WAMSI NODE 3 PROJECT 1 SUBPROJECT 3.1.1: DEEPWATER COMMUNITIES AT NINGALOO MARINE PARK

Ningaloo Reef Marine Park Deepwater Benthic Biodiversity Survey: Metadata Report – Number 2

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EXECUTIVE SUMMARY

- The 2007 survey for the 'Deepwater Communities at Ningaloo Marine Park' project combined AIMS staff, a West Australian Museum technician, a side scan sonar acoustic technician, PhD Candidate from the Applied Sedimentology and Marine Geosciences Group Department of Applied Geology, Curtin University of Technology, volunteers and an experienced and professional RV Cape Ferguson crew.

- The 2007 field work and metadata built on work done in 2006. These include completing the sediment grab sampling and initial towed video transect programs to provide broad scale sample coverage of the entire marine park. Detailed analysis of both sets of data is progressing well and is on track for reporting schedules.

- Towed video transects and sediment grab samples in 2007 were stratified from Point Murat to Red Bulff to distribute sampling effort over the whole reef. Three-four towed video transects and sediment grabs were collected from each cross shelf track from the base of the reef slope seaward out to the State marine park boundary.

- Single beam acoustic survey is almost complete with some minor gaps to be filled in 2008. Staff from CMST CUT are currently processing the data and will provide detailed bathymetry and Nearest Neighbour Interpolation to develop seabed texture maps.

- Side scan sonar acoustic survey was conducted between Gnaraloo and Red Bluff in two parts. It initially produced good images and mosaics, but technical problems affected equipment performance limiting coverage substantially.

- The newly designed benthic sled, associated methods of deployment and post-processing protocols have improved sampling for benthic inventories.

- Metadata gathered from 2006/2007 will be provided as appendices in electronic format with the accompanying CD. The GIS database is evolving into a multi-layer interactive tool which will help planners, policy makers and managers to interpret and evaluate different types of data. A workshop with key stakeholders to optimise the GIS protocols is planned.

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 policy makers and managers in the appropriate placement of Marine Protected Areas (MPAs). Advocates perceive that few other management strategies are as conceptually simple, are as easily enforced, or provide as great a potential return as MPAs (Coleman et al. 2004). One of the main goals for MPAs is to protect keystone species and habitat-forming species (Airamé et al. 2003) like corals on coral reefs and sponges in sponge gardens.

The design and planning of Marine Protected Areas (MPAs) has increasingly adopted the concept of representativeness as a major criterion (Stevens and Connolly 2004). 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; adequacy is 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 representativeness is the extent to which MPAs reflect the range of biological diversity of communities within ecosystems and habitats (Jordan et al. 2005).

Representativeness here means the intention of planners to include samples of each habitat, landscape or community type, depending on the scale of the MPA area and the issues being addressed (Stevens and Connolly 2004). For considerations of representation in design planning, it is the biological distributions that are the central interest (Stevens and Connolly 2004). The effectiveness of marine reserves depends on their goals, but many are envisaged to play an ecosystem role on a scale larger than the reserve boundaries (Palumbi 2003). Marine reserves, regardless of their size, and with very few exceptions, lead to increases in density, biomass, individual size, and diversity in all functional groups (Halpern 2003).

Previous theoretical and empirical work on the functional consequences of changing biodiversity has focused on the relationship between species richness and ecosystem functioning (Chapin III et al. 2000). Altering biodiversity will change the functional traits of species in an ecosystem in ways that directly influence ecosystem goods and services either positively (increased agriculture or forestry production) or negatively (loss of harvestable species or species with strong aesthetic/cultural value) (Chapin III et al. 2000). Changes in species traits affect ecosystem processes directly through changes in biotic controls and indirectly through changes in abiotic controls, like availability of limiting resources, disturbance regime, or micro- or macroclimate variables (Chapin III et al. 2000).

In broad outline the global distribution of marine biodiversity has been established by observation, however, our 'theories' to account for these patterns generally lack explanatory power especially at regional scales (100's to 1000's of km) (Roff et al. 2003). There has been a lack of investigations into relationships between biodiversity and habitat characteristics (through geophysical factors) at such regional scales, yet it is precisely at this scale that nation states exert jurisdiction over their marine resources and can best affect conservation measures (Roff et al. 2003). Zacharias and Roff (2001) 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 regional 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 and determination of the demographic rates in various habitats (Eggleston and Dahlgren 2001). Comparisons of organism abundance are needed over a broad range of habitats (Eggleston and Dahlgren 2001). Habitat heterogeneity, acting as a proxy for maximizing the number of species protected, can be used to guide the selection of individual reserve units (Roberts et al. 2003). As the number of habitats increases at a site, the site becomes more heterogeneous, so does the value of that site as a reserve (Roberts et al. 2003).

Choosing the most suitable mapping method 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 led many mapping studies to equate benthic habitat with bottom sediment or substratum type (Ball et al. 2006). This approach to mapping emphasize 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 can be limiting, however many of these studies also include biological sampling or observations (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 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) (Fig.1). 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).

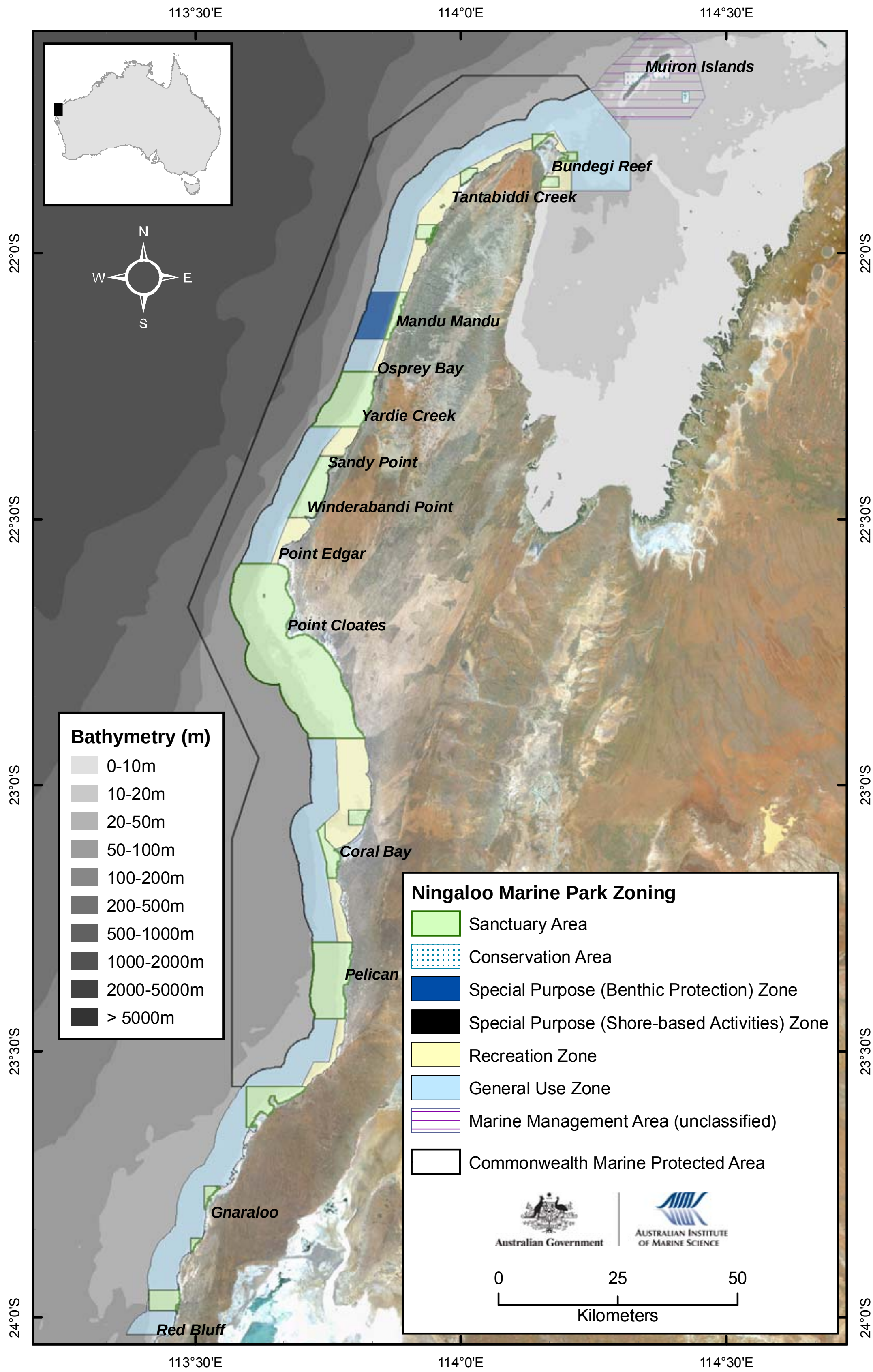

Figure 1. Map of Ningaloo Marine Park and Muiron Islands Marine Management Area.

A notable feature of the marine park is the bathymetry. There is a rapid drop-off in bottom depth in the northern part of the Marine Park fronting 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 bring oceanic species like whales and pelagic fish close to the coast (LeProvost Dames and Moore 2000). At the southern end of the marine park the shelf broadens to greater than 30 km near Amherst Point and one has to go 26 kms seaward from the reef to reach 100 m depth and 40 kms to reach 200 m depth (LeProvost Dames and Moore 2000). The location and morphology of the reef, the complex intertidal and subtidal geomorphology and oceanography play a significant role in the variety of marine habitats and their dynamics and correspondingly high species diversity.

Ningaloo Marine Park includes portions under Commonwealth (2,326 km^2) and State (2,240 km^2) 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 is 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 predominantly (2 to 4 m deep) varying in width from 200 m to more than 7 km (MPRA CALM and CCPAC 2005). From the reef crest seaward, the reef slopes steeply down to 8 to 10 m depth and then gently to 100 m approximately 5 to 6 kms from the reef edge in northern parts of the marine park but up to 26 kms in southern parts. Ningaloo Reef is a unique fringing reef, the largest in Australia and among the longest fringing corals reefs in the world (MPRA CALM and CCPAC 2005) The marine park is one of the most biologically diverse shallow water marine ecosystems in the world (Roberts et al. 2002). Ningaloo Reef is a marine biodiversity hotspot however little 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. The paucity of knowledge about seabed biodiversity in the intermediate and deeper waters of the marine park has been recognised since the park's inception in 1987. Roberts et al. (2002) identified the NW Cape and Ningaloo Region as one of the 18 richest multi taxon centres of endemism.

The work in this report is being delivered via Project 3.1.1 of the Western Australian Marine Science Institution (WAMSI) Node 3 Ningaloo Research Program Project 1: Deepwater Communities in Ningaloo Marine Park proposed and coordinated by the Australian Institute of Marine Science (AIMS). The project was originally a start-up project: 'Ningaloo Research Program start-up project for habitat and biodiversity surveys in the deep waters of the Ningaloo Marine Park', which was administered under the governance of the Joint Venture Management Committee of the Strategic Research Fund for the Marine Environment under the auspices of the former Office of Science and Innovation of the Department of the Premier and Cabinet.

Dominant Benthic Communities

Due to the logistical constraints sampling benthos in the deeper State waters of the marine park (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 park (Carrigy and Fairbridge 1954; Wilson 1972; Western Australian Museum 1988; Rees et al. 2004). Previous studies suggest the substrate of the deeper waters of the northern marine park in general consists of a varying veneer of sand overlying limestone with a predominant sessile flora and fauna of algae and sponges and diverse mobile fauna of crustacean and mollusc (LeProvost Dames and Moore 2000). The Western Australian Museum (1988) discovered that the bottom fauna in waters >40 m is dominated by sponges; however they have never been systematically examined.

Biodiversity analyses of the Australian marine tropical fauna, at smaller intra-regional spatial scales, indicate that sponges frequently form spatially heterogeneous assemblages with patchy distributions in the deeper waters of the Northwest Shelf (Wörheide et al. 2005). These assemblages often contain high numbers of species not found in adjacent communities, 'apparent endemics', sometimes with as little as 15 % similarity in species composition between geographically adjacent reef sites (Wörheide et al. 2005). Studies on cross-shelf distributions have shown certain environmental variables have been 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, larval recruitment and survival (Wörheide et al. 2005).

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 on 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 Ningaloo Marine Park (Fromont pers. comm.). 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 Marine Park, 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 at Ningaloo Marine Park so that changes to biodiversity can be assessed and quantified in the future.

Project Aims

The aims of the project are:

- To develop broad scale habitat maps of the deepwater component of Ningaloo Marine Park (offshore of the fringing reef), in the context of providing surrogate information for broad scale biodiversity assessments.
- Conduct acoustic surveys to establish accurate bathymetry and provide textural maps of the seafloor.
- Characterise the surficial sediments and seabed geomorphology of the deeper waters of Ningaloo Marine Park.
- Characterise the diversity and abundance of filter feeding communities in Ningaloo Marine Park, especially in the deeper waters and establish baseline species inventories.

- Characterise finfish diversity and abundance in the deeper waters of Ningaloo Marine Park and support the development of management targets for commercially and recreationally targeted species.

2007 Survey

In April/May 2007, AIMS carried out the 'Deepwater Communities in Ningaloo Marine Park' field work. The primary objective was to extend the survey coverage south of Point Cloates to Red Bluff and to fill in any initial sampling gaps in the northern section of the marine park (see 2006 report). Assessing and testing side scan sonar to map the seafloor was another objective in 2007. The focal point of the biodiversity survey was benthic habitats in depth strata greater than 20 metres, seaward from the back of the fringing reef out to the 5.5 km Ningaloo Marine Park boundary adjoining Commonwealth waters. All the surveys were conducted on board the AIMS research vessel RV Cape Ferguson (Fig.2).

Figure 2. Australian Institute of Marine Science Research Vessel, RV Cape Ferguson.

METHOD AND DESIGN

The initial field survey in 2006 provided valuable new information about what communities may be expected in the southern part of the marine park stratified across the continental shelf by depth. However the shelf widens considerably in the south relative to the north off Point Cloates e.g. at Red Bluff you can travel up to 26 kms to reach waters of 100 m depth and up to 40 kms to reach waters in excess of 200 m. Therefore at the 5.5 km seaward boundary of the southern part of the marine park waters are considerably shallower than in the northern part sampled in 2006.

Due to the large area being surveyed logistical constraints, the 2007 survey conducted 500 m towed video transects (Speare et al. 2004) in conjunction with sediment grabs stratified every 5 kms from Point Murat to Red Bluff in areas previously not sampled in 2006. Every 5 kms 3-4 towed video transects and sediment grabs were conducted from the shallows of the back reef to the seaward marine park boundary (Figs.10 and 13).

The towed video system was used to obtain a visual record of the benthos in different areas of the marine park and to quantify the general diversity, abundance, and variability in these communities. Surficial sediments, sampled by grab, were used to investigate coastal geomorphology and seabed geomorphology. Protocols for sampling with a newly designed benthic sled were conducted to evaluate, standardise and quantify fishing time and to structure and streamline post-processing procedures. In 2008 the new sled will sample different habitats identified with towed video and acoustic sonar. These samples will allow us to quantify biomass, further investigate diversity and abundance and obtain voucher specimens for identification by the West Australian Museum. While the single beam was used continuously the side scan sonar was tested in the southern part of the marine park, unfortunately without the success that was hoped for. Technical problems led to only a small area of seafloor being mapped with this acoustic technology. Fish diversity and abundance was not carried out on the 2007 survey but will be achieved in future field work once the habitat mapping is complete.

ACOUSTIC SURVEYS

Single Beam Acoustic Survey

With the assistance of the Centre of Marine Science and Technology, Curtin University of Technology (CMST CUT) acoustic mapping, using a Simrad EQ60 Single beam echo-sounder, across and along shelf profiles, was completed. Coverage extended from the southern boundary of the park at Red Bluff to south of Cloates and from north of Mandu to Point Murat at the northern boundary of the marine park (Fig.3). Detailed soundings with dates, times and coordinates (latitude and longitude) were recorded and will form another layer in ArcGIS™. The real-time single beam acoustic on-board display in conjunction with the research vessels' echo-sounder allowed for the identification of any features of interest on the seafloor. These were subsequently targeted with towed video and sediment grab. There are several gaps that can be completed in the 2008 survey season, which will give us total single beam coverage of Ningaloo Marine Park (Fig. 3). Although this is a course method of acoustic survey, it is cost effective and gives us a baseline bathymetry which has not been achieved previously in Ningaloo Marine Park.

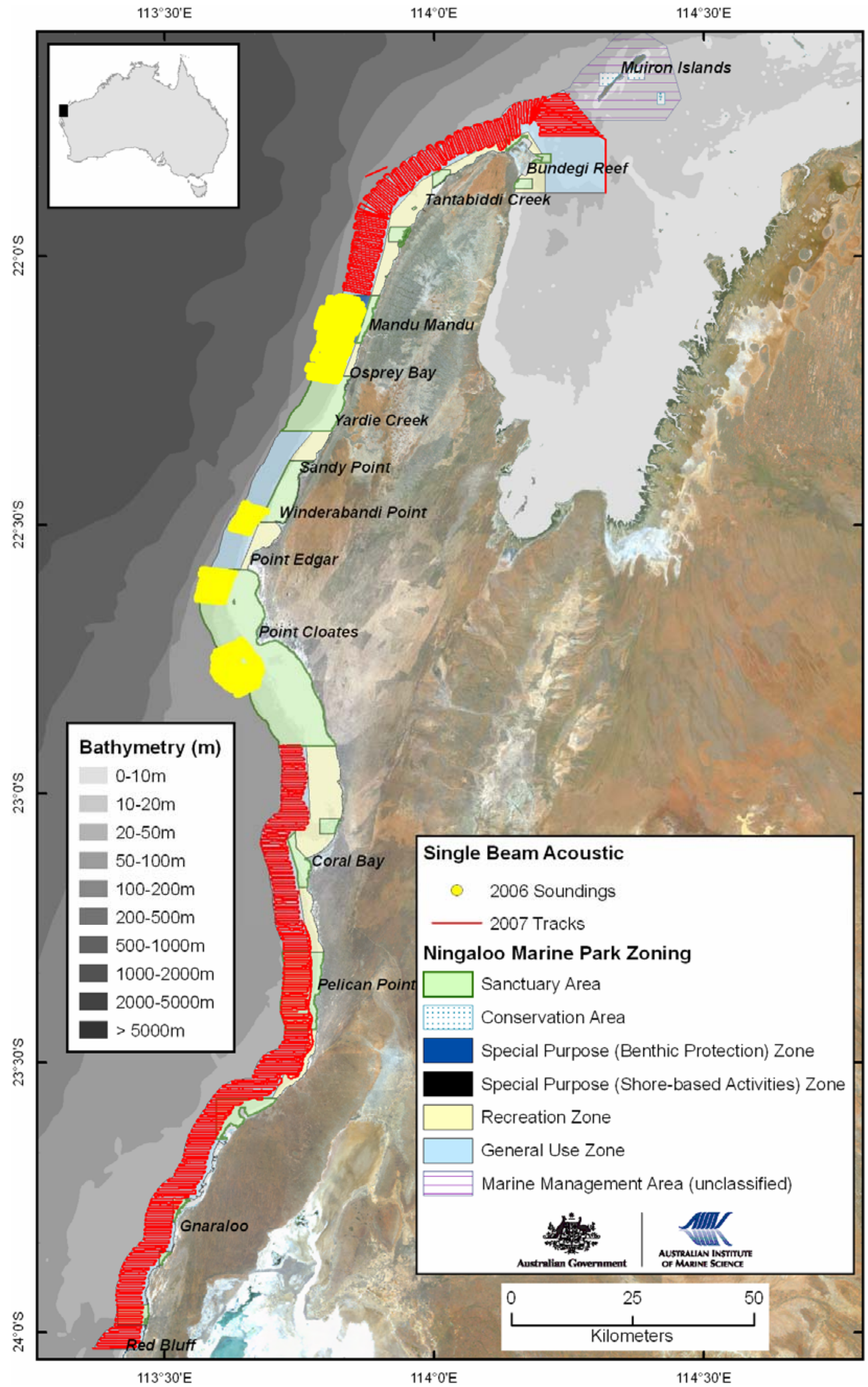

Figure 3. Simrad EQ60 Single beam echo-sounder soundings and tracks 2006/2007 surveys.

Preliminary onboard processing of single beam acoustic backscatter data for the Mandu area in 2006 displayed differences in seabed acoustic roughness (irregularities in topography – E1) and hardness (type of substrate – E2) aiding in the identification of broad scale habitats for sampling. 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 (CMST CUT), will aid in the preparation of broad scale marine habitat maps of the areas surveyed, detailed soundings of the marine park, and provide surrogate information for additional broad scale biodiversity assessments.

Klein 3000 Side Scan Sonar System Acoustic Survey

The Klein Side Scan Sonar system is used in a wide variety of underwater search, survey, and engineering applications (Figs.4 and 5). These systems employ acoustic energy and electronics to create a continuous graphical record of the sea floor surface topography. The graphical record produced by this system approximates an aerial photograph of the sea floor surface. The objective of the acoustic survey was to test its capabilities for mapping the seafloor in the deep waters of Ningaloo Marine Park and determine the textural differences in the seafloor which in turn correlate to particular benthic habitats. The different textures (habitats) could then be ground-truthed to confirm the correlations between textures and habitat type/benthos.

A Sub-Bottom Profiler was not used in this survey but could compliment any future acoustic survey by providing information about the thickness of the sedimentary veneer present in any given location and how the characteristics of this veneer affects colonisation of benthos and its ability to sustain itself in any given place. A profiler of this type may also provide information about the changes occurring temporally and spatially in sediments overlying the limestone base of the slope. Initial set-up and testing of the Klein system was completed close to Exmouth at the Muiron Island Marine Management Area. The unit and technician were hired from Seismic Asia Pacific Pty Ltd. Problems were encountered with the winch, cable, tow-fish and software from the outset; however some areas of the marine park were successfully surveyed.

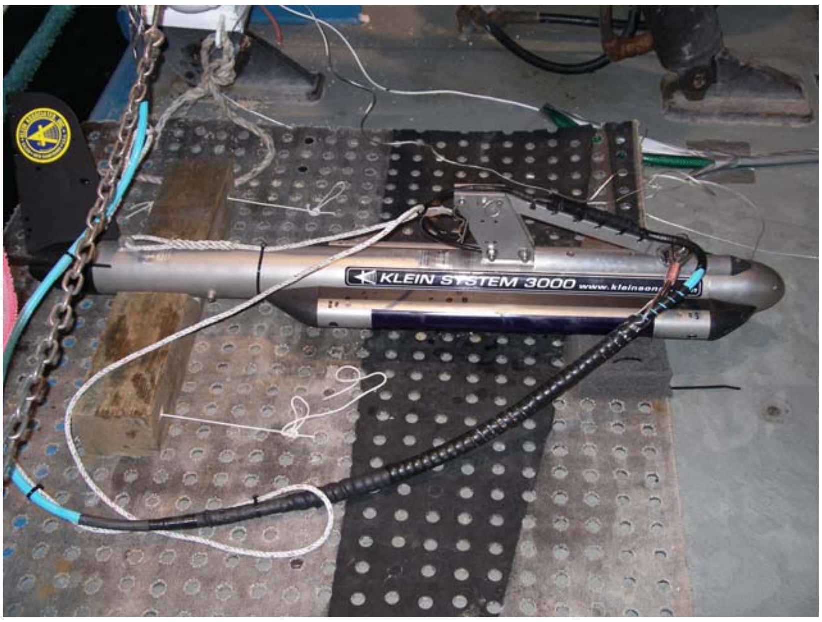

Figure 4. Klein System 3000 side scan sonar tow fish

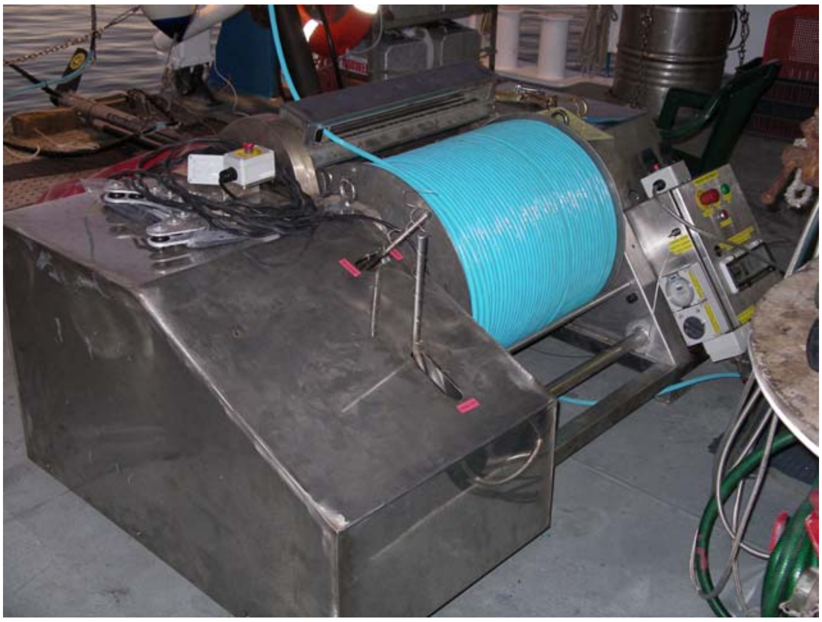

Figure 5. AIMS winch with coax cable for side scan sonar tow fish.

Side scan sonar surveys were concentrated between the areas of Gnarloo and Red Bluff and were conducted in two parts (Fig.6). The first part of the survey covered a total swath area of 21,871,725.4 m^2 and a total track line length of 117,861.1 m parallel to the coast from Red Bluff to Gnaraloo (Fig.6) The second part of the survey covered a total swath area of 11,979,623.5 m^2 and a total track line length of 70,108 m and ran perpendicular to the coast in two areas in between Red Bluff and Gnaraloo (Fig.6).

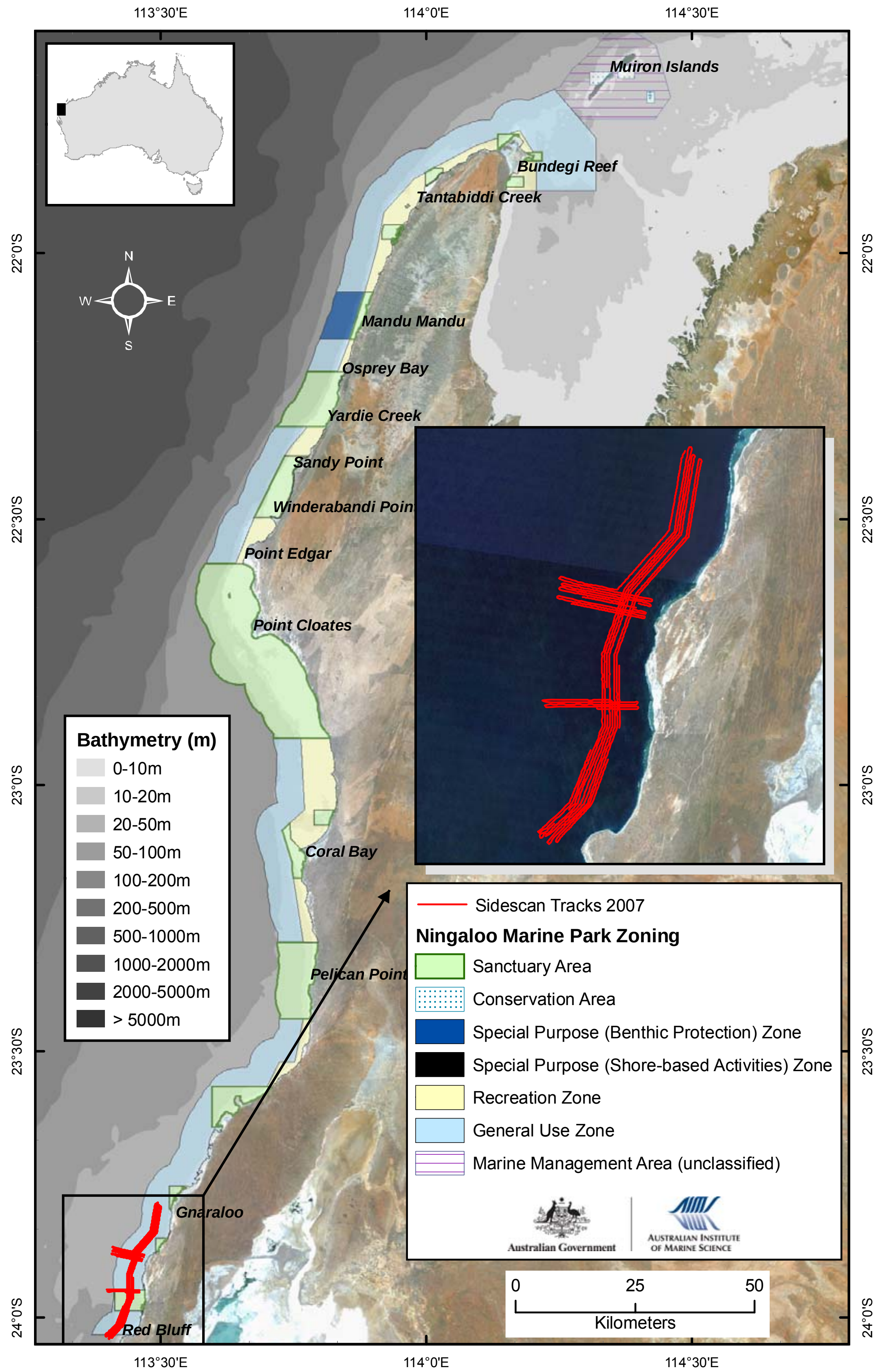

Figure 6. Side scan sonar area of operation and survey tracks.

Geo-referenced acoustic images (Fig.7) from both stages of the survey are being processed; however technical problems may have rendered many unusable in stage two of the side scan survey. Further detailed analysis of the images' textural properties and correlated benthos will be conducted and presented in future reports. All usable geo-referenced side scan images will be imported into ArcGIS™ to form part of the acoustic layer being built up over different surveys. The GIS layer will incorporate all the acoustic surveys including the FUGRO multi beam survey, the side scan images and single beam soundings (Figs. 3, 6, 7 and 8) and will aid in the interpretation of textural qualities of images and their correlation to the overlying benthos. Single beam processing of the raw acoustic data is being carried out by CMST CUT. All acoustic data is verified, stored and managed by AIMS Townsville Data Management Center and integrated into ArcGIS™ by AIMS scientists. Any of this data can be accessed by authorized personnel upon request through the proper channels.

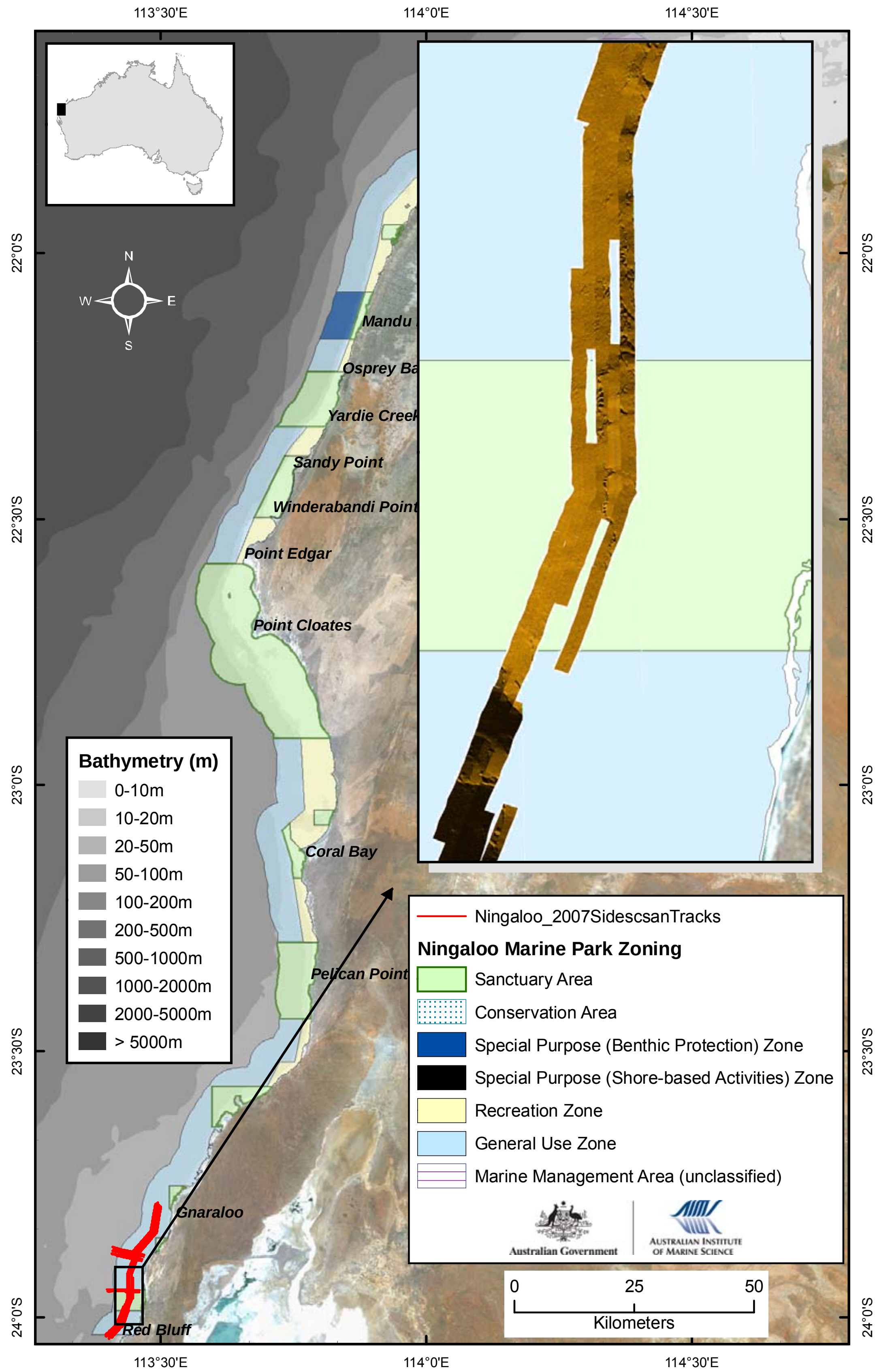

Figure 7. Side scan sonar seafloor acoustic images.

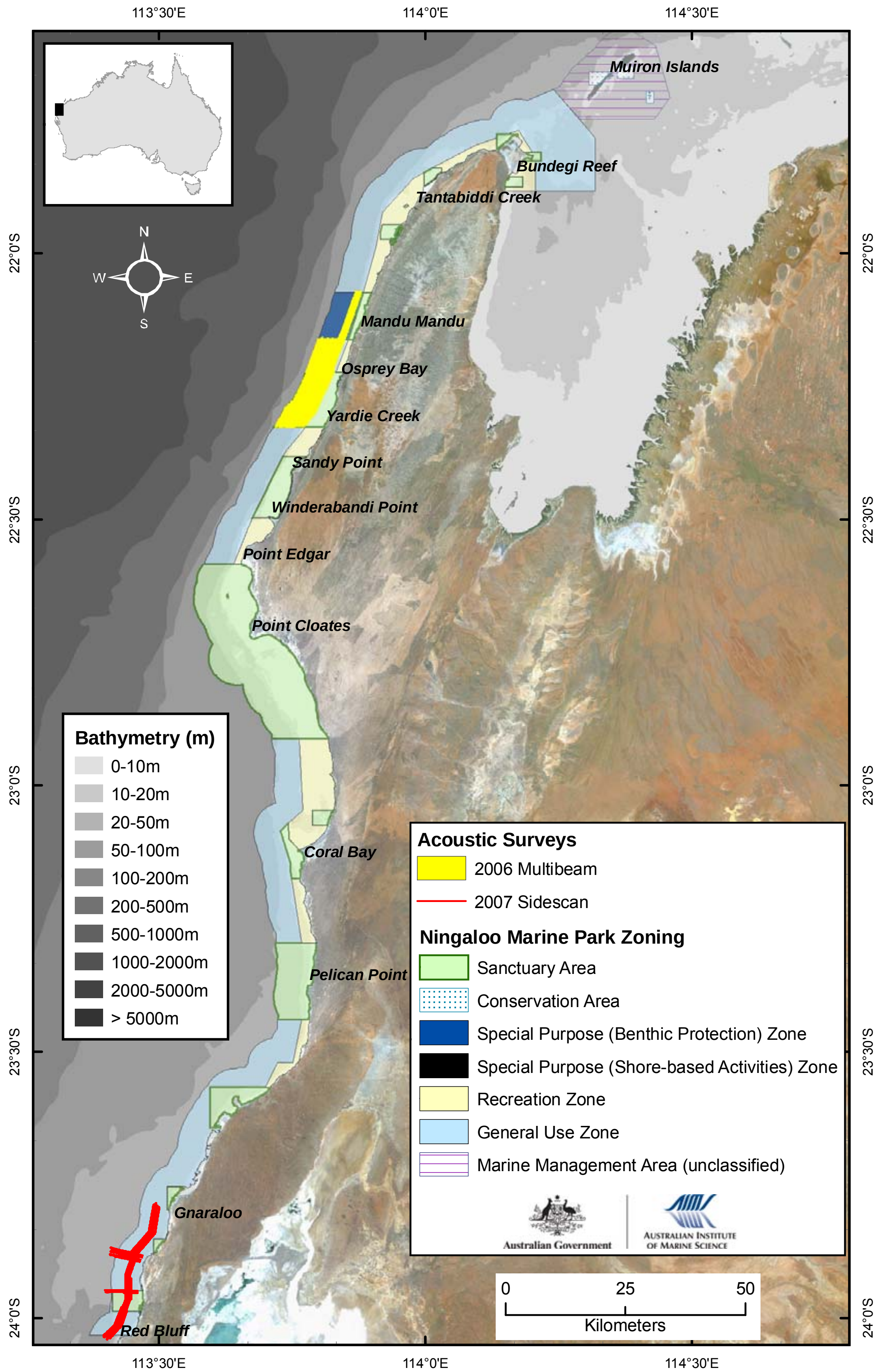

Figure 8. Multi beam and side scan sonar acoustic surveys 2006/2007.

GEOMORPHOLOGY

Surficial Sediments

Sample Design and Collection

One hundred and sixty seven sediment samples were collected during the 2007 survey using a van Veen grab sampler (Fig. 9; Appendix 1). The grab sampler collects surface and subsurface material to a depth of ~10 cm. A total of 335 sediment samples have been collected over the 2006/2007 surveys providing broad coverag of Ningaloo Marine Park (Fig.10). Sampling sites were chosen to include geomorphic provinces across the shelf from the base of the fore 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 up to the edge of Ningaloo Marine Park State boundary (Fig.10). Positions were fixed using a Global Positioning System (GPS) and imported directly into ArcGIS™ for live onboard spatial analysis. Grabs were dropped at or close to towed 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 from the single and multi beam surveys completed in 2006/2007.

Limestone substrate and coral samples from offshore ridges were dredged and recovered using a benthic sled. The coral samples will be dated using U-series Thermal Ionization Mass Spectrometry (TIMS) method, providing an insight into the geological and sea-level history of the continental shelf in this region.

Figure 9. van Veen grab sampler for collecting surface and surface material to a depth of ~10 cm.

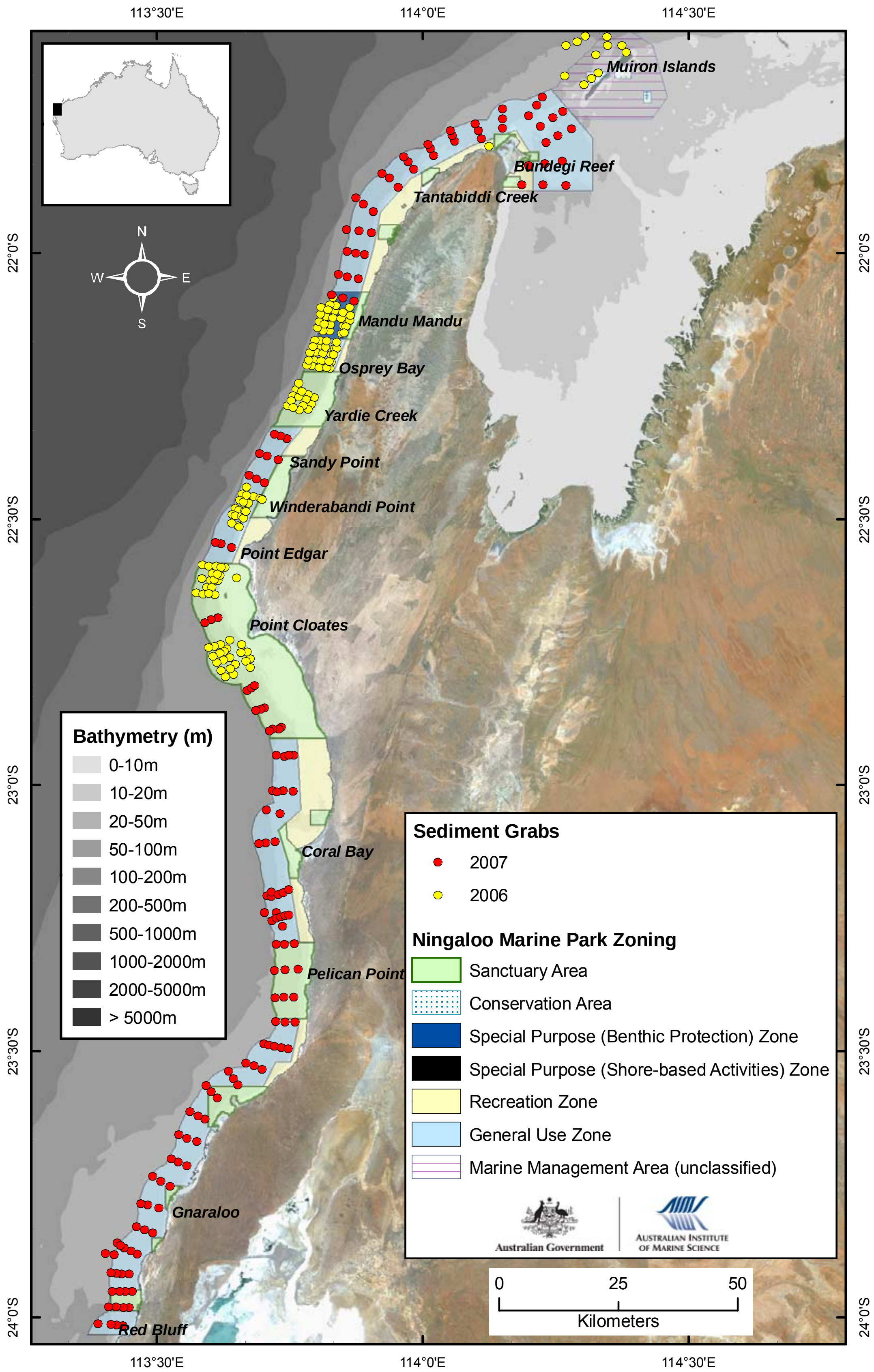

Figure 10. Sediment grab sample locations 2006/2007 surveys

Granulometric Analysis

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

Granulometric grain size analysis of the 2006 sediment samples has been completed and analysis for the 2007 samples is currently underway. Dried samples have been sieved using a mechanical sieve shaker with -1 – 4 phi (Ø) sieve units at 0.5 Ø intervals based on the Udden-Wentworth grain size scale (Udden 1914; Wentworth 1922). 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 in the calculation of grain size statistics, textural parameters and descriptive terminology, allowing both tabular and graphical output into Microsoft Excel™ and easy integration into ArcGIS™ software. The physical description of the textural group from which the sample belongs, and the sediment name (such as “fine gravely coarse sand”) is based on the classification by Folk (1954).

Future Analysis

Quantitative 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 and photographs of each main compositional group present in the slides. These 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 determine mineral composition on cross-shelf samples, including ratios of carbonate mineralogy.

Underwater video imagery was captured near each sediment grab sample and AIMS AVTAS and TowVid software will be used in analysis. These analyses will quantify biotic and abiotic variables for each video transect using the classification system represented in Table 1 and 2 in the towed video section of this report.

Further visual GIS analysis of the acoustic data will include characterisation of geomorphic features on the continental shelf using both bathymetric and textural data. The sediment samples and video analysis will provide ground-truthing for the acoustic methods. 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.

Physical factors including geomorphology, sediment composition, mobility of substrate, bathymetry, the hardness and roughness of the seabed and water depth will be significant in describing the distribution of benthic biota and classifying habitat types over the region. The relationships determined at this scale will improve our understanding of habitat variability and be used to aid in the production of offshore habitat maps for Ningaloo Marine Park.

BENTHIC COMMUNITY SURVEY

Towed Video Survey

Visual imagery of the benthos 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 electro-mechanical cable (Figs.11 and 12 a and b). Two 12 Volt, 35 Watt underwater lights illuminated the field of view (Speare et al. 2004). The video signal was recorded on a shipboard miniDV tape recorder. In addition to the visual imagery the miniDV tape recorder received GPS data (latitude and longitude, ground speed, true heading, date and time), which was recorded on the audio track. A computer-based application (TowVid), developed by AIMS (Speare et al. 2004), allows for real-time touch-screen classification of substrata, benthos and individual organisms interfaced with a GPS to facilitate real-time geo-referencing of all data points. C-Map™ vector charts and Maxsea™ electronic navigation software were used to record the ship's track and water depth. Data points were recorded at 8-second intervals or on demand when a new substrate, benthos or organism was recorded on TowVid. An average speed of 1.5 knots was achieved over the Towed Video surveys equating to a horizontal resolution of 6 m.

A total of 365 towed video transects have been completed in the 2006/2007 surveys (Fig.13; Appendix 2). The sampling has identified a vast array of habitats and will be used for broad scale mapping of benthic communities in the marine park, however further transect tows will be conducted in 2008 in areas of special interest, where sampling is considered limited and where ground-truthing is required. Towed video sampling effort was concentrated around Mandu, Osprey, Yardie, Winderabandi and Point Cloates in 2006 (Fig.13). In 2007, to ensure adequate sampling effort throughout the marine park, sampling was stratified at 5 km intervals from Point Murat to Red Bluff conducting 3-4 transects from the back of the reef out to the seaward marine park boundary at each point (Fig.13). Towed video will allow us to visualise the range of benthic communities, ground truth areas with significant bathymetric and textural properties and provide detailed information on the variability in diversity, abundance and biomass of all the different communities within the marine park.

Towed video data will be analysed using AIMS Video Transect Analyses System (AVTAS) (Abdo et al. 2003) and AIMS real-time TowVid software (Speare et al. 2004). Two different habitat classification systems were developed due to the different types of analysis and software (AVTAS – post processing; TowVid – real-time) being used in the survey (Table 1 and 2). The classification systems are both specifically designed to identify the geomorphology, habitats, substrates and dominant macro benthos in the deep waters of Ningaloo Marine Park (Table 1 and 2). The AVTAS and TowVid analysis will provide details about habitat type, how they vary throughout the park, the dominant species and diversity within these communities, the relative abundance and biomass of different species groups, the geomorphology and substrate they are associated with and whether there are clear patterns of distribution and abundance associated with physical factors like depth, substrate, sediments and position.

Short video snippets, representing each of the 365 towed video transects have been extracted, described and geo-referenced for input into ArcGIS™. These provide visual record of the different habitats throughout the park and a means for interpretation and explanation for planners, policy makers and managers. The complete visual record for each transect will be archived but can be accessed if required.

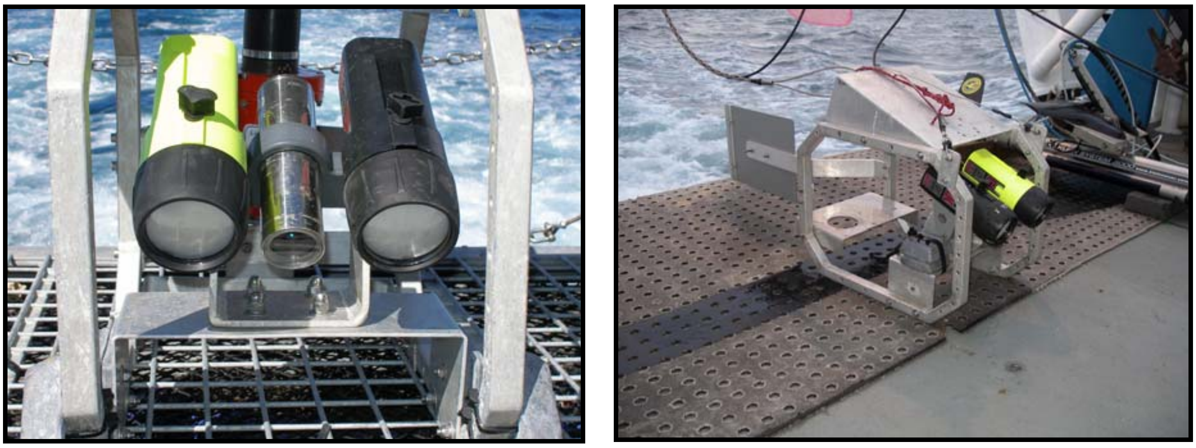

Figure 11. Towed video vane with video camera and lights

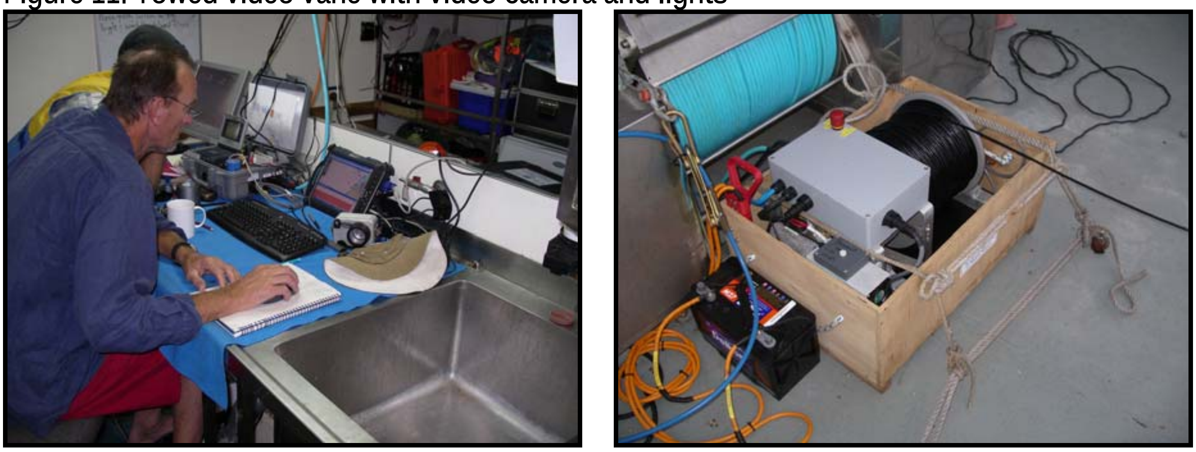

Figure 12. (a) Operating real-time AIMS TowVid software. (b) Towed video winch and electromechanical winch and cable.

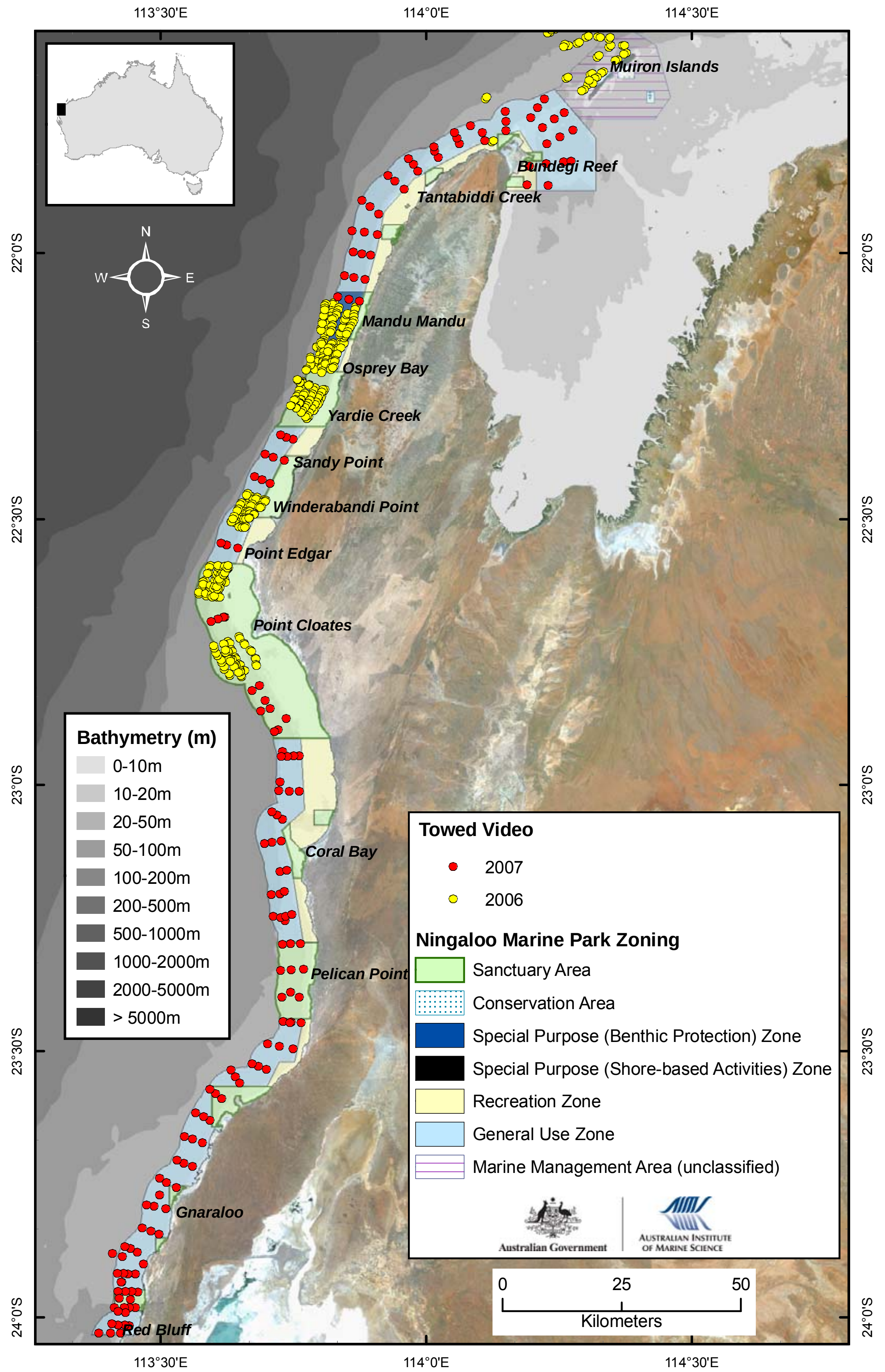

Figure 13. Towed video transect locations 2006/2007 surveys.

Table 1. Real-time habitat classification system for towed video TowVid analysis.

Habitat (Descriptor = Dense, Medium, Sparse)	**Substrate**	**Organism/Items of Interest**
Filter Feeders (Sponge Dominant)	Rhodoliths	Sea Star
Filter Feeders (Soft Coral Dominant)	Rhodoliths/Sand	Holothurian
Filter Feeders (Gorgonian Dominant)	Rubble	Urchin
Filter Feeders (Whip Dominant)	Rubble/Sand	Schooling Fish
Filter Feeders (General)	Bedrock	Rubble Mounds
Hard Coral Reef	Bedrock/Sand	Sand Holes
Hard/Soft Coral + Macroalgae + Sponge	Sand Burrows	
Macroalgae dominated + Sponge + Hard/Soft	Sand Mounds	
Seagrass	Sand Mega Ripples	
Macroalgae	Sand Ripples	
	Sand Flat	

Table 2. Post-processing habitat classification system for towed video analysis

Habitat	**Geomorphology/ Bedform**	**Substrate**	**Benthos**	**Organism**
(Frame analysis)	*(Frame analysis)*	*(Point analysis)*	*(Point analysis)*	*(Point/ Frame analysis)*
Filter Feeders (Sponge Dominant)	Unrippled sand flat	Rhodoliths	Sponge	Holothurian
Filter Feeders (Soft Coral Dominant)	Unrippled sand flat with biogenic traces	Coarse Sand	Soft Coral	Urchin
Filter Feeders (Gorgonian Dominant)	Sand ripples < 0.6m	Fine Sand	Soft Coral Whip	Sea Star
Filter Feeders (Whip Dominant)	Sand mega ripples >0.6m	Mud	Soft Coral Gorgonian	Other
Filter Feeders (General)	Irregular sand ripples (hummocky)	Rubble 2-64 mm	Hard Coral	Uncolonised
Hard Coral Reef	Rubble field	Rubble >64 mm	Sea Pen	Undefined
Hard/Soft Coral Dominant + macroalgae + sponge	Rhodolith field on sand	Bedrock	Bryozoan	
Macroalgae Dominant + sponge + hard/soft coral	Rhodolith field on hard ground	Undefined	Crinoid	
Seagrass	Mounds/burrows		Hydroid	
Macoralgae Dominant	Low outcrop/reef <1m		Ascidian	
Rhodolith Dominant	High outcrop/reef >1m		Macroalgae	
Uncolonised	Undefined		Coralline Algae	
Undefined			Halimeda	
			Turf Algae	
			Seagrass	
			Uncolonised	
			Undefined	

LBV Seabotix Remote Operated Vehicle (ROV) – Dual Video Camera Operation

The AIMS LBV Seabotix Remote Operated Vehicle is a small observation class ROV. It is portable and has capabilities of capturing high quality video footage down to 300 m (Fig.14a). The ROV has dual video camera operation and is remotely operated from a console (Fig.14b). The ROV was used in four different locations and communities of the marine park to gather more detailed video data of different benthic communities, previously identified from towed video. Two locations were in the northern section of the park, North West Cape and Point Murat and two in the southern part, Red Bluff and Warroora (Fig.15; Appendix 3). Four 50 m ROV video transects originating from a centre weight at four different bearings (90°, 180°, 270°, 360°) were conducted at each location. Each transect will be analysed using AVTAS software to investigate in more detail the diversity and composition of different communities in the marine park. Due to its stability and manoeuvrability the ROV was also used to gather '*in situ*' video footage of individual sponges, soft corals, gorgonians and other benthic species making up each community. The data will assist the WA Museum with the taxonomy of different species. Video footage from all transects and '*in situ*' footage will be included in the ArcGIS™ framework.

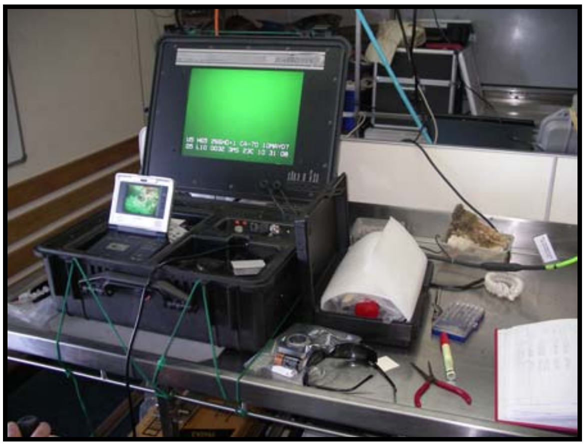

Figure 14 (a) LBV ROV Seabotix remote operated vehicle (b) ROV operating console

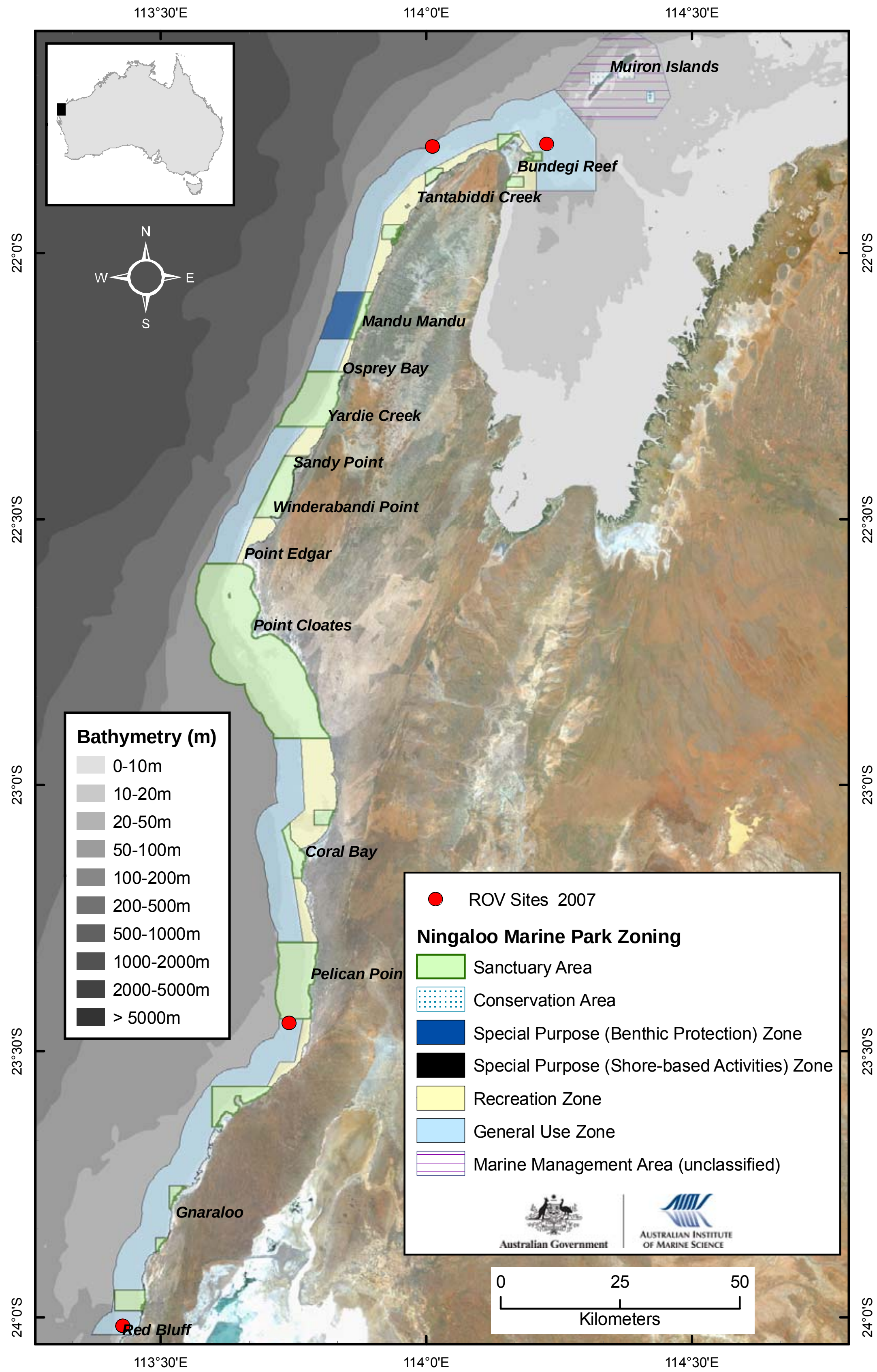

Figure 15. Remote Operated Vehicle (ROV) deployments 2007.

Benthic Sled

Towed video footage and single beam sonar allowed for the detection and targeting of different benthic communities with the benthic sled, so species and functional groups could be identified (Western Australian Museum) and their distribution, abundance, biomass and size composition investigated. Due to the large size of some of the benthos collected (i.e. sponges and gorgonians) in the 2006 field work the CSIRO designed benthic sled was sometimes inadequate dimensions for the purposes of our survey and a new sled was designed and built for the 2007 field work.

The new steel benthic sled is based on the design of a commercial fishing Tri-gear Trawl Beam, slightly modified for our purposes (Fig.16). Traditionally a Tri-gear Trawl Beam is used to locate, track and sample scallops and deep water prawns in depths less than 1000 metres. The dimensions of the sled used at Ningaloo are 1.5 m wide x 1 m high. The net and cod end (Fig.17) are made of 48 ply 2" Amican™. It is a 4 seam net; top and bottom panels 100 meshes wide with wing panels 50 meshes high. It has a 9 bar 1 point taper with panels 75 meshes long with dimensions of 55 meshes long and 100 meshes round. The net and cod end are protected by rubber chafe matting design to minimise damage from abrasive substrates (i.e. rock, coral). There is a double cod end to help secure the sample from being lost from a torn net.

Twelve benthic sled samples were collected over 4 days in different habitats with varying degrees of benthos (i.e. dense, medium, and sparse). The sled was lowered to the bottom by a winch with steel cable and dragged along the bottom (Fig.18; Appendix 4). Distance fished was estimated by the winch operator, recording the GPS position when the sled touches the bottom and when it leaves the bottom. GPS positions provide the distance travelled in metres of all the samples conducted. To ensure more accurate fishing times for the sled in the future a depth sensor, time synchronised to the ships GPS, will be attached to provide a downloadable profile of fishing time and distance.

Trials indicated the new sleds' sampling wan an improvement on 2006 and all the macro benthos shown on towed video was being sampled. Trials also indicated that the most representative and manageable sled sample distance, out of several tested, was 50 metres in all the habitats sampled. Fifty metre long samples will be adopted as the standard for future samples to be carried out in 2008. The improved benthic sled design and fishing time/distance measurement capabilities to be fitted before 2008 will allow us to quantify more accurately the abundance and biomass of phyla that make up the benthic communities in different areas of the marine park. An improved processing protocol for each sample has been established, with the assistance of the West Australian Museum, and will be further developed and documented in preparation for 2008.

Figure 16. New benthic sled used to sample taxa from targeted communities in 2007.

Figure 17. New benthic sled net and cod end.

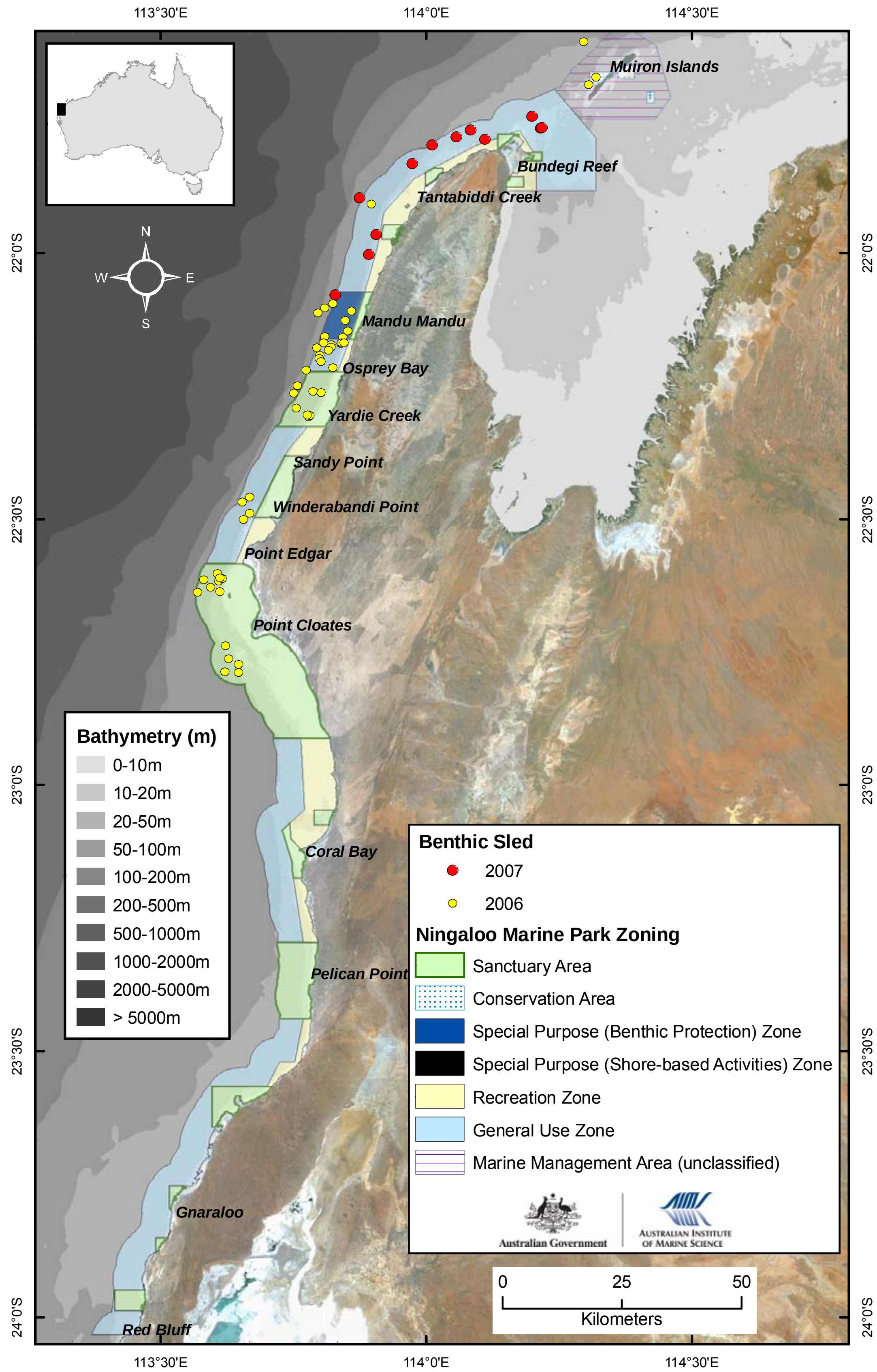

Figure 18. Benthic sled sample locations 2006/2007 surveys.

Overall weight of each sample was calculated by weighing the empty and full cod end with a 200 kg capacity digital scale attached to the end of a crane. A standard fixed lifting point was made at the end of the cod end. Weighing both empty and full allowed for the total biomass of each sample to be calculated in varying conditions on board the vessel. The whole sample was then emptied onto the sorting tray (Fig. 19). Each phyla represented was separated (Fig. 20). The dominant taxa from the main habitats were selected for priority identification i.e. Porifera (sponges), Alcyonaria (gorgonians, whip corals). Overall sponge weight in each sample was measured. Individual sponge weights in each sample were measured. The weight of other dominant sessile phyla was measured (i.e. bryozoans, soft corals etc) (Appendix 4). The weights of the dominant mobile phyla were weighed. Trials indicated that both a higher capacity scale >200 kg and lower capacity scales <100 g were required to get accurate biomass measurements from all the phyla collected in each sample. Voucher specimens of all taxa were labelled, photographed and preserved for identification at the Western Australian Museum according to the procedures in Appendix 5.

The 2006/2007 species collections form the basis for primary species inventories at Ningaloo Marine Park however, a significant proportion of taxonomy remains to be done by the West Australian Museum. The 2008 field work will focus on acquiring benthic samples from as many different habitats that have been identified to date in the surveys. Replicate sled samples will be stratified in different habitats depending on their size and variability. Sled tows will be standardised to 50 metres fishing distance (e.g. from the time the sled is on the bottom sampling to the time it leaves the bottom).

Figure 19. Benthic samples emptied into sorting tray.

Figure 20. Benthic sample sorted, photographed and weighed.

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 utilised and portable allowing easy packaging of the data and associated maps etc for the 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. The GIS layers to date for the data collected in April – May 2006/2007 are described below:

- Multi beam surveys conducted by FUGRO Pty Ltd have been included as both point and raster (gridded) GIS datasets.
- Side scan sonar survey geo-referenced tracks and images showing the area data was collected.
- Single beam survey geo-referenced tracks showing the area data was collected.
- Demersal Fish Assemblages Surveys using BRUVS – ArcGIS™ point shape file created with attributes including date, time and operational code for each camera deployment. Video snippet 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 and will be created.

Data can be exported from ArcMap™ to create Google Earth™ kml/kmz files (Fig.21). 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 (Fig.21).

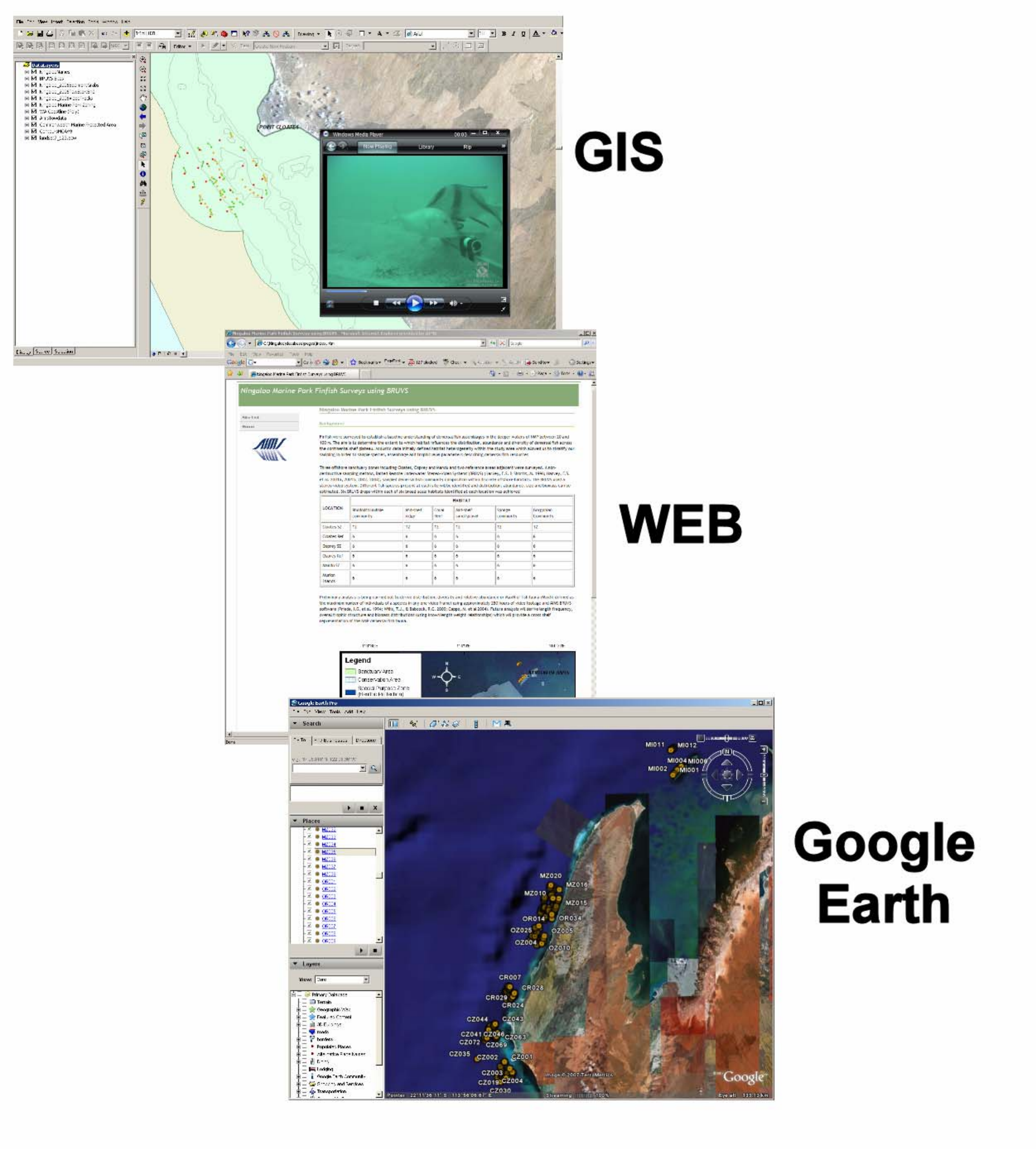

Figure 21. Different visual formats some of the data will take in the final GIS database

DISCUSSION

Field work conducted in April-May 2006/2007 has enabled us to complete the deepwater sediment grab sampling program for Ningaloo Marine Park. Samples are currently in the laboratory being processed and analysed. A significant picture of the characteristics and dynamics of sediments in the deep waters of the marine park is evolving and should give us great incite into the characteristics and functions underlying the benthic communities. The geomorphology section above explains the analysis being performed and perceived outcomes. These outcomes, with others, will form some of the primary layers of the GIS database providing a valuable interactive tool for marine park planners, policy makers and managers.

Broad scale towed video sampling in the marine park is complete however more samples will be gathered in areas of interest that were not identified in 2006/2007 but may become evident from the side scan sonar and single beam survey analysis currently being processed. Towed video has provided an excellent broad scale, relatively simple and quick way to visually assess benthic communities in the field. Towed video footage also provides valuable data that is post-processed to investigate details of benthic community composition and variability throughout the marine park.

The Western Australian Museum has identified 39 species of sponge from 22 sled samples to date. The identification of other taxa has commenced and will be reported in due course. A preliminary report can be seen in Appendix 5. As taxonomy progresses on the different functional groups forming these communities we can start to built a more complete picture of their diversity and structure. All voucher specimens have been photographed from the benthic sled and it is planned to compile as many '*in situ*' images of these specimens as possible. These will be gathered from ROV, drop cameras and using SCUBA in the shallows. Spicule preparation images from different sponges will be obtained from the West Australian Museum. All images will be input into the ArcGIS™ framework to form an interactive taxonomic layer.

Multi beam, single beam and side scan sonar analysis and interpretation have commenced. Information will become available later in the year. The acoustic data will provide accurate bathymetry, building up a topographical layer of the seafloor which can easily be integrated into ArcGIS™. The acoustic data will help us distinguish habitats associated to areas of topographical or bathymetric interest and to particular textual qualities (substrates and/or benthos) in side scan sonar images. The scope for further acoustic surveys in 2008 is currently being investigated.

The 2006/2007 surveys have indicated the deep waters (20-110 m) of Ningaloo Marine Park have a diverse array of filter feeding communities in different depths and areas with potentially high and unique biodiversity values. Hooper et al. 2002 identified the Northwest shelf of Australia as a sponge biodiversity 'hotspot', from the few surveys that have been conducted in the region, all north of Ningaloo Marine Park. These communities seem to vary in composition depending on depth and position and can be dominated by sponges, soft corals, whip corals or gorgonians. They have been located in depths from 30-110 m. Few coral communities were evident during the survey, however in the shallower areas close to the back reef some coral communities persisted to greater depths than others. Extensive rhodolith fields (rubble and coralline algae) in depths of 30-60 m are evident with little associated macro benthos. Extensive areas of sand forming dunes, mega ripples and ripples, mounds and burrows occur throughout the marine park and in many areas considerable sediment movement is evident. Two unique ridge systems were evident from the multi beam survey and towed video footage. Each ridge system seems to have a particular structure, substrate and associated benthos, different from other filter feeding communities.

To date no clear zonation of benthic habitats associated with depth from the back reef slope out to the edge of the continental shelf plateau is evident, however this may change as the suite of analyses are completed. A clearer picture will emerge of the number of different deep water habitats there are in the park, their structure and composition and some of the abiotic and biotic variables driving the dynamics of these communities.

ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1: Sediment grab sample locations 2007

Appendix 2: Towed video transect locations 2007

Appendix 3: ROV transect locations 2007

Appendix 4: Benthic Sled locations 2007

Appendix 5: West Australian Museum Report - Preliminary identification of specimens from the Ningaloo Deepwater Survey – 2006 Expedition. J. Fromont and M. Salotti

***Note.** Appendices will be provided in electronic form only and are available from the accompanying CD.