Kimberley Benthic Biodiversity: *Synthesis Report*

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WAMSI Kimberley Marine Research Program

Synthesis Report

Project 1.1.1

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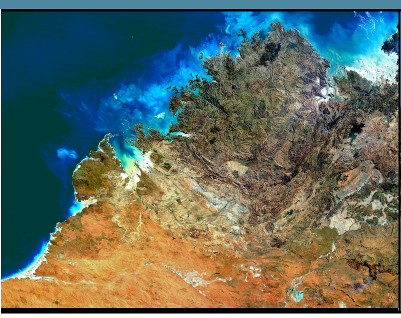
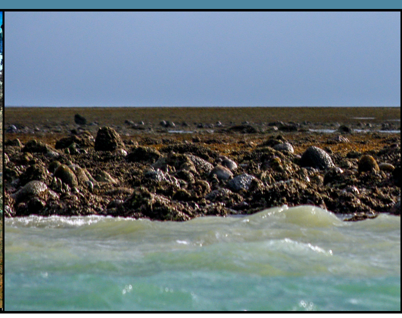
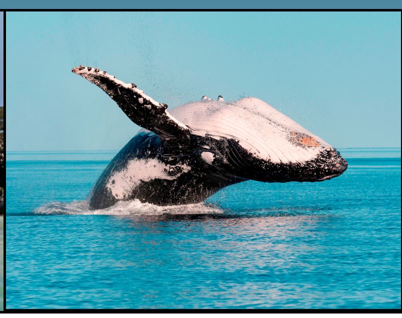


WAMSI Kimberley Marine Research Program

Initiated with the support of the State Government as part of the Kimberley Science and Conservation Strategy, the Kimberley Marine Research Program is co-invested by the WAMSI partners to provide regional understanding and baseline knowledge about the Kimberley marine environment. The program has been created in response to the extraordinary, unspoilt wilderness value of the Kimberley and increasing pressure for development in this region. The purpose is to provide science based information to support decision making in relation to the Kimberley marine park network, other conservation activities and future development proposals.

Front cover images (L-R)

Image 1: Satellite image of the Kimberley coastline (Image: Landgate)

Image 2: Early morning low tide showing exposed corals at the reef edge and turbid water (Image: Andrew Heyward)

Image 3: Humpback whale breaching (Image: Pam Osborn)

Image 4: Turtle area echinoderms (Image: Andrew Heyward)

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Contents

Executive Summary

I. Four major ship-based surveys of subtidal seabed were completed in the Southern (Camden Sound), Central (Bonaparte Archipelago) and Northern (Eclipse Archipelago) Kimberley regions, to provide a representative benthic biodiversity assessment along the Kimberley ria coast. Survey methods included multibeam to characterise the seabed, Smith McIntyre grab samples to determine the nature of sediments, towed video observations of the abundance (as % cover) and diversity of benthic biota, and benthic sleds to collect biological specimens for taxonomic identification. Four additional smaller scale expeditions focussed on nearshore intertidal areas, including two surveys on RV Solander, in collaboration with Wunambal Gaambera and Dambimangari sea rangers, assessed shallow fringing reef and rocky shoreline habitats using single-beam surveys and drop cameras inshore of the subtidal expeditions. The research has characterised habitat distribution and species abundance at representative locations within the Greater Kimberley Marine Park.

II. The study has led to greatly increased knowledge of marine biodiversity of the Kimberley. For many species the northern range of known distribution in Western Australia (WA) has been extended and in most taxonomic groups there were new records for WA and Australia. Multiple new species were discovered, some of which have been described as a result of this study. Overall, close to 2200 species or nominal species were identified from the three regions. Sponges, echinoderms, molluscs and crustaceans accounted for 83% of all species identified. Individual species exhibited a wide variety of distribution patterns: e.g. inshore, offshore, northern, southern, widespread or localised and patchy. Diversity indices were used to measure community structure across depth and substrate type. The highest diversity occurred in deeper >45 m, 40 to 45 m and shallower < 20 m rocky habitat and was lowest in mud habitat.

III. In the Lalang-garram/Camden Sound Marine Park large areas of sand with sparse biota were typical in the central part of the Sound. This finding suggests that the biodiversity values associated with the central area of the marine reserve relate more to pelagic and migratory species, such as whales, than the benthic habitats. Throughout the Marine Park localised areas of harder ground supported key seabed habitats with much more abundant and diverse biota. In those locations, sponges contributed the overwhelming majority of biomass sampled by epibenthic sled, while sponges, crustaceans, echinoderms and soft corals were the most numerous.

IV. In the Central region the broad scale habitat composition and distribution observed was similar to the Southern region. Sponges, echinoderms and bryozoan were the phyla represented by the greatest number of individuals in sled samples and biomass was much greater for sponges and bryozoan than other taxa.

V. In the Northern region filter feeding and detritivorous species characterised most of the sessile seabed biodiversity. Sponges and various echinoderms had the greatest number of individuals, but as in all other regions, biomass was much greater for sponges than other taxa.

VI. The relative abundance, measured as percent cover of the seabed in still images, differed from data for organism counts and weights from the sled collections with one key difference being the estimated abundance of bryozoan species. Notwithstanding the probability that some bryozoa and other very small or indistinct biota were classified together in the "bryozoa" group, the higher cover estimates for small, low lying biota is a good example of the influence of growth form on different sampling metrics. Many of the larger sponges grow vertically and are effectively sampled by an epibenthic sled, whereas bryozoa may be very small and often spread laterally. The small size and fragility of bryozoans also predisposes those collected in a sled to fragmentation and loss through the collection net, resulting in a high probability of under-representation of biomass in sled samples.

VII. In the deeper areas surveyed, i.e. >15 m depth, the most diverse taxonomic groups were sponges (426 species), crustacea (229) and molluscs (211 species), indicating that sponges were almost twice as speciose as any other taxon group.

VIII. Individual species exhibited a wide variety of distribution patterns: e.g. inshore, offshore, northern, southern, widespread or localised and patchy. Mapping individual species demonstrated they are associated with different environmental variables and so have different distributions — even similar, congeneric species - thus emphasizing the importance of species level identifications that were undertaken in this study.

IX. The broad scale distribution of substrates and associated biota was similar in the southern, central and northern survey regions. Sand or mixed sand-mud areas with sparse epibenthic life, was the most widespread habitat type accounting for >85% of the seabed cover in all three regions. Areas of hard ground with abundant and diverse biota, were found both in offshore and inshore locations, but were more commonly encountered adjacent to shallow nearshore areas.

X. Legacy seabed channels from the Holocene transgression were found in all regions, reflecting former river channels and drowned valleys. These features provided an increased diversity in seabed morphology, with rapid changes in depth, slope and aspect over relatively short distances. Locations with complex seabed geomorphology or where strong currents could shift sediment, featured exposed underlying rock which was associated with an abundant and diverse sessile biota. The areas of highest abundance and diversity, which represented 10.4% of all towed video transects, tended to be closer to shorelines or paleo channel edges. While comparable examples were found in all three regions, very high cover transects accounted for only 4.2 and 5.3% of transects in the northern and central survey regions respectively, but 15.9% of transects in the southern survey region. Those were mostly located around the island archipelago at the northern end of Lalang-garram/Camden Sound Marine Park, including North Lalang-garram Marine Park, or adjacent to the coast in the region of Hall Point.

XI. Generally, photosynthetically active radiation attenuated rapidly with depth, typically measured at <5% of surface sunlight below 10-15m depths, with little light reaching depths beyond 20-25 m in most locations. The majority of survey work was conducted in water 15-60m deep, where little or no light reached the seabed. As a consequence, benthic primary producers, such as algae, seagrass and Scleractinian corals, were not present or represented a very minor component of the biological samples collected by sled or observed by towed video. Filter feeding and detritivorous species characterised most of the sessile seabed biodiversity observed in those depths. Sponges, echinoderms and bryozoans were the phyla represented by the greatest number of individuals in sled samples. Biomass was greatest for sponges, with sponges and various echinoderms also contributing the greatest number of individuals collected from all regions. Estimates of abundance determined by measuring the percentage of seabed covered by different organisms based on analysis of high resolution images, found bryozoans were the most abundant taxonomic group, averaging close to 9% cover across the study regions with sponges and soft corals the next most common, although contributing lower mean cover close to or just under 1%.

XII. Benthic primary producer habitats, including corals and algae, were predominantly restricted to the shallow margins adjacent to shorelines. Abundant Scleractinian corals and macroalgae were present in shallow water subtidal and intertidal habitats in all survey regions. Coral reef habitats with dense live coral cover, some with species diversity equivalent to well recognised offshore coral reef ecosystems, have been observed in southern, central and northern locations and have been best documented around outer coastal islands. While the Bonaparte Archipelago in the central region remains the location of maximum documented species diversity, locations of high coral diversity can also occur to the north and south as well as very near the mainland.

XIII. While a number of large coral reef type platforms are now known in the Kimberley, the presence of small patches of reef or coral-dominated habitat on rocky substrate is pervasive and may represent the majority of coral habitat in the region. Corals are likely to be present on much of the rocky shoreline which is prevalent along the Kimberley coast, if the elevation in relation to tidal heights is appropriate. Mid- and upper reef flat coral abundance is frequently <5-10%, with macroalgae the major habitat component. Both abundance and diversity rise when the corals are less exposed further seaward, but also within intertidal ponds and rock pools at all elevations. The outer reef flat and crest region provide larger and more continuous areas of substrate that support the highest levels of diversity and coral cover. Observations on tidal exposure of the coral dominated habitats indicate that in many locations this rich coral zone tends to commence on the seaward margins where the substrate lies lower than 1m below LAT, with reef crest habitats at 0.6m LAT or lower often characterised by high coral abundance and diversity.

XIV. Multibeam sonar provided greatly improved bathymetry for each of the three survey regions. The Southern region included the greatest range of depths (8-65 m), followed by Northern (15-70 m) and Central regions (10-60 m). The mean depth was similar for the Central (41±8 m) and Northern (43±13 m) region, while it was slightly shallower for the Southern region (33±11 m). In combination with benthic habitat information, multibeam data was also used to develop spatial predictive models of mixed benthic assemblages, showing the probable distribution of various mixed benthic habitat classes. The models also provide a means to estimate the percentage area covered by each class of habitat, for example, the location and extent of dense filter feeder habitat. In general, validation of the benthic habitat models showed they performed well. Areas of high model accuracy were more widespread across Southern than Central. The overall classification accuracy for the Northern study area was notably lower than for either the Southern or Central region, and areas of low accuracy were much more widespread spatially than areas of high accuracy.

XV. Analysis combining field data and a broad suite of environmental variables identified nine habitat/species assemblages that provide an overarching spatial characterisation of the broader region. There was a deeper offshore assemblage that ran the entire along-shelf range of the three sub-regions surveyed and then a series of inshore and intermediate assemblages which, broadly speaking comprised a northern set and a southern set. There is some overlap, but the transition zone between the northern and southern sets is at about 14° 45'S (Lamark Island and Augereau Island). In general, the offshore habitats were mostly unconsolidated sediment and were characterised by moderate diversity and low biomass while the intermediate and some inshore assemblages had a higher proportion of hard substrate, which in some cases had high biomass and a highly diverse invertebrate fauna.

Implications for Management

I. In terms of representativeness, for seabed biodiversity encountered in the subtidal waters deeper than 15m, the results confirm that multiple marine park areas with sanctuary zones are needed within the Greater Kimberley Marine Park. A northern and southern set of intermediate shelf and inshore assemblages represented the most marked biogeographic differentiation. At more local scales, inclusion of representative sedimentary, geomorphological and oceanographic characteristics will provide reasonably effective predictors of associated biodiversity.

II. Areas that include inshore-offshore gradients, such as archipelagos, with a variety of environmental settings including sheltered and exposed shorelines, should be effective in ensuring a representative sample of coral and other benthic primary producer habitats and species. The Champagny Sanctuary Zone, in combination with the Jungulu and Kuri Bay Special Purpose Zones and the recently declared North Lalang-garram Marine Park provide example areas likely to meet those needs for corals and algae in the shallows and filter feeders in the adjacent deeper subtidal areas.

III. Most of the more diverse and abundant filter feeding habitat was observed adjacent to shorelines or near channel margins in between islands or along drowned river channels that extend across the shelf. Island archipelagos are likely to capture a number of these submerged features. In addition, in lieu of more extensive bathymetry, the configuration and extent of paleo channels may be inferred in a general sense from existing bathymetry and consideration of the existing catchment geography of the ria coast.

IV. Where detailed bathymetric data is available, the information that modelling provides can be used for making informed spatial allocation decisions for conservation, such as determining the placement of management zones. Ideally, it would be preferable to make use of these local area models to assist in management decisions, such as a spatial zoning and use approach, for areas that were predicted with high rather than low confidence. The Projects maps of classification accuracy enable such decision processes for the first time.

V. The Project's surveys, in combination with the results of recent work by the WA Museum and ongoing drop camera assessments along the coast by DBCA indicate that Scleractinian corals feature as a component of benthic habitats throughout the Kimberley. Large areal extent of coral habitat on individual reefs is not a preeminent environmental value for most of the Kimberley reef systems. More notable is the occurrence of coral habitats in a broad variety of sometimes unusual and largely undisturbed environmental settings, in addition to the more typical coral reef-like habitats observed on larger reef platforms around the coastal islands.

VI. The presence of key benthic primary producers such as corals, algae and seagrass in intertidal and shallow subtidal waters (this study; Kendrick et al, 2016) suggest that remote sensing is likely to be useful in identifying some of those habitats. Despite the constraints of high turbidity across the region (Fearns et al, 2017), tidal predictions for the ria coast indicate that at least 50 days per year feature low tides of 1.0m LAT or less between 6am and 6pm. This is likely to allow future satellites, which are rapidly increasing temporal coverage and spatial resolution, to detect those major areas of fringing reef habitat with moderate to high coral cover, which occur at elevations between 0.3-1.0m LAT. Some of the same methods used to produce fine scale spatial models of the deeper water filter feeder habitats, in combination with the increasingly accessible rapid return satellite data, are likely to produce useful outcomes for mapping and monitoring the shallow benthic primary producer habitats.

Representativeness of seabed biodiversity in the current zoning

At the regional scale, the nine benthic assemblages identified and mapped in 1.1.1.5, Figure 9 had varying degrees of species richness, dominated by invertebrate filter feeders. Sponge and octocoral biohabitat types occurred at all three study locations and along with bioturbated sedimentary habitats made up the majority of sites. Of the eight assemblages that incorporated species data from sled collections in this Project, median species richness values were highest in assemblages 3, 2, 1 and 7 (see subreport 1.1.1.5, Figure 12). Hence, protecting areas containing high richness should be part of the considerations in conservation planning, which should primarily aim to comprehensively represent all types of biodiversity composition.

While not advocating any specific targets, as this is a matter for management agencies, in recent conservation initiatives worldwide, targets as high as 30 percent for areas within MPAs with high level protection, such as strict no take areas, have been recommended (e.g. within Lord Howe Island Marine Park, sanctuary zones represent 30% of the park and are managed to maintain them in as undisturbed state as possible (www.environment.gov.au/system/files/resources/5eaad4f9-e8e0-45d1-b889-83648c7b2ceb/files/benefits-mpas.pdf). As such, in the light of this new data on habitat and species assemblages, overlapping the current MPA boundaries with the mapped assemblages provides some guidance on how much of each assemblage has been captured within the boundaries of the current zoning structure used in the Greater Kimberley MPA (see subreport 1.1.1.5, Figure 9 and Table 2). While IUCN categories used in commonwealth marine parks and those in use by the State within WA MPAs may differ somewhat, the sanctuary zones in the Greater Kimberley MPA best match the IUCN II category, as shown in 1.1.1.5, Figure 9.

Benthic assemblages 4, 5, 6 and 8 have 27-53% within the current MPA sanctuary zones, but the higher diversity assemblages 3, 2, 1, 7 and 9 are less well represented, with 8-16% of the modelled areas falling within existing sanctuary zones in both state MPAs (see subreport 1.1.1.5, Table 2). This result indicates that some revision might be considered to include additional areas with those assemblages, but also noting that two of the four high diversity assemblages (3 & 7) both have an additional 20+% of their modelled areas captured within existing Special Purpose zones (IUCN IV, see subreport 1.1.1.5, Figure 9) and a total of 26% of assemblage 7 is included in sanctuary zones if areas included in commonwealth marine parks are also considered (subreport 1.1.1.5, Table 2). However, any review/revision/update of the zoning should take account of all the available information e.g. including the species distribution models (see subreport 1.1.1.6) and using systematic spatial planning tools (e.g. Zonation, Moilanen and Kujala 2014) to prioritize areas to add.

The greatest sampling effort during the Project, providing the most detailed data, was in the Southern region and the results provide new insight into the distribution of the key benthic communities within the Lalang-garram/Camden Sound Marine Park that may assist future adjustment of management boundaries. For example, there is good agreement between results for the abundance of key taxa from epibenthic sled tows (subreport 1.1.1.5, Figure 2), fine scale data from the towed camera transects (subreport 1.1.1.2, Figure 17) and modelled filter feeder habitat distribution (subreport 1.1.1.3, Figure 9). The more abundant sponge and soft coral communities were predominantly located around the island archipelago at the northern end of Lalang-garram/Camden Sound Marine Park. The data suggest that those key taxa are widely distributed across that archipelago, extending across the current Champagny Sanctuary zone sanctuary and towards the more coastal parts of the archipelago (see subreport 1.1.1.3) in both the Jungulu and Kuri Bay Special Purpose zones (Figure 1 below). Thin bands of more dense filter feeder habitat were also encountered south of the archipelago, likely associated with more complex seabed around paleo channel environments and also some dense habitat inshore, adjacent to the coast in the region of Hall Point. Consequently, a range of options exist, should a greater percentage of filter feeder habitat need to be included in sanctuary zones within the Lalang-garram Marine Parks. For example, consideration could be given to enhancing benthic protection to cover examples of paleo channel habitat, additional measures within the Jungulu and Kuri Bay Special Purpose zones and similarly, further assessment of seabed biodiversity values in the current Hall Point General Use Zone.

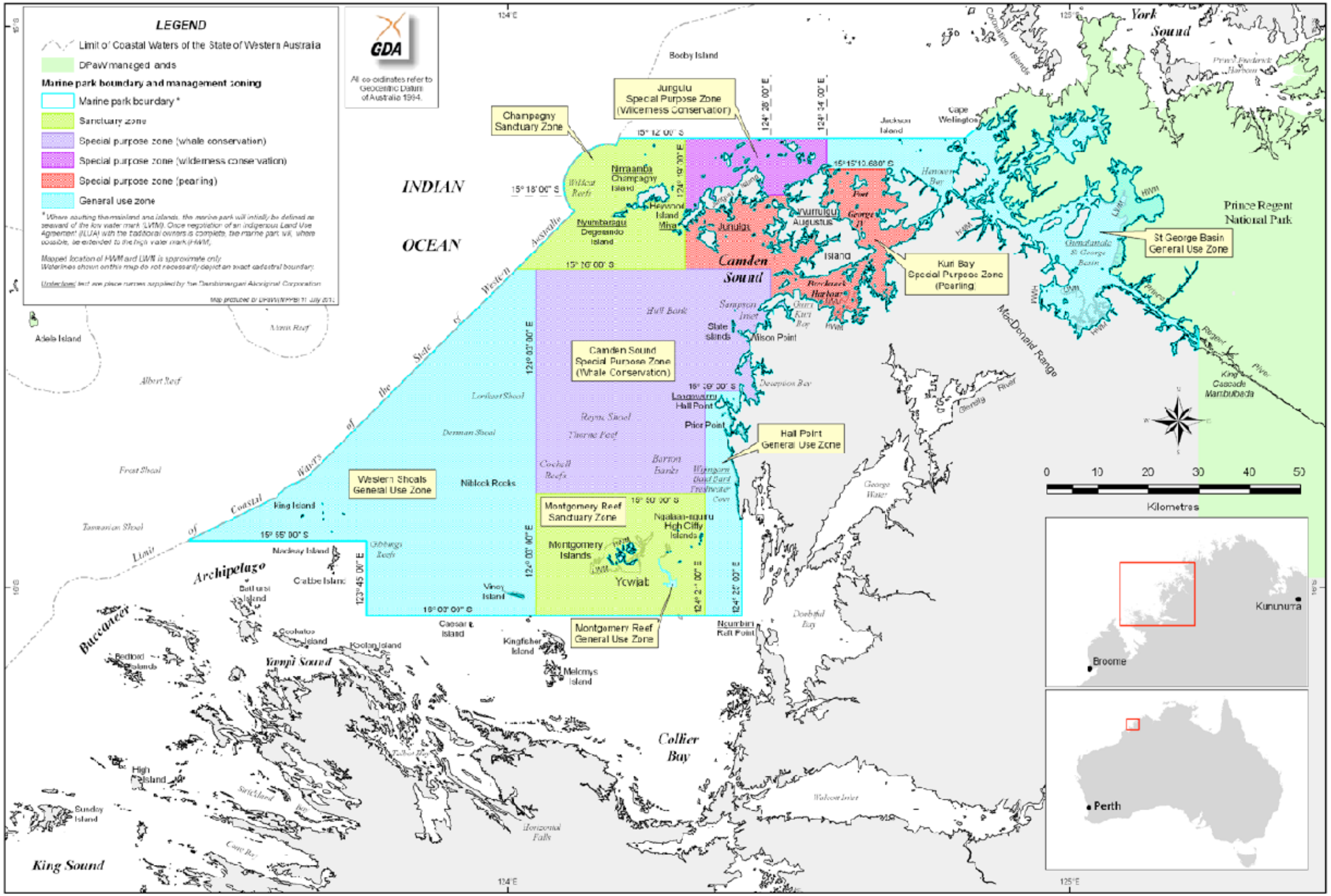

Figure 1. Map of Lalang-garram/Camden Sound Marine Park management zoning. From www.dpaw.wa.gov.au/parks/management-plans/approved-management-plans, accessed 18 September 2018.

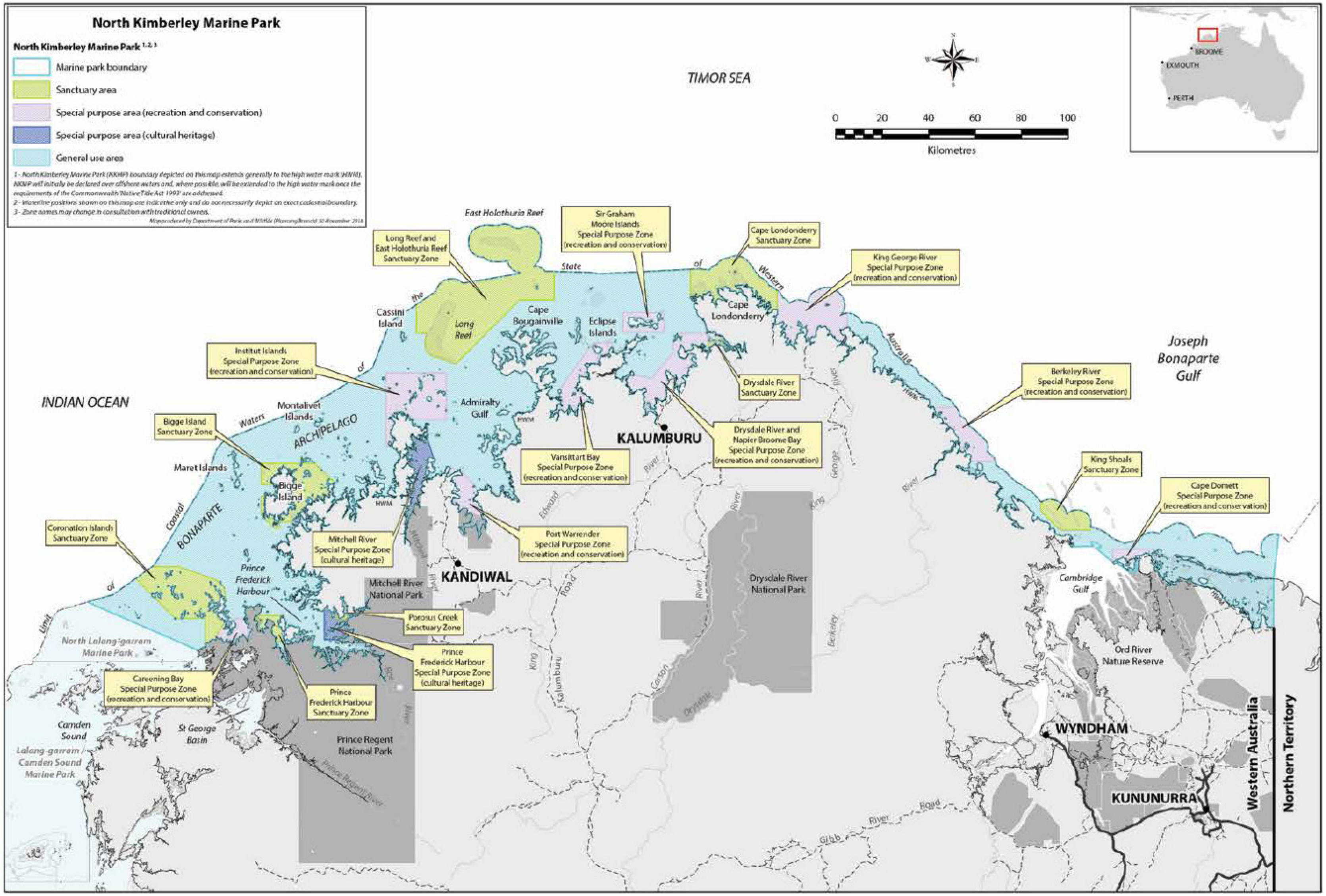

Figure 2. Map of the North Kimberley Marine Park management zoning. From https://www.dpaw.wa.gov.au/parks/management-plans/approved-management-plans , accessed 18 September 2018.

In other regions of the Greater Kimberley Marine Park the Project's data, although less detailed than for the Southern study area, provide similar insight into the representativeness of current zoning (www.dpaw.wa.gov.au/parks/management-plans/approved-management-plans). The regional modelling (1.1.1.5) indicates the presence of some different benthic assemblages in the central and northern region from those in the Southern region. The Project's detailed sampling and modelling data are geographically most relevant to areas around the Bigge Island Sanctuary zone in the Central region and the Long Reef and East Holothuria Reef sanctuary zone in the Northern region (Figure 2).

The fine scale field data and spatial models indicate widespread habitats containing sparse mixed benthic classes, including sponges, gorgonians and sea whips, in the Central region (subreport 1.1.1.3, Figure 1). However, areas of highest filter feeder abundance were found along the western coast of Bigge Island (see subreport 1.1.1.2, Figure 16) which may not fall within the narrow existing Sanctuary zone boundaries on that coast, and further offshore near various islands, including the Maret Islands. The data suggest that the additional areas of elevated seabed biodiversity occur in this area that lie outside the current Sanctuary zone boundaries. In addition, as noted in 1.1.1.8, the Bonaparte Archipelago (subreport 1.1.1.8, including Appendix 5) and the Maret Islands in particular, have some of the highest Scleractinian coral diversity yet documented for the Kimberley region. Consequently, including additional island fringing reefs and adjacent deeper hard seabed areas in future protective zones is highly probable to support enhanced conservation of high diversity benthic filter feeding species and reef building corals.

In the northern region the current zoning has a large Sanctuary zone surrounding the Long Island and Holothuria Reef region (Figure 2). While that Sanctuary zone clearly captures biodiversity values associated with the two emergent reef systems, the Project field data indicates that significant areas representative of key benthic habitats would also be included within the existing boundaries. Fine scale modelling can also be used to assess the degree to which the key habitats have been captured (e.g. 1.1.1.3, Figure 15), although it should be noted that the modelling in this region is less robust than for the Central and Southern areas. Nonetheless, when the models and field data are combined (Cf. 1.1.1.3, Figure 15 & 1.1.1.3, Figure 15) there are indications that additional higher filter feeder habit exists east of the current boundary, towards Cape Bougainville.

Knowledge Gaps

I. Despite the Project delivering increased knowledge of marine biodiversity in the Kimberley, it is evident from the sampling undertaken, that varying amounts of latent diversity remains to be described for most taxonomic groups. Furthermore, a number of mobile and habitat forming taxa collected during the Project remain unidentified because of a lack of available expertise for these groups. These include worms, bryozoa, hydroids and ascidians. The taxonomy and ecology of bryozoans in the Kimberley is an important knowledge gap, given they can be a major component of the benthos in some other areas.

II. The study did not use methods to specifically sample fish fauna, although some were collected in the benthic sleds. Similarly, infauna in offshore habitats, where extensive burrowing biota were inferred from imagery, and nearshore shallow (<10m) soft bottom habitats, remain an important knowledge gap in characterising biodiversity associated with the seabed. The recent study in Koolama Bay, offshore of the King George River (Keesing 2014) highlighted the high diversity and understudied nature of these shallow-water soft bottom habitats in the Kimberley.

III. Detailed bathymetry is lacking for the broader region, with numerous nearshore areas still unsurveyed. The utility of very high resolution multibeam bathymetry to assist in prediction of habitat distribution was demonstrated in the Project, but any additional depth data, even using single beam acoustics to acquire soundings opportunistically from DBCA and Department of Fisheries vessels, would be beneficial for future habitat assessment and modelling.

IV. Better knowledge of the relationships between habitat forming sessile invertebrates in the Kimberley, such as sponges and gorgonians, and mobile animals including echinoderms and crustacea, would likely lead to an improved understanding of the patterns found in this study.

V. While many of the Kimberley coral species are widely distributed and form a subset of the broader Indo-Pacific coral taxa, genetic evidence from the recent WAMSI connectivity project (Berry et al, 2017) indicated corals typically exhibited localised population structure, based on genetic analysis, with evidence for limitations to routine dispersal on scales of tens of kilometres or less. Consequently, they suggest conservation would be most effective with protected areas of similar scale (10–20 km). They also found evidence that King Sound, subject to strong tidal flows and seasonal salinity effects, could be a barrier to dispersal to corals, which spawn during a narrow seasonal window, but not species such as *Trochus* that spawn all year. While the presence of coral habitat on islands and submerged reefs is likely to provide important stepping stones for dispersal across this barrier over multiple generations, this finding raises the question of whether other large Sounds within the Greater Kimberley Marine Park, may form additional dispersal barriers for some species with narrow annual spawning windows.

VI. As the Project focused on three regions of the ria coast, which may only be broadly representative, the location of both benthic primary producer habitat and deeper areas of filter feeding or detritivore species habitat requires further mapping to confirm these general patterns and also identify additional areas or very localised habitats that provide exceptions. The good performance of fine scale models to identify the probable distribution of filter feeder assemblages is promising as a technique to aid management decisions regarding benthic habitat protection within subsections of the Marine Park. This technique requires at a minimum some detailed bathymetric data, ideally multibeam, and associated classification of seabed biota and habitats.

VII. The finescale modelling approach used in this Project (spaced multibeam with interpolated infill, GRTS spatial stratified sampling based on multibeam and CATAMI type categorization of observed seabed biota) has worked well where a) there has been sufficient data collected (Camden is the best example here but the central area has done well here with less data) and b) there is a decent ecological gradient by depth, slope, aspect, rugosity. If new areas are similar geomorphologically (and the coastline will be a good indicator) then the extension of this approach is very valid. However, if soft sediment environments are more likely (with sediment veneers over pavement or hard substrate) then the inclusion of multibeam backscatter to the bag of modelling variables is likely to be very useful. As soft sediments generally have spatially extensive ecological gradients with more stochastic and patchy habitats, sampling would have to be adapted carefully to take this into account and be over broader scales.

VIII. The Project results suggest that remote sensing is likely to be useful in detecting very shallow or emergent fringing reef habitats, including elevated terraced and ponded areas (see Collins et al, 2015). However, detection of even the shallowest subtidal habitats may be constrained by turbidity in many locations, or under certain tidal conditions. Rapid light attenuation through the water column was noted across the region, but it is not known if the frequency of high turbidity days varies substantially between locations, such as Camden Sound and Eclipse Archipelago, which have markedly different tidal amplitudes. Further application of the WAMSI Remote Sensing Project (Fearns et al, 2017) tools may assist in determining the distribution of light energy at the seabed across the region's shallow subtidal environments, to better understand the distribution of benthic primary producers.

Report Structure

The full report for WAMSI project 1.1.1 is structured as a synthesis report followed by eight individual sub-project reports that focus on project design and descriptions of the distribution, abundance, and characterisation of benthic biodversity and habitats. The synthesis report provides an overview and regional perspective through summarising the key findings for each sub-project, and the broader management implications these have for the region and the State.

The following sub-project reports and a Flatback turtle foraging habitats report are included as separate documents:

1.1.1.1 Project Design, field work completed and initial results for subtidal surveys

1.1.1.2 Distribution and abundance of benthos using digital photo imagery

1.1.1.3 Fine Scale Spatial Models

1.1.1.4 Species diversity and distribution

1.1.1.5 Species assemblages, biomass and regional habitat characterisation

1.1.1.6 Prediction of species distributions

1.1.1.7 Habitat Associations

1.1.1.8 Shallow coral habitat distributions

1.1.1a Flatback turtle foraging habitats

1 Introduction

The Project's Science Concept Plan, with a focus on existing and proposed marine park areas in the coastal zone, was finalised in March 2014, enabling the project to formally commence in the second half of that year. The WAMSI budget of $3.6M, which included additional contribution of State funds from environmental offsets in acknowledgement that the project would include research related to turtle habitats, was matched by equivalent co-investment from the research partners. A series of ship-based expeditions were undertaken between late 2014 and mid-2017. Annual progress reports and individual cruise reports were produced, while ongoing laboratory analyses of the field data were conducted by AIMS, the WA Museum, CSIRO and Curtin University. This report summarises the major results of those analyses, for all the expeditions in the coastal zone relevant to the declared and proposed Marine Parks. Results from the specific research to better understand foraging habitats and biodiversity important to migrating turtles, are provided as a separate report.

The geographic focus of the State's Kimberley marine park initiative at the commencement of the project (Figure 1) identified a number of focal areas along the length of the Kimberley coast. The priority for this project was to assess patterns of seabed biodiversity relevant to development of the Great Kimberley Marine Park along the Kimberley ria coast, north of Cape Leveque. The Science Plan focussed on the nature and distribution of seabed biodiversity mainly in WA coastal waters, from Camden Sound northward.

For the purpose of the Project, coastal waters vested in WA were defined as a belt of water between the limits of Western Australia and a line 3nm seaward of the territorial sea baseline. The average water depth along this jurisdictional boundary line is approximately 31m, but can vary between 10-80m. The coastal region of interest was north of 16^0S, spanned more than two degrees of latitude and consisted of a highly convoluted coastline estimated to exceed 4000km in length, extending for ~ 700 km (simplified) along the coast.

At the initiation of the Project, seabed biodiversity in the region was poorly characterised, particularly within the coastal subtidal waters. It was expected that planning for sustainable resource use and conservation activities in the future would benefit from better characterisation of the marine biological resources in this area. Consequently, the Project sought to broadly describe the major subtidal seabed habitats and commence the process of establishing a comprehensive biodiversity database to build on knowledge from preceding surveys of very shallow habitats and intertidal zones.

A selective approach to survey locations was adopted, to provide a broad representation of biogeographic patterns across the region, while creating more detailed knowledge of habitat distribution and species abundance in existing and future MPA areas. As well as mapping seabed morphology and habitat distribution patterns, collection of organisms sought to extend the WA Museum Kimberley collections and enable a more comprehensive understanding of species distributions. The information on abundance and diversity of the benthos would be evaluated in the context of physical parameters such as substrate, depth, current and light to develop spatial models, facilitating predictive and testable extrapolation of key habitat distributions.

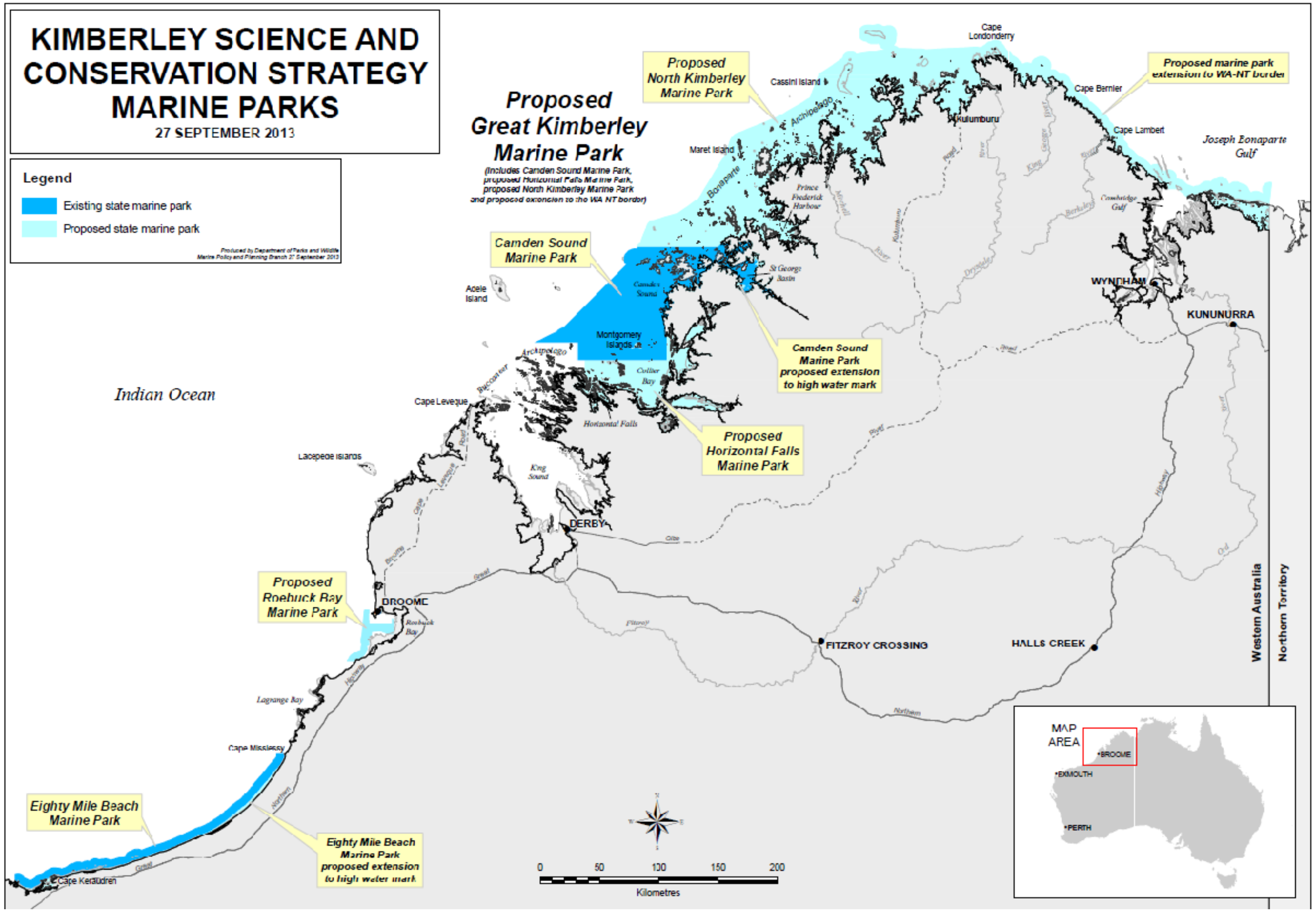

Figure 1. Map of the Kimberley showing Kimberley science and conservation strategy boundary and existing and proposed marine parks (modified after the Western Australian Marine Science Institute Kimberley Marine Science Program, Science Plan (Simpson, 2011).

1.1 Study site selection

Information related to Kimberley marine biodiversity, such as available physical and geomorphic datasets, the WAM/Woodside Marine Life of Kimberley Project, the Inpex Ichthys Project biological studies of the Bonaparte Archipelago, AIMS previous Kimberley benthic surveys and other readily available sources were used to provide a useful indication of key locations and a guide for final design preparation during the project.

Spatial gradients likely to influence biodiversity, including depth, substrate complexity, hydrodynamic variability and water quality were identified from available information and modelled to assist in the selection of survey locations. A gradient analysis was conducted using existing data analysed with three different methods over Kimberley sub bioregions, based on existing and available physical and geomorphic datasets indicating areas of uniqueness and similarity: 1) geomorphic isoclassification based USGS bathymetry and NASA SRTM digital elevation models (model outcomes are based on analysis of depth, slope, aspect and rugosity); 2) Principal Component Analysis of the finest scale sediment data available from the AUSEABED database and Geosciences Australia MARS sediment database (data was co-kreiged using bathymetry to produce surfaces for analysis); 3) cluster analysis combining all available spatial databases including USGS/NASA bathymetry, Geosciences Australia MARS database, AUSEABED, CSIRO CARS 2009 and CSIRO Tidal datasets.

Patterns of cross-shelf and latitudinal gradients in the biodiversity predictors were apparent (Figures 2,), although the coarse scale and the limited extent of much of the existing data resulted in high levels of uncertainty associated with the modelled patterns, particularly at fine spatial scales.

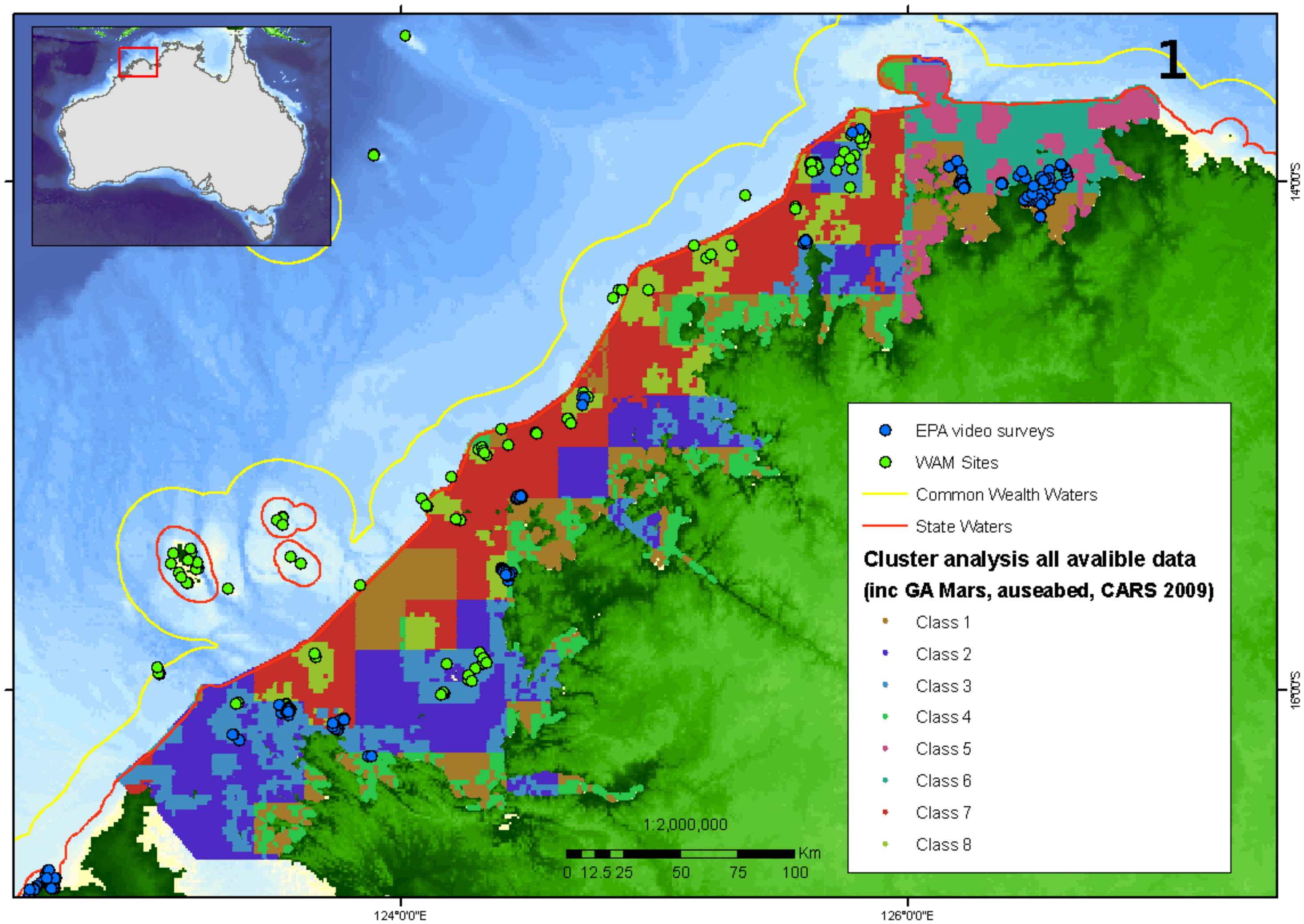

Figure 2: Cluster analysis of all available physical databases of the Kimberley bioregion, indicating latitudinal and cross shelf gradients and location of existing field data.

Three areas in southern, central and northern regions of the ria coast (Figure 3) representing examples of the major groups of physical variables (Figure 2) and also including different latitudes, longitudes and tidal ranges, were selected as study sites for the Project. The southernmost location centred on Camden Sound, where the Lalang-garram/Camden Sound Marine Park had recently been declared. A central area around the Bonaparte Archipelago and a northern location in the vicinity of Cape Bougainville spread the survey across the bioregion. Based on the available time and resources, a series of four major ship-based voyages were planned to enable sampling of the three regions, each with a nominal duration of sixteen days.

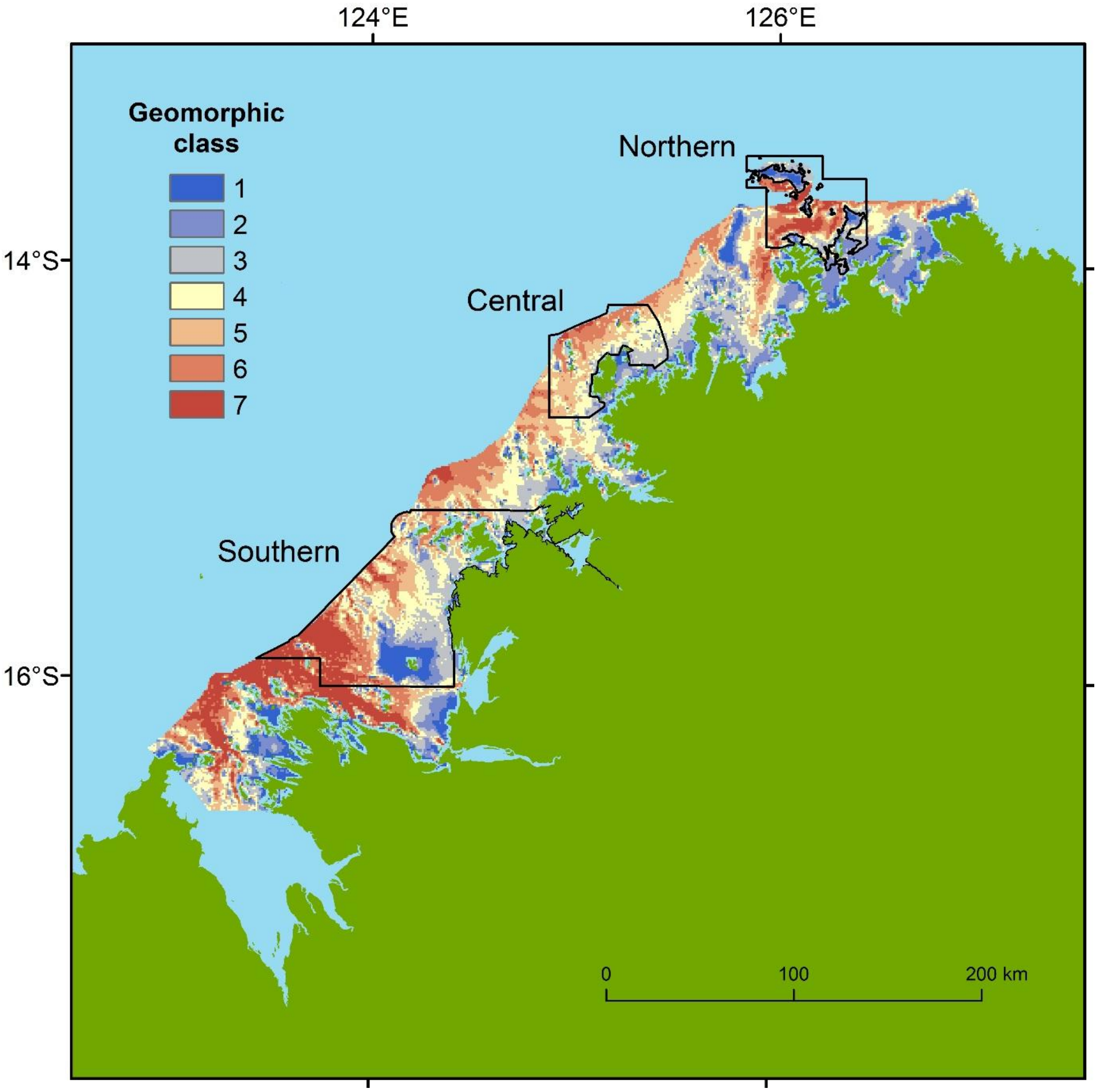

Figure 3. Map of sampling areas for the project, overlaid on a model of seabed geomorphology at the start of the Project. The southern site focussed on Lalang-garram/Camden Sound Marine Park, including locations in the broader sound and the island archipelago to the north (now North Lalang-garram Marine Park). The central region included the Bonaparte Island group and the northern study area covered the Cape Bougainville-Eclipse Island-Holothuria Reef region.

Sampling of the seabed biota in these three regions aimed to provide broad scale information, a regional context for future management of specific locations and some predictive capability to identify additional areas that may support unusual or notable habitats.

1.2 Sample design and field methods

The major survey expeditions primarily employed the AIMS vessel RV Solander, augmented in Camden Sound by CSIRO vessel RV Linnaeus. Spatially balanced habitat survey design using GRTS (Generalized Random Tessellation), was used to guide partitioning resources in a balanced manner over all habitats in each of the three regions. This sampling methodology combines information on ecological and geomorphic surrogates, landscape scale ecological process and knowledge of how seafloor physical properties act as both direct and indirect drivers of these processes. The sampling designs developed prior to each voyage used available information such as depth, slope, aspect and rugosity to develop indices of geomorphic complexity. Survey sites for towed video and sled sampling transects were then selected in a randomized, stratified design to distribute available sampling effort in a representative manner throughout each study area, e.g. Figure 5. The RV Solander supported a full complement of crew and scientists, allowing it to maintain a 24/7 schedule without anchoring. Daylight activities included towed video transects for habitat characterisation, epibenthic sled sampling to collect biota, CTD casts for water column profiling and seabed grab sampling for sediment characterisation. During nights the vessel surveyed a pre-planned grid pattern with the multibeam to map depth and seabed morphology. The key elements of sampling were as follows:

I. Multibeam analysis to identify geomorphological structure and major areas of hard and soft bottom
II. Towed camera assessment to characterise the nature of the seabed and dominant macro-epibenthic communities present. This provided broadscale habitat data
III. Sampling the benthic organisms using a towed sled or dredge, usually directly along the same transect as the towed camera line, for a distance of 50m in dense biota and 100m in sparse biota.
IV. On board processing to sort, weigh, photograph and preserve the biological collections at each station as thoroughly as possible
V. Sediment sampling (using Smith McIntyre grab) and water column characterisation (using CTD) at the majority of stations

2 Field Results

2.1 Study species

The three regions were surveyed as planned (see Figure 4) and the sampling methods and devices worked effectively at most locations. Areas where charts indicated unsurveyed waters were generally avoided or surveyed with extreme caution. Seabed hazards affecting sampling gear performance were occasionally encountered, notably when towing cameras in very poor visibility. Image quality was affected, but was adequate in all but the worst conditions, which required the camera to be placed almost in contact with the seabed to provide interpretable imagery. Optimal times for deployed camera assessments were around neap tides and the few days following, regardless of location. Visibility through the water was highly variable and occasionally relatively clear. On the other hand, the water could be equally turbid in all regions, despite that gradient in tidal amplitude from north to south. When water clarity was too poor for imaging, other sampling was continued until imaging was possible. In some cases, alternate sampling locations used. Adjusting workflows to suite the conditions and having a set of alternate sampling stations prepared in advance enabled useful imagery to be obtained in the majority of sampling stations throughout the Project sled sampling was effective in collecting the macro-epibenthos at most stations, other than in a few particularly rocky seabed areas where there was a probability of skipping on and off the seabed, reducing effectiveness, or becoming snagged.

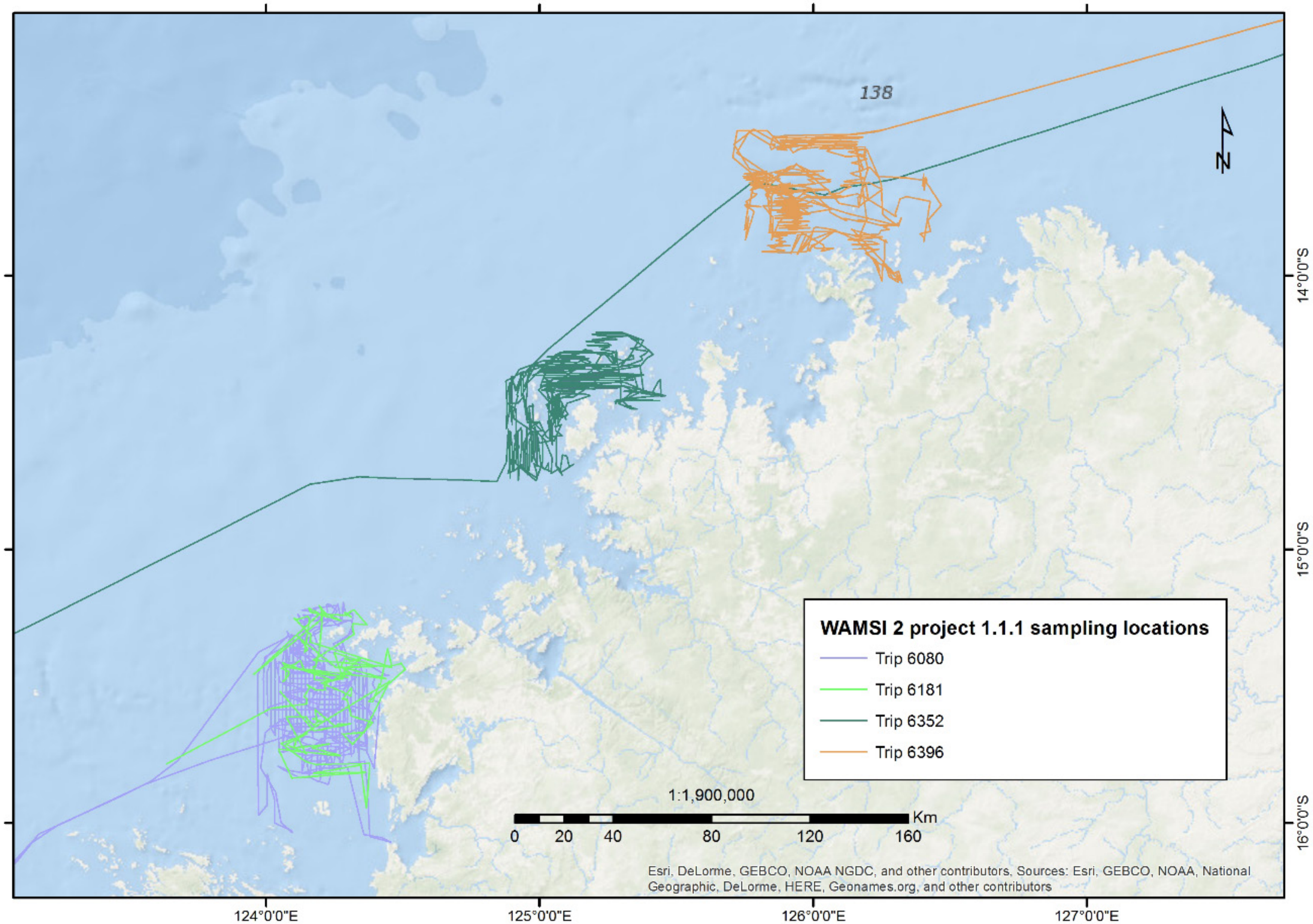

Figure 4. Vessel tracks indicating the location of field effort during the major subtidal field surveys in the three regions.

2.2 Southern region

In the Lalang-garram/Camden Sound Marine Park, the initial expedition surveyed a large number of stations, focussing on towed video and multibeam methods (Figure 5). The resulting preliminary characterisation of the seabed habitats was invaluable in planning the follow up expedition, which extended the number of sampling stations for habitat characterisation and multibeam mapping, but also added in collection of biological samples (Figure 6). Sand-dominated areas with sparse biota were typical in the central part of the Sound, interspersed with localised areas of harder ground with abundant and diverse biota, possibly related to legacy seabed channels from the Holocene transgression or more recent shifting sediment events exposing underlying rock, were found in both offshore and inshore locations, but were more commonly encountered closer to shallow nearshore areas. Marked changes in seabed substrates and rugosity were noted in some locations, with concomitant changes in biodiversity sometimes occurring over short distances (Figure 6). Filter feeding biota most frequently observed included gorgonians, sponges, ascidians, bryozoans and sea whips. Sponges contributed the overwhelming majority of biomass sampled by epibenthic sled, while sponges, crustaceans, echinoderms and soft corals were the most numerous.

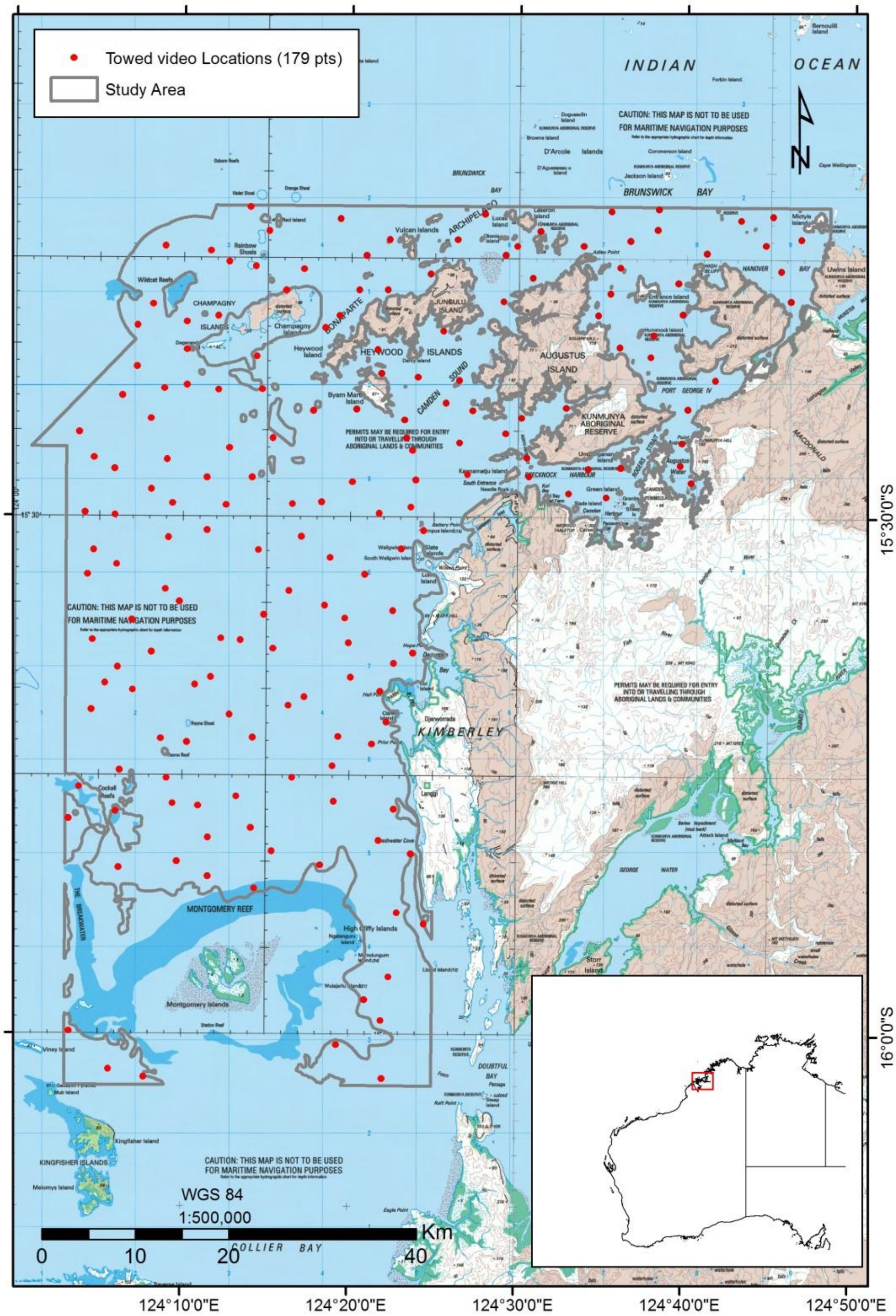

Figure 5. Location of seabed towed camera survey stations within the Campaign 1a study area. Dots represent the starting point of each 1.5km transect. Red dots indicate the total number of target stations developed in the sampling plan prior to the field work. Green dots are the actual sampling stations completed at the end of field campaign 1a.

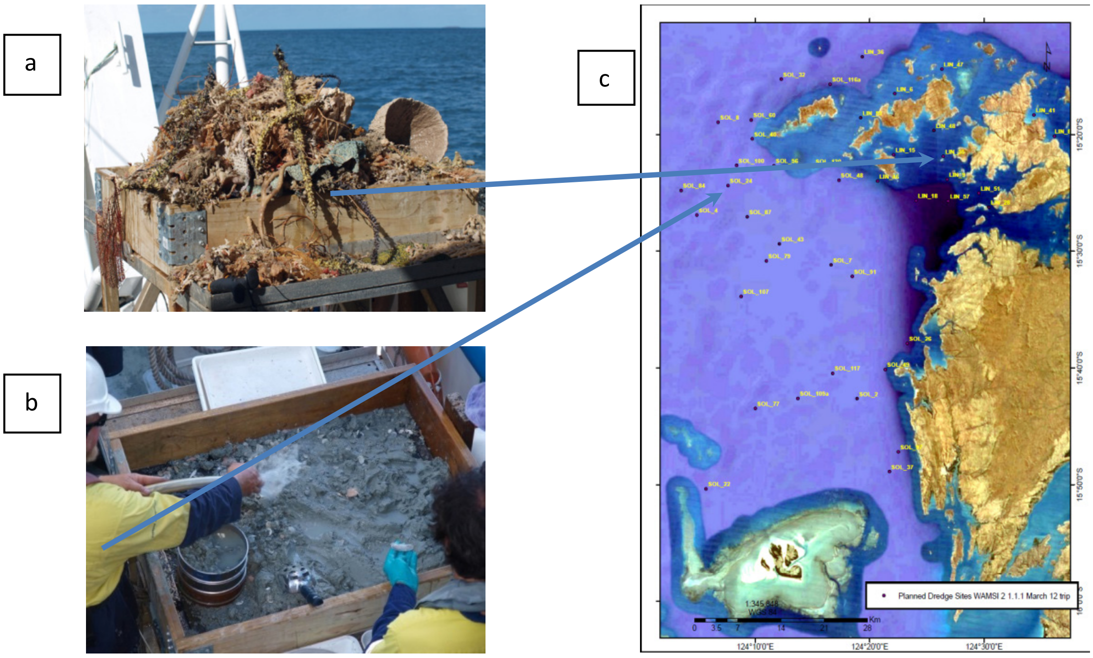

Figure 6. Example of sled collections in Lalang-garram/Camden Sound Marine Park. Images a and b show the markedly different abundance and diversity of samples collected not far apart in the geomorphologically more complex nearshore region of the northern sound.

Generally, little light reached depths beyond 20 m in most locations, resulting in benthic primary producer habitats being restricted to the shallower margins. Due to the depth constraints for the survey ships and the typically turbid water conditions, the majority of survey work was conducted in water >15m deep, over areas where little or no light reached the seabed (see Figure 7). As a consequence, benthic primary producers, such as algae and Scleractinian corals, were mostly not present or represented a very minor component of the biological samples collected by sled. Analysis of high resolution imagery confirm the general absence of phototrophic biota along the towed camera transects (Figure 6). Observation of more variable habitats around channels and shorelines, suggested that finer scale changes in seabed biodiversity paralleled changes in geomorphic complexity, which, in particular, was a feature in the northern area of the Marine Park through the Champagny island archipelago.

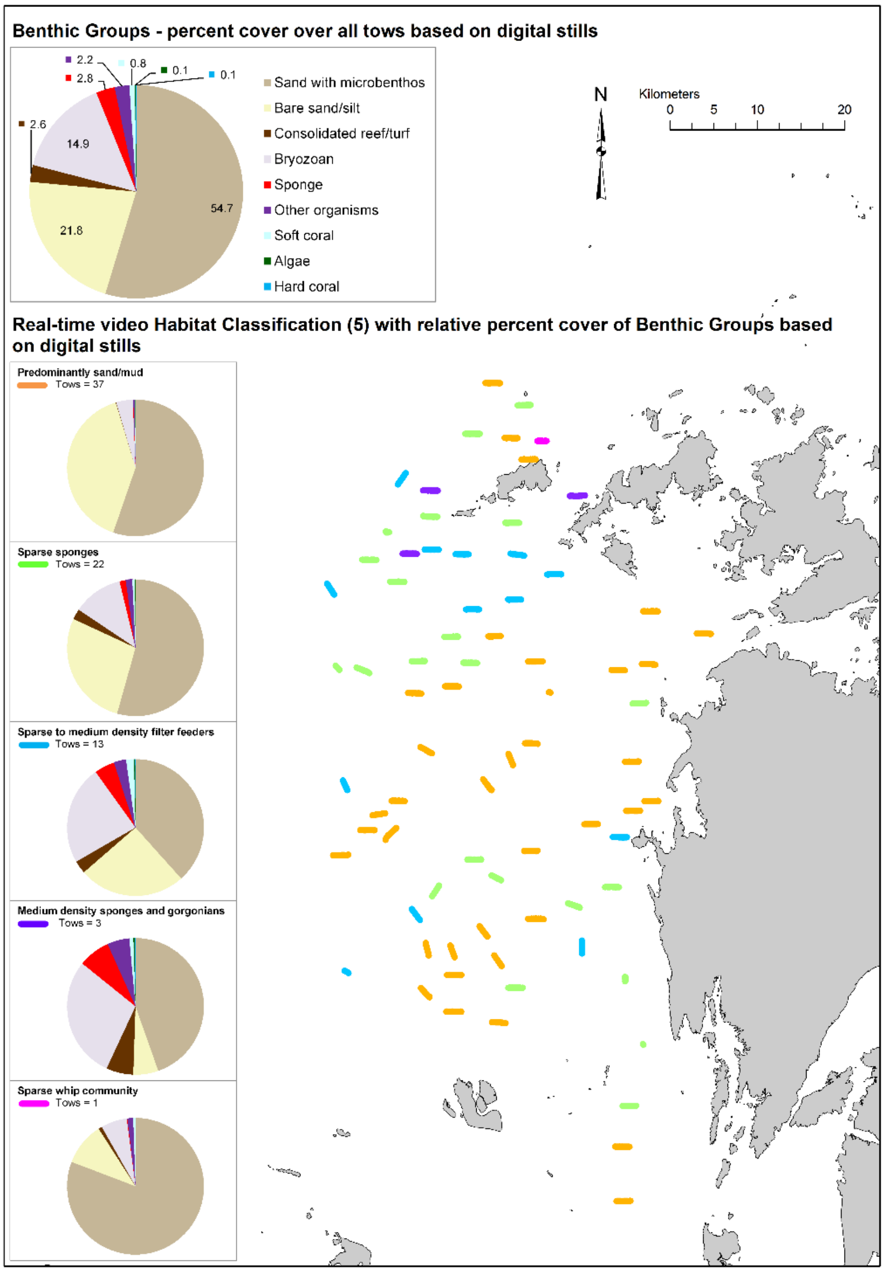

Figure 6. Camden Sound – distribution of major habitat classes derived from towed video data, with percent contribution of substrate types and biota produced from analysis of associated downward-facing still images.

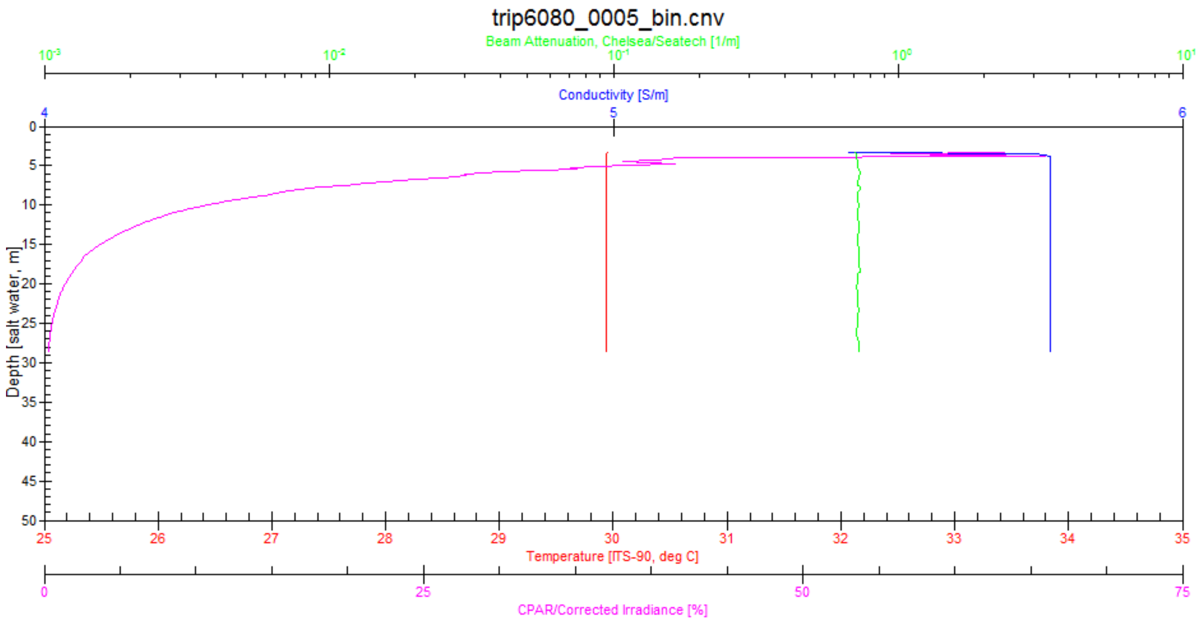

Figure 7. Example of water column physical properties in Camden Sound produced by deploying a CTD plus PAR device vertically below the ship to profile the water column. Each colour represents a different sensor – the pink line (CPAR) shows the rapid reduction in light below approximately 10 m, declining to zero at less than 30m depth. In contrast conductivity (proxy for salinity), temperature and beam attenuation are uniform from surface to the seabed, reflecting a well-mixed body of water.

2.3 Central region

Broad scale habitat composition and distribution observed in the Central Region was similar to the Southern region. In water depths of 10-50 m, filter feeding and detritivorous species characterised most of the sessile seabed biodiversity. Sponges, echinoderms and bryozoan were the phyla represented by the greatest number of individuals in sled samples collected (Figure 9), but biomass was much greater for sponges and bryozoan than other taxa. Real-time habitat classification from the towed video (Figure 8) shows most of the filter feeding habitat to be nearer shorelines or in between islands. Two transects encountered extensive burrowing biota well offshore, south southwest of the Maret Islands.

Most areas in depths accessible to the primary research ship (>10-15m) supported little or no benthic primary producer habitat. CTD casts again showed a rapid attenuation of light, particularly beyond approximately 10m depths, with little or no surface light reaching the seabed at 20-25m in many locations.

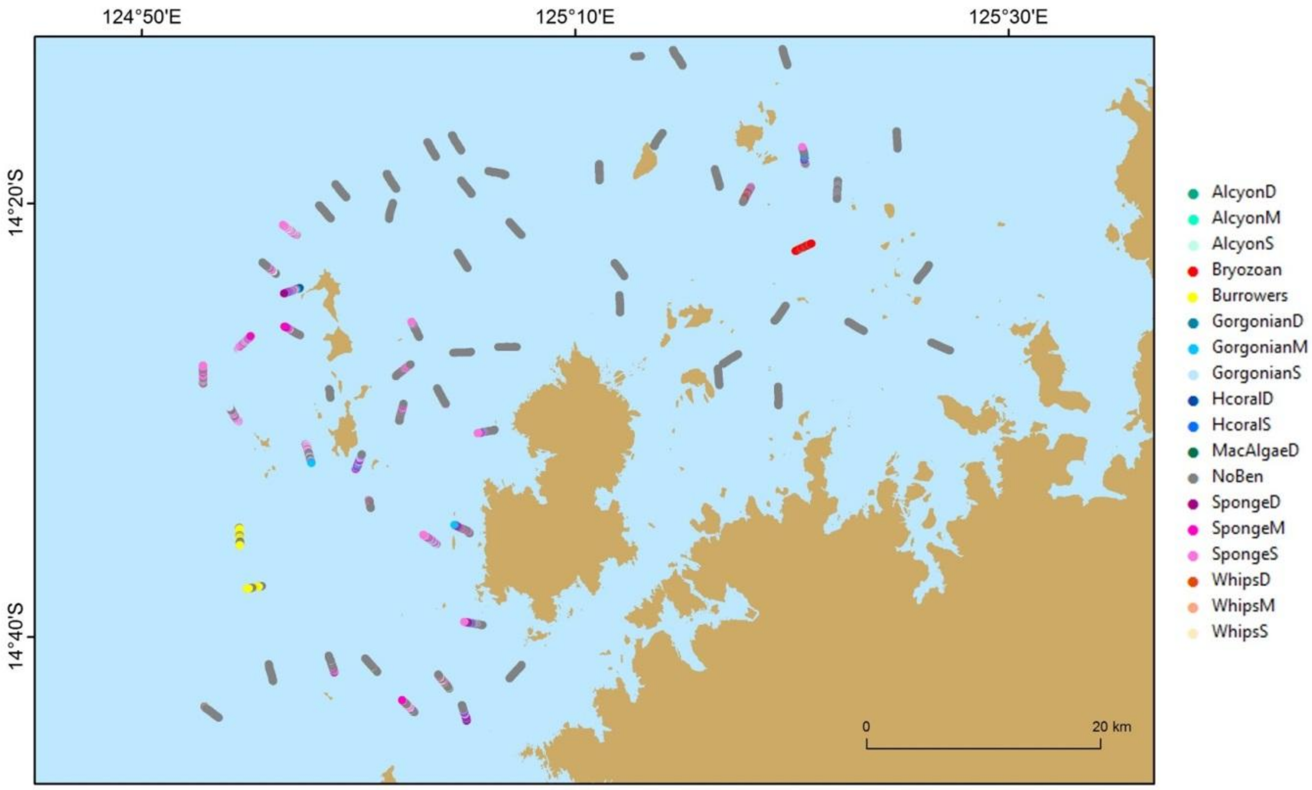

Figure 8. Central Region -Summary of real-time classification of benthic biota from 61 towed video transects in the Bonaparte Archipelago area, Central Kimberley.

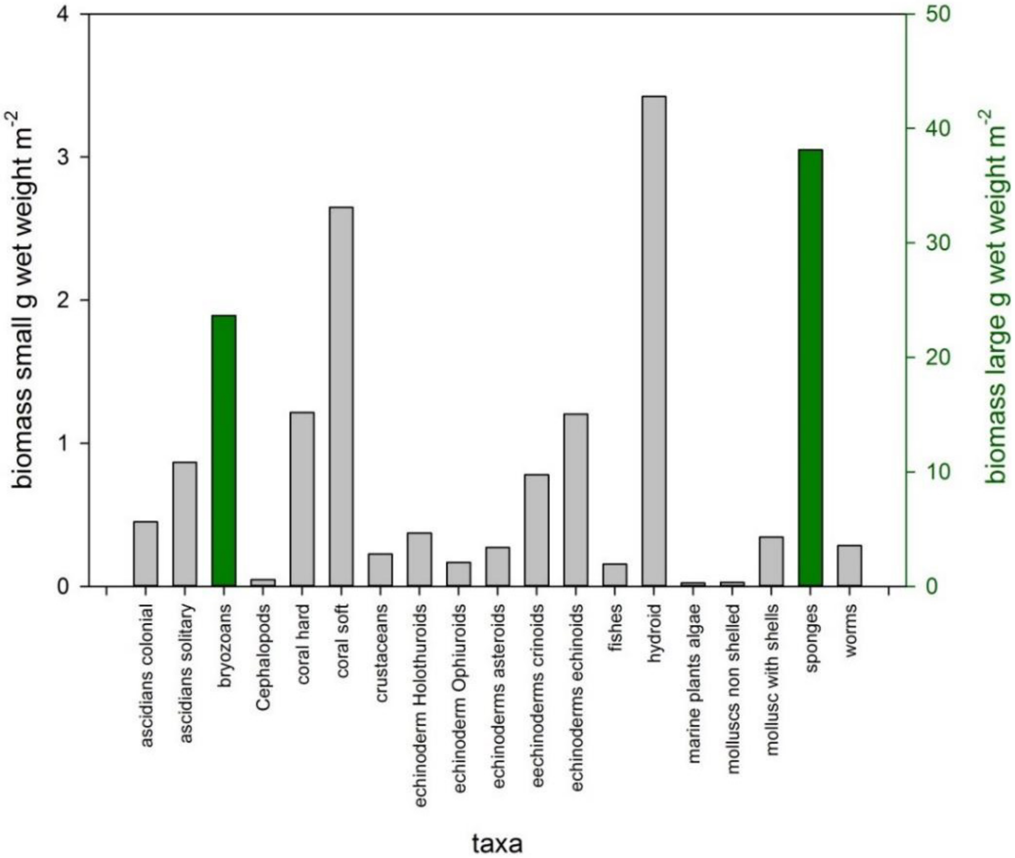

Figure 9. Preliminary summary of the biomass of invertebrate groups from sled samples in the Bonaparte Archipelago. Note two scales are used, with the higher biomass bryozoan and sponge groups requiring units one order of magnitude larger (green, right vertical axis) than other groups.

2.4 Northern region

The northern region study area was approximately 2,300 km^2, which included waters around the Eclipse Archipelago, East Holothuria Reef, Cape Bougainville and Long Reef. Initial observations on habitat types and dominant biota indicated general similarities in the major groups of organisms to the central and southern survey areas. Filter feeding and detritivorous species characterised most of the sessile seabed biodiversity.

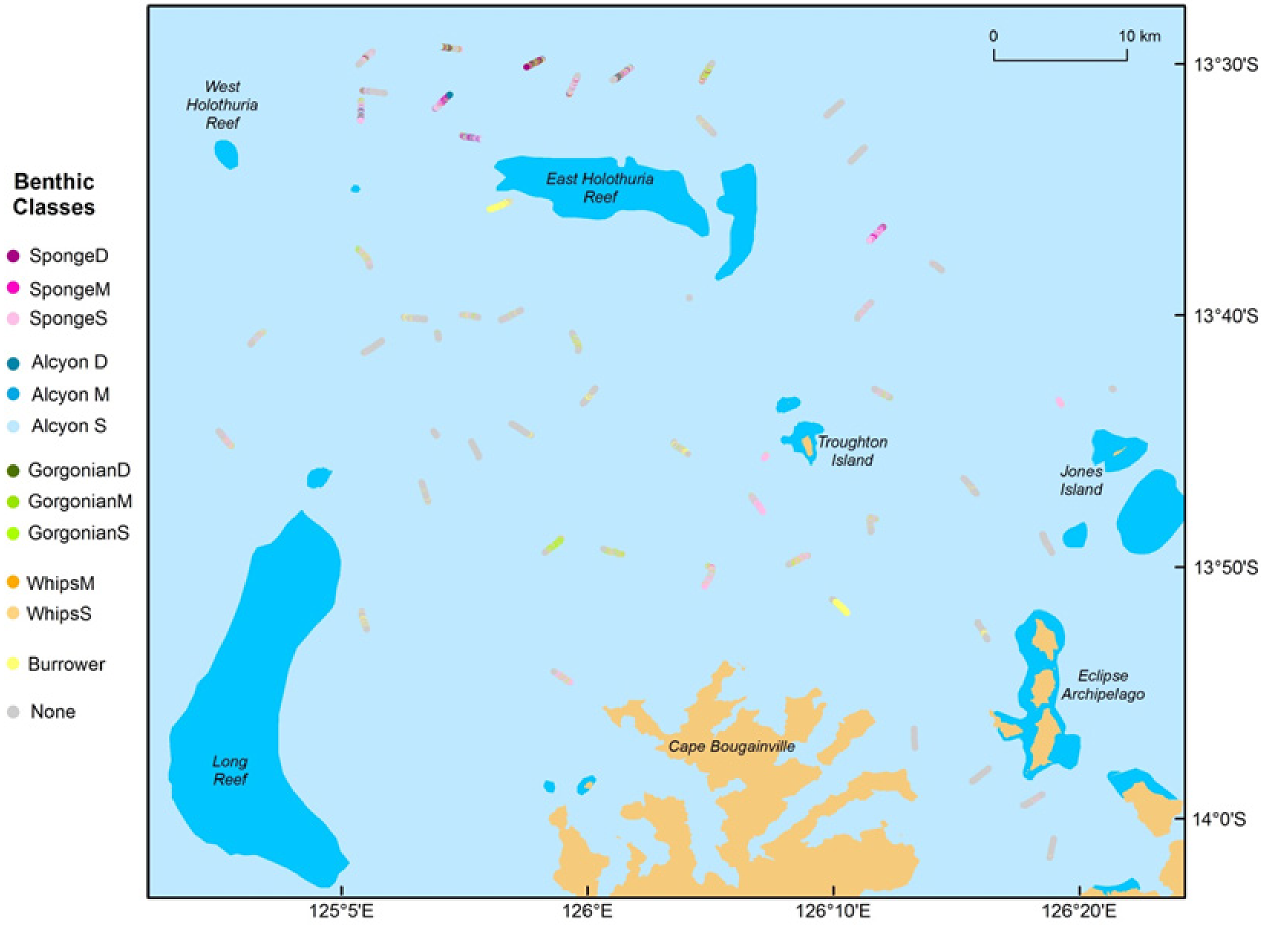

Figure 10. Northern Region - Summary of real-time classification of benthic biota from towed video transects in the Northern Kimberley

Sponges and various echinoderms were the phyla represented by the greatest number of individuals in sled samples collected from all regions, but as in all other region biomass is much greater for sponges than other taxa. In comparison to the central region, echinoids were less common, with crinoids the most abundant echinoderm group.

2.5 Sediment Distributions

A total of 127 locations across the region (see Figure 11) were sampled for seabed surface sediment samples (Southern 69, Central -37, Northern -21). The samples were shipped to Geoscience Australia in Canberra for standard grainsize analysis into mud, sand and gravel fractions. The majority of samples were a mix of sand and mud, with >94% of the samples featuring either of those size fractions as the dominant components. Gravel featured as the major component in only 2-6% of samples.

While varying percentages of sand and mud made up most samples (Figure 11), sediment size fractions for individual stations were found to be highly variable in each of the three regions, with some locations overwhelmingly dominated by particular size fractions. Mud contributed a range from 0.16-98 % at a single location and sand fractions ranged between 3.91-99%, while the coarser gravel fraction contributed between 0-63%.

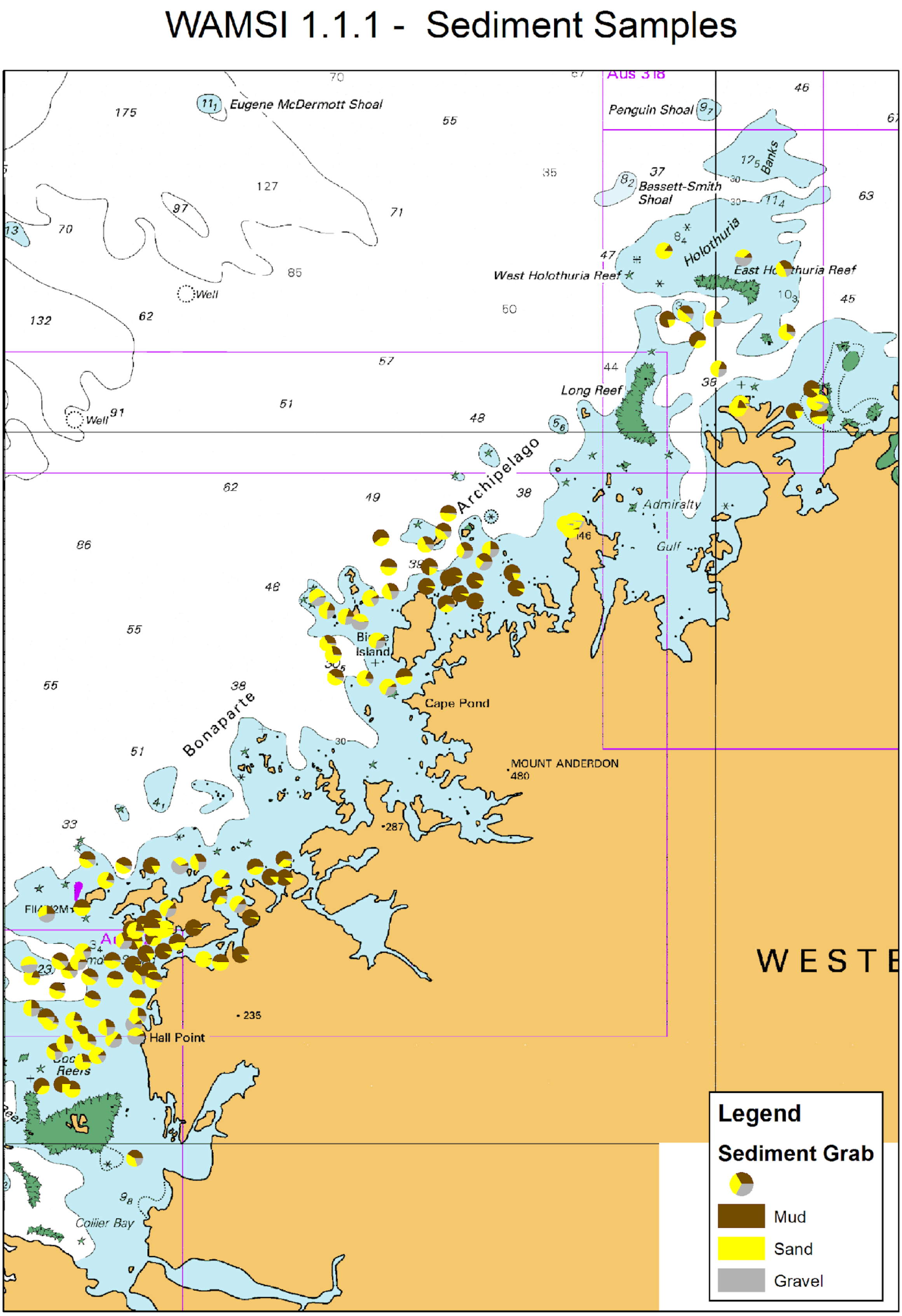

Figure 11. Distribution of sediment size fractions collected across the three regions

3 Comparative analysis of the benthos from high resolution photos (see subreport 1.1.1.2)

The towed video system used for real-time, broad-scale habitat classification incorporated a downward facing camera, which captured more detailed images of the seabed every 8-10m along each survey transect. The images provided an additional type of habitat sampling, at a much reduced scale but higher resolution than the forward facing video used for broad-scale habitat classification. Approximately thirty-nine thousand photos from 212 transects (southern (107), central (57) and northern (48) regions) were analysed. The position and depth of each image was also recorded, providing a useful summary of the depth ranges covered by the towed camera surveys. As shown in Figure 12 all of the surveys covered depths between 15-60m, with a few deeper or shallower transects in some regions.

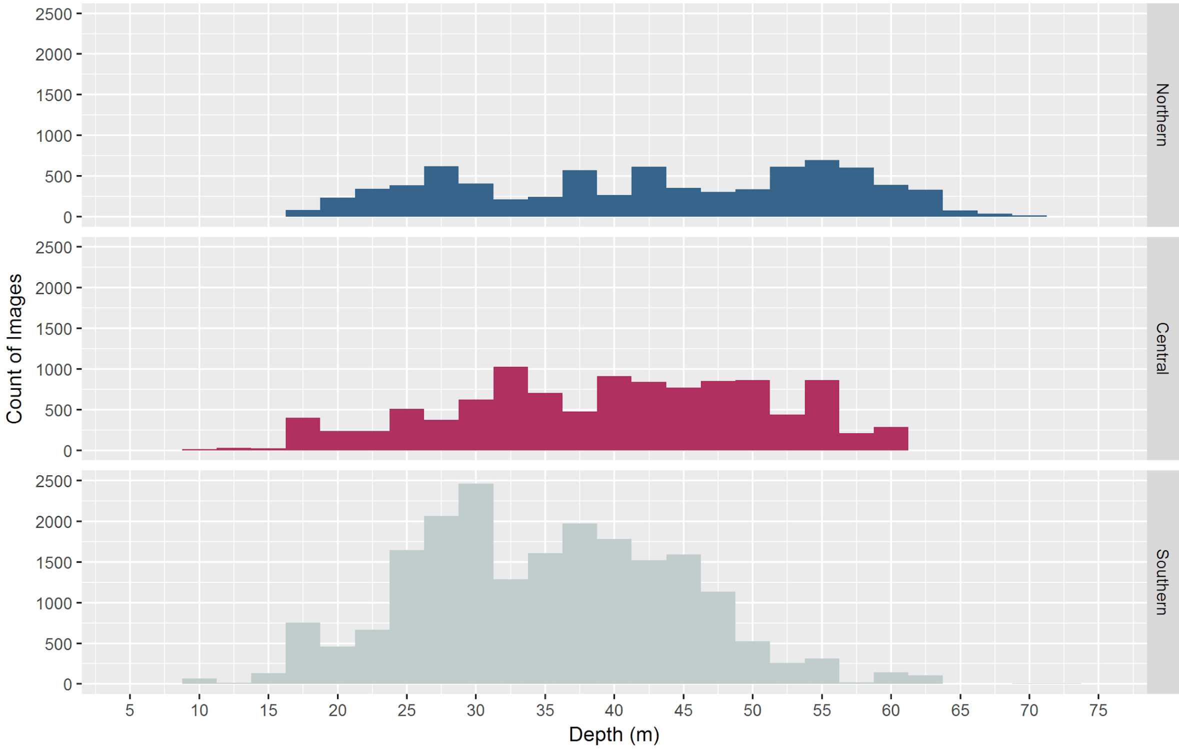

Figure 12. Histogram by region showing the depth distribution of images analysed.

Surveys in all three regions reveal a preponderance of abiotic components (sand, substrate, substrate with turf/coralline algae), representing average cover of 88% across all surveys (Figure 13). Of the 212 transects surveyed, 35 had > 99% cover by abiotic components (5 Northern, 8 Central and 22 Southern) with 10 of these having 100% abiotic cover. The most abundant biotic group was bryozoa which averaged 9.4% cover across surveys. The remaining five biotic groups (sponge, other organisms, soft coral, algae, and hard coral) had very low presence, contributing on average across surveys < 1% cover each. This pattern was consistent across the surveys regions however there was variability at the scale of transects across regions.

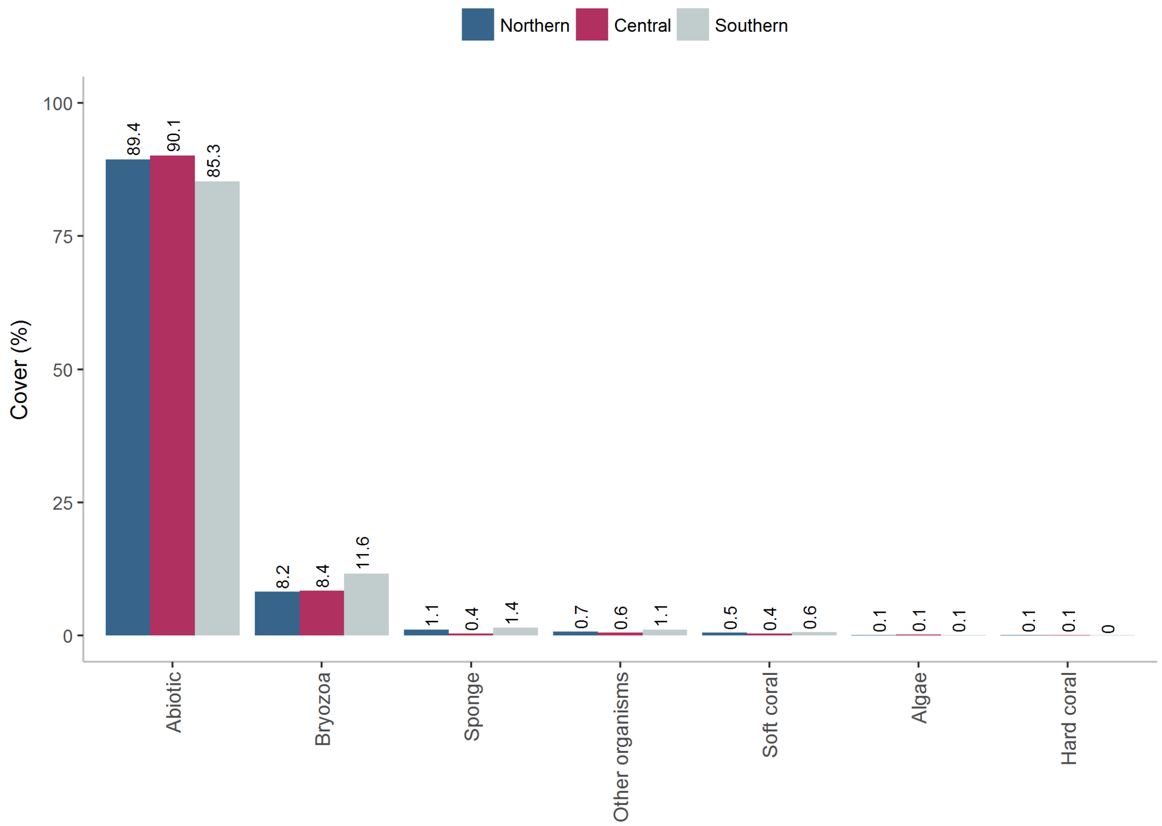

Figure 13. Abundance (% cover) of the seven major benthic categories derived from the still image analysis. Cover of these categories is summarised by region and labelled on the bar plot.

A cluster analysis at the transect level for image derived observations indicated regional differences in the number of distinct habitat types. Eleven biological groups were present in the southern survey region, 9 shared with the central and 8 with the northern region. Across the three regions there were four groups with mean live cover of >10%. The abundance of biota in these groups at the transect scale (1.5 km) was mostly moderate, in the range of 10-30%. While each group was differentiated in the statistical analysis by the presence or absence of minor components, such as algae or coral, the fundamental characteristics shared by habitats with the most abundant biota were either an overwhelming contribution to cover by the bryozoa, with a minor contribution from other taxa, or a more evenly mixed filter feeding habitat with higher benthic cover overall, consisting of a majority of bryozoa but also sponges, soft corals and other organisms. Examples of mixed filter feeder habitats with high mean cover in the range of 40-50% were found in all three regions. Those areas of higher abundance and diversity, which represented 10.4% of all transects, tended to be closer to shorelines or paleo channel edges. While comparable examples were found in all three regions, very high cover transects accounted for only 4.2 and 5.3% of transects in the northern and central survey regions respectively, but 15.9% of transects in the southern survey region. Those were mostly located around the island archipelago at the northern end of Lalang-garram/Camden Sound Marine Park, including North Lalang-garram Marine Park, or adjacent to the coast in the region of Hall Point.

While many small organisms not detected in real-time on the towed video were revealed in the still photos, the more common larger types of sessile biota captured in the images were the same as recorded by towed video and collected by sled sampling. However, the relative abundance, measured as percent cover of the seabed, differed along each transect from data for organism counts and weights from the sled collections (see subreport 1.1.1.2). The most marked difference to the sled sampling results was the estimated abundance of bryozoans as a group. Low lying bryozoan species were widespread and covered more of seabed than other taxa, across all regions. These results need to be treated with caution, given the small sizes of many individuals, together with sometimes suboptimal imagery associated with turbid conditions, present difficulties for identification of bryozoa in the still images, elevating the chance of observer classification error. Hence the category “bryozoan” is likely to include mostly bryozoa and a complex mixture of very small other biota. Nonetheless, mean percent cover the bryozoan category for the northern, central and southern regions ranged from 8.2-11.6%, much greater than the substrate cover of the next most abundant group, which was sponges. This type of disparity in estimated abundance is largely due to growth form, with many of the larger sponges growing vertically, whereas larger bryozoa or mixtures of very small biota and biofilms often spread laterally and hence much more likely to be better represented in fine-scale, percent cover assessments of images taken with a camera oriented perpendicular to the seabed. Both the forward looking towed video classification and the epibenthic sled collection methods tend to more effectively sample the larger habitat-forming species such as sponges. The small size and fragility of bryozoans also predisposes those collected in a sled to fragmentation and loss through the collection net, resulting in a high probability of under-representation of biomass in sled samples.

4 Fine Scale Spatial Models (see subreport 1.1.1.3)

For this project, we used multi-beam sonar data in combination with benthic habitat information to create spatial predictive models of mixed benthic assemblages in each of the three Kimberley regions (see subreport 1.1.1.3). The study areas varied in the range of depths they covered, with Southern including the greatest depth range followed by Northern and Central regions. The mean depth was similar for the Central (41±8 m) and Northern (43±13 m) study areas, while it was slightly shallower for Southern region (33±11 m). Greatly improved bathymetry data for each of the three survey regions e.g. Figure 14, were used to generate maps showing the probable distribution of various mixed benthic habitat classes, which use the broadscale classification structures from the real-time towed video analysis, e.g. Medium Density Sponge, Medium Density Gorgonians (Figure 15). These models also provide a means to estimate the percent area covered by each class of habitat in the survey region (see Figure 15).

The accuracy of the models was tested using a portion of field data from each region. Classification accuracy for the study areas overall was ‘almost perfect’ for Southern and Central and ‘substantial’ for Northern region. Areas of high accuracy were more widespread across the Southern (see Figure 16) than for the Central region, even though their overall classification metrics were very similar. The overall classification accuracy for the Northern study area was notably lower than for either Southern or Central region, and areas of low accuracy were much more widespread spatially than areas of high accuracy. The lower overall classification accuracy at Northern was matched by widespread moderate to low accuracies across that study area. Nonetheless, in general, validation of the benthic habitat models showed they performed well.

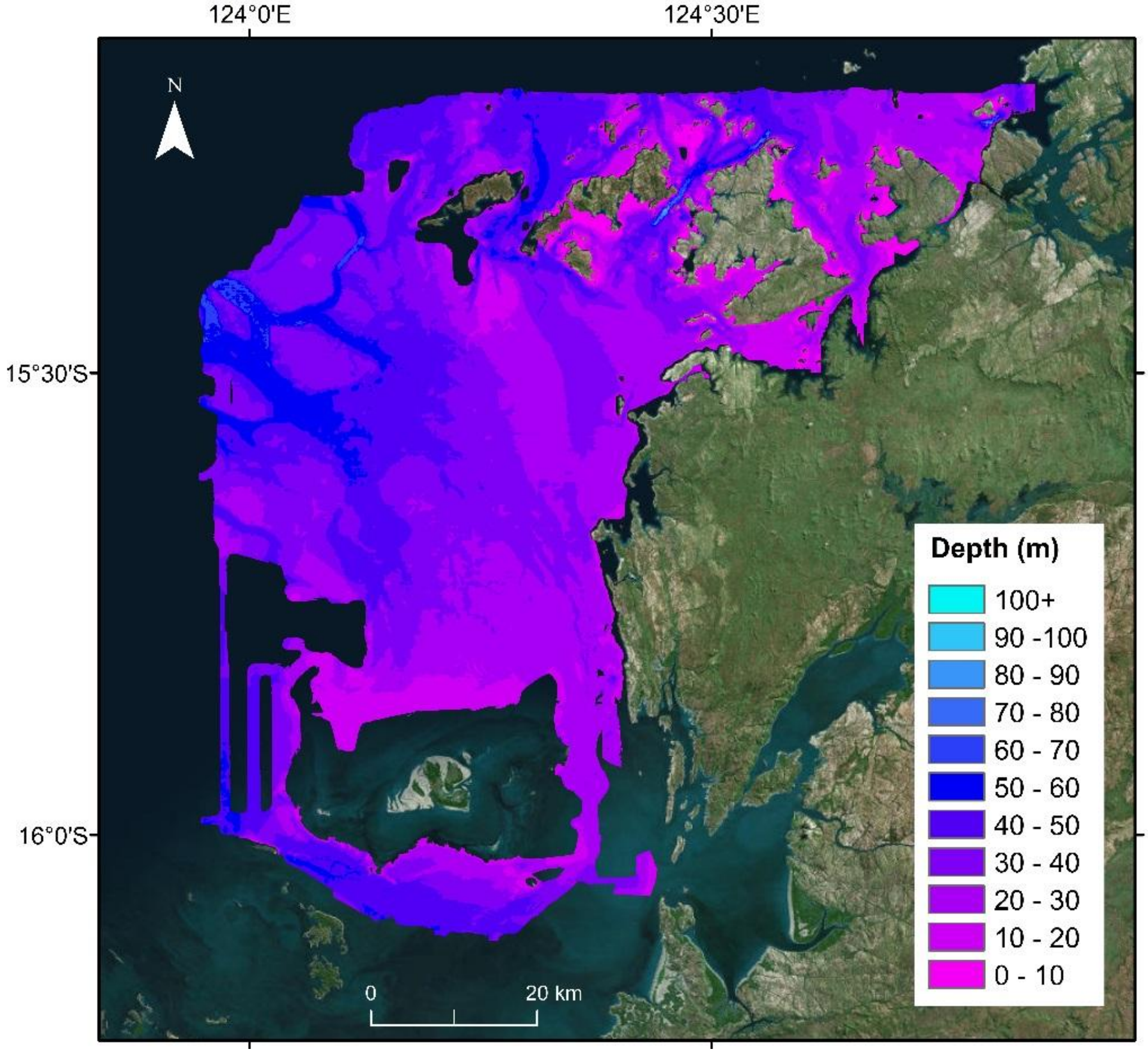

Figure 14: Southern region -Bathymetry at 25m spatial resolution, interpolated from multi-beam sonar data collected as part of this project.

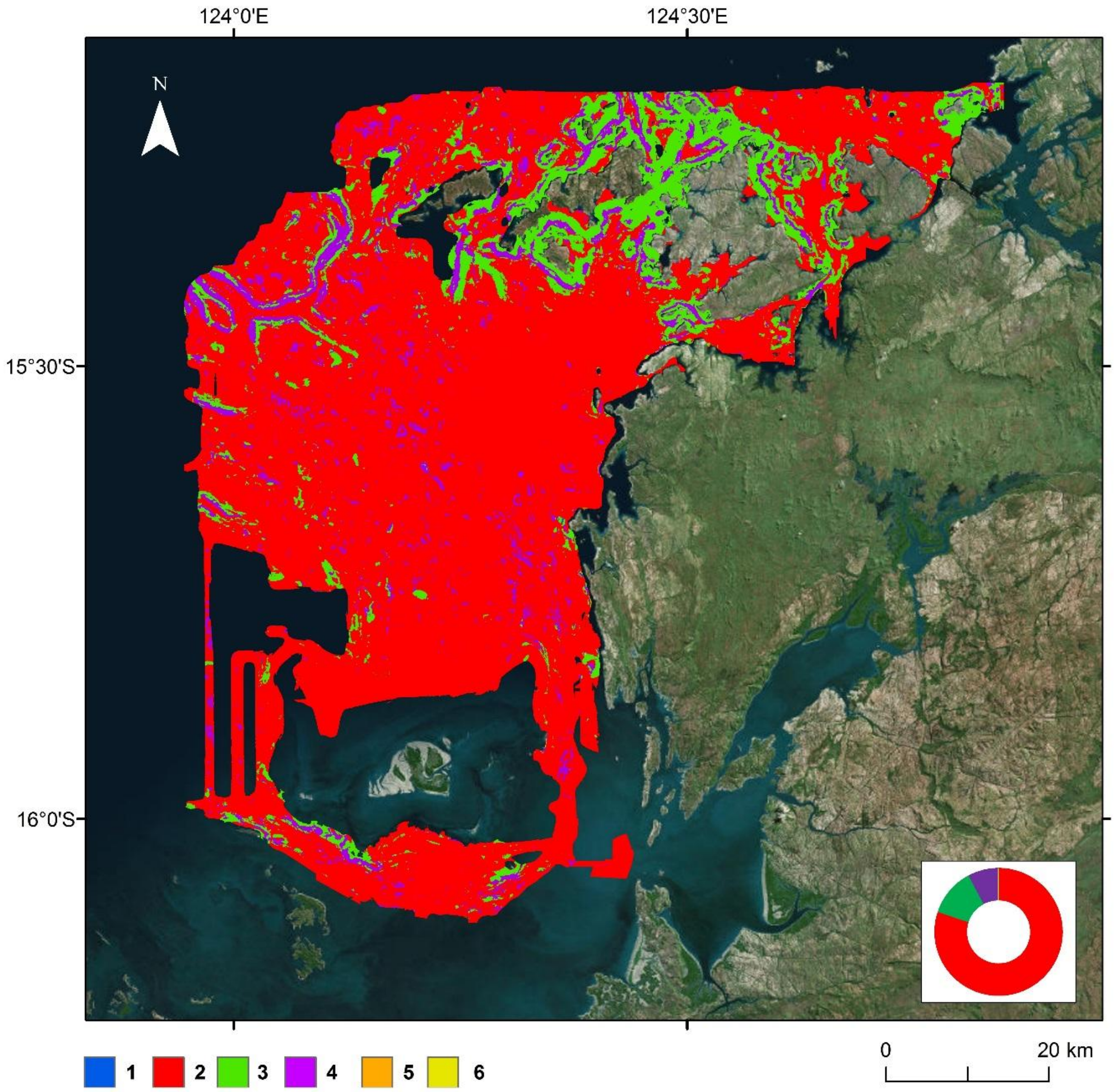

Figure 15: Mixed benthic habitat classification map of the Southern study area (C1). The doughnut diagram shows the % area covered by each mixed class (1 – 0.03%, 2 - 80%, 3 - 12%, 4 - 8%, 5- 0%, 6 – 0.009%). Mixed benthic classes are as follows: 1 – dense Gorgonian, dense Sponge, 2 – Alcyon, Burrowers, Caulerpa, medium/dense Whips, No Benthos, 3 – medium Gorgonian, medium Sponge, 4 – sparse Gorgonian, sparse Sponge, sparse Whips, 5 – dense hard coral, dense Macroalgae, 6 – sparse / medium hard coral, Bryozoans.

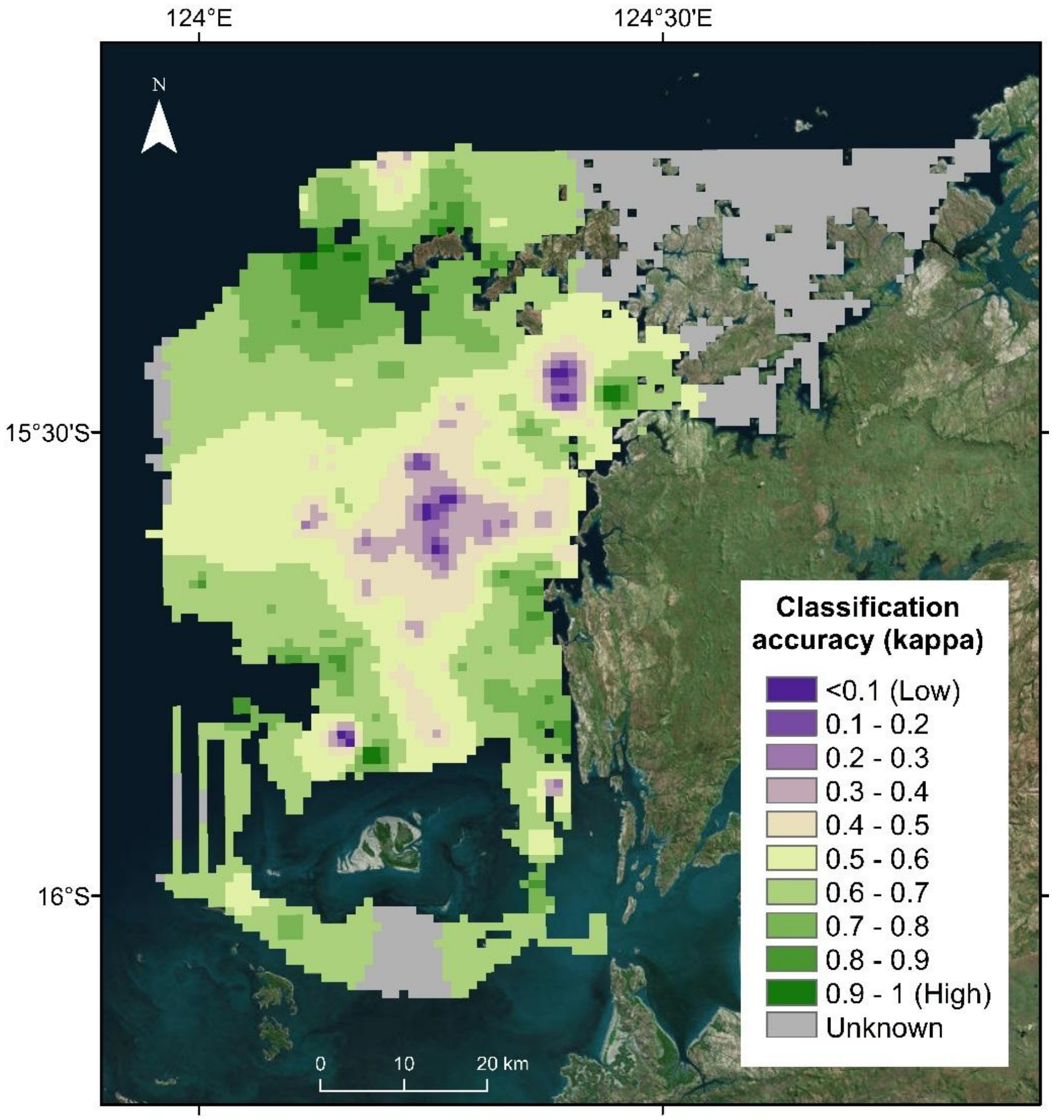

Figure 16: Spatial distribution of classification accuracy (as measured by Cohen's kappa) for the Southern study area (c1). Grey shaded areas were located too distant from sample points to estimate accuracy reliably. Landis and Koch (1977) rate the skill of the classification into five categories: slight (K=0.01-0.20); fair (K = 0.21-0.40); moderate (0.41-0.60); substantial (0.61-0.80); and almost perfect (0.81-.99). On the map, slight to fair performance is shown in purples and moderate to almost perfect performance in greens.

The detailed spatial information that mapping classification accuracy provides can be used for making informed spatial allocation decisions for conservation such as determining the placement of protective zones to ensure an adequate percentage of high biodiversity habitat types are within Sanctuary zones. Ideally, it would be preferable to make use of these local area models to assist in management decisions, such as a spatial zoning and use approach, for areas that were predicted with high rather than low confidence. The maps of classification accuracy enable such decision processes for the first time.

5 Species diversity and distribution (see subreport 1.1.1.4)

Sampling of seabed biodiversity in each of the three survey regions used a towed epibenthic sled. The study has led to a very significant increase in the knowledge of biodiversity of the Kimberley. For many species the northern range of known distribution in WA has been extended and new records for WA and Australia were reported in most taxonomic groups. New species were discovered some of which have been described as a result of this study. Overall, close to 2200 species were identified from the three locations. Sponges, echinoderms, molluscs and crustaceans accounted for 83% of all species identified. Diversity indices were used to measure community structure across depth and substrate type. The highest diversity occurred in deeper >45 m, 40 to 45 m and shallower < 20 m rocky habitat and lowest in mud habitat.

5.1 Overall summary of collections made

Noting that detailed taxonomy was undertaken for most but not all taxonomic groups, the collections can be summarised as follows:

For the Southern region (Camden Sound) 51 sites were sampled yielding 2882 specimens and 808 species for the taxa identified. The most speciose groups were sponges, molluscs and crustacea accounting for 71% of all species identified.

For the Central region (Bonaparte Archipelago) 26 sites were sampled yielding 1939 specimens and 607 species for the taxa identified. The diversity was dominated by sponges, crustacea and echinoderms making up 70% of all species identified. Only about half as many molluscs were found as at Camden Sound.

For the Northern region (Eclipse Archipelago) 26 sites were sampled yielding 2822 specimens and 771 species for the taxa identified. Sponges, echinoderms, molluscs and crustacea accounted for 83% of all species identified.

5.2 Estimates of species richness (see subreports 1.1.1.4 and 1.1.1.5)

The most diverse taxonomic group was sponge, with 426 species collected, compared to the next most speciose groups: crustacea and molluscs (229 and 211 species respectively). Hooper et al. (2002) developed a biodiversity hotspot concept for sponges suggesting that bioregions with >250 species could be considered sponge biodiversity hotspots. If this concept is used for the Kimberley, then the Camden Sound bioregion (272 species and OTUs) would be considered a hotspot. The Eclipse region is also very close to this category (228) but not the Marets region (156). However, sampling effort differed as did the area of these survey regions so they are not directly comparable. By comparison where sampling has been much more intensive using multiple methods e.g. sled, trawl, scuba, over many projects and years three Pilbara IMCRA bioregions were found to be hotspots: Pilbara Offshore, Pilbara Nearshore and Ningaloo with 413, 406 and 331 species & OTUs respectively. Noting the species accumulation curves for total species diversity (Figure 17) and each of the major taxa in each region continue to rise in all three of the survey the regions, it seems highly plausible that Central region around the Bonaparte Archipelago and potentially also the Northern region may also be sponge diversity hotspots.

Diversity varied significantly between sampling stations and regions. Highest diversity was on rocky substrates in > 45 m depths, followed by rocky substrates at < 20 m and 40-45 m depth. Lowest diversity was in muddy substrates in 20-30 m depths, followed by muddy substrates < 20 m and 30-40 m. Rocky substrates > 45 m depth were significantly different to all muddy substrates: < 20 m, 20-30 m and 30-40 m depth

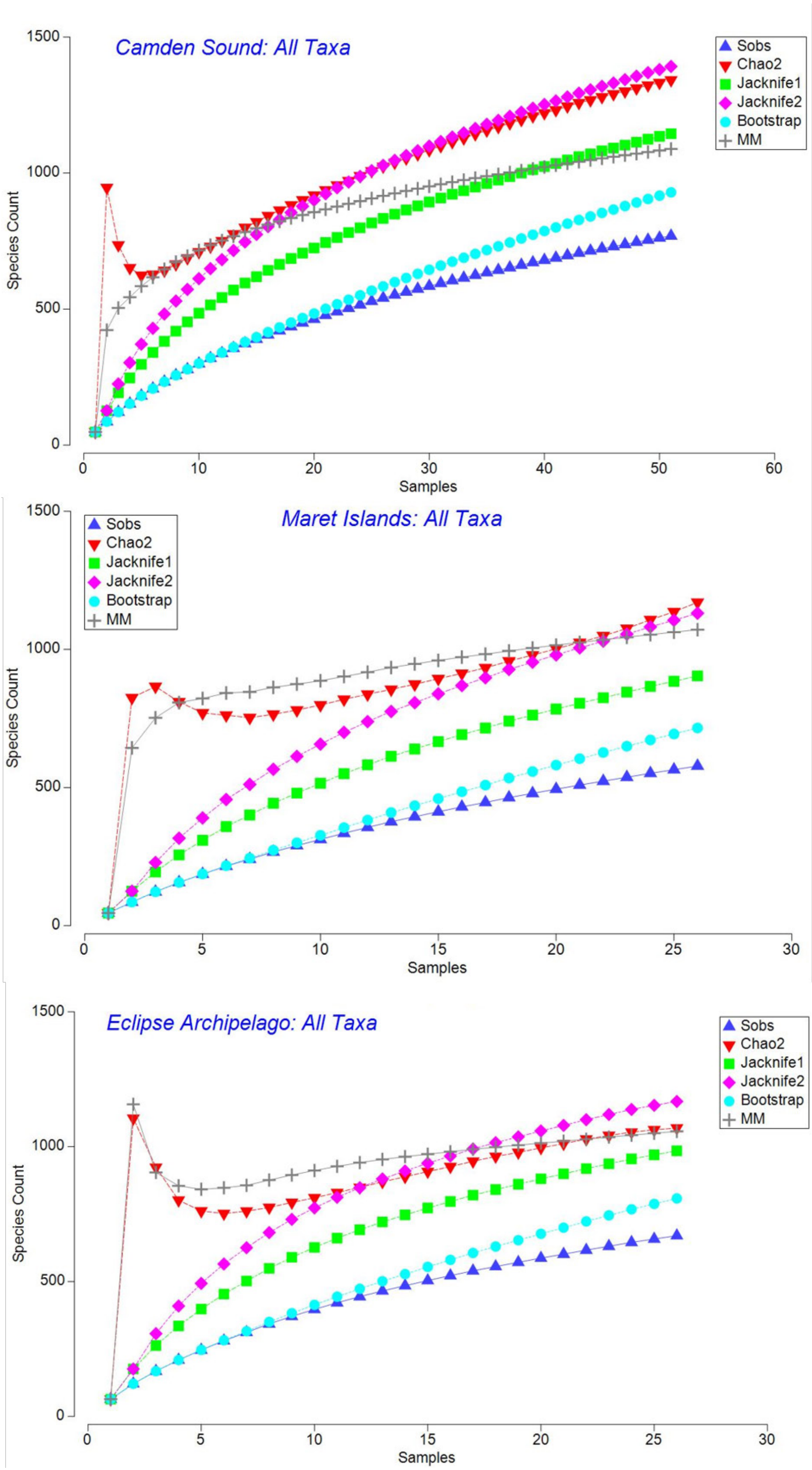

Figure 17. Species accumulation curves for the three survey areas (all species).

The work provides a key input for determining the extent to which the new marine parks provide adequate protection for the habitat of these species. Despite the increased knowledge of marine biodiversity in the Kimberley, as a result of this study, it is evident from the sampling undertaken, that varying amounts of latent diversity remains to be described for most groups and the collections of a number of mobile and habitat forming taxa remain unidentified because of a lack of available expertise for these groups. These include worms, bryozoa, hydroids and ascidians. The study did not use methods able to adequately sample fish fauna, so this remains a gap. The study also largely neglected nearshore shallow (<10m) soft bottom habitats and this also remains an important knowledge gap.

6 Species assemblages, biomass and regional habitat characterisation (see subreport 1.1.1.5)

The objectives of this component of the study were to determine the compositional patterns of biodiversity in the broader region, how these patterns were related to environmental gradients, and to predict and map their spatial distribution and extent. This included identifying for management purposes, a useful number of discrete or sufficiently different habitat/species assemblages that occur in the region.

Analysis of tow video and epibenthic sled collections matched to wide set of environmental data at three locations in the Kimberley identified nine habitat/species assemblages that provide broad spatial characterisation of the region. There was a deeper offshore assemblage that ran the entire along shelf range of the three regions surveyed and then a series of inshore and intermediate assemblages which, broadly speaking comprised a northern set and a southern set. There is some overlap, but the transition zone between the northern and southern sets is at about 14°45’S (Lamark Island and Augereau Island). In general, the offshore habitats were mostly unconsolidated sediment and were characterised by moderate diversity and low biomass while the intermediate and some inshore assemblages had a higher proportion of hard substrate, which in some cases had high biomass and a highly diverse invertebrate fauna including of habitat forming sessile invertebrates, mostly sponges and octocorals. All but one of the assemblages had greater than 50% of coverage of mostly unconsolidated sediment habitats with no habitat forming or defining biota. Conversely one of the nine assemblages had the highest coverage of habitat dominated by sponges and octocorals. Seagrasses, macroalgae and hard corals were not a dominant feature of any of the nine assemblages.

There was poor agreement between the abundance of habitat forming filter feeders collected in the sleds and the criteria used to partition habitats within survey locations, based primarily on bathymetry and the relative abundance of habitat forming filter feeder taxa assessed by towed video. The result probably reflects the differing scales of the two methods (sleds 50-100m length, towed video transects 1500m) and the patchiness of the habitats. These results reinforce the importance of using as wide a range of biological, physical and environmental attributes when seeking to spatially segregate the marine environment over large, sparsely sampled domains.

The nine assemblage types identified provide the basis for considering whether the current marine park boundaries and their zoning provide adequate protection. Between 78.5% and 100% of the nine assemblages overlaps with state MPAs or commonwealth CMRs, mostly in IUCN category IV, however less than 20% of six assemblages are within IUCN category II zones.

6.1 Animal and plant biomass

The range of biomass among sleds was similar between locations with sponges dominating the benthic biomass in all regions (Figures 18 & 20) Some sleds had high biomass of cnidarians, especially around the Central and the Northern survey regions. Echinoderm biomass was high in the nearshore sleds at all three regions. Sediment data derived from the towed video (Figure 19) could be related to that collected by grab but also provided additional information on rocky seabed areas where the grab would generally be ineffective (Figure 11 c.f. Figure 19)

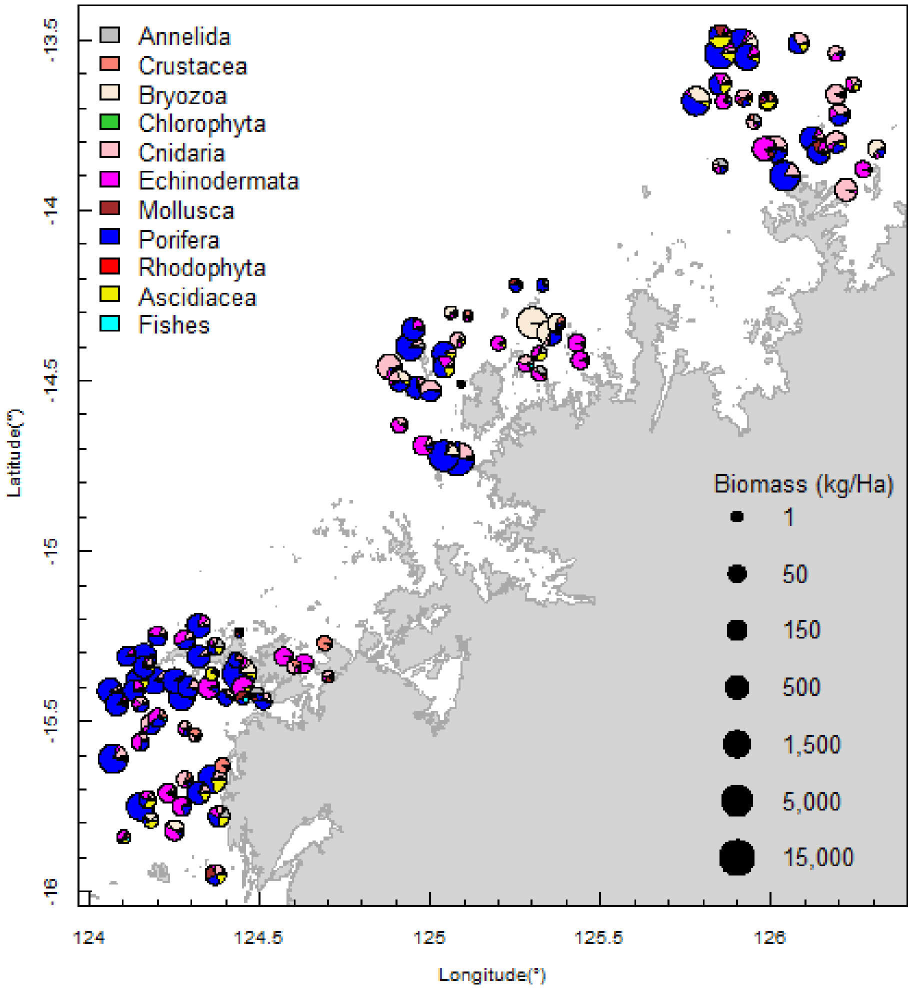

Figure 18. Map of the distribution of biomass of key taxa from epibenthic sled tows undertaken across the three study locations

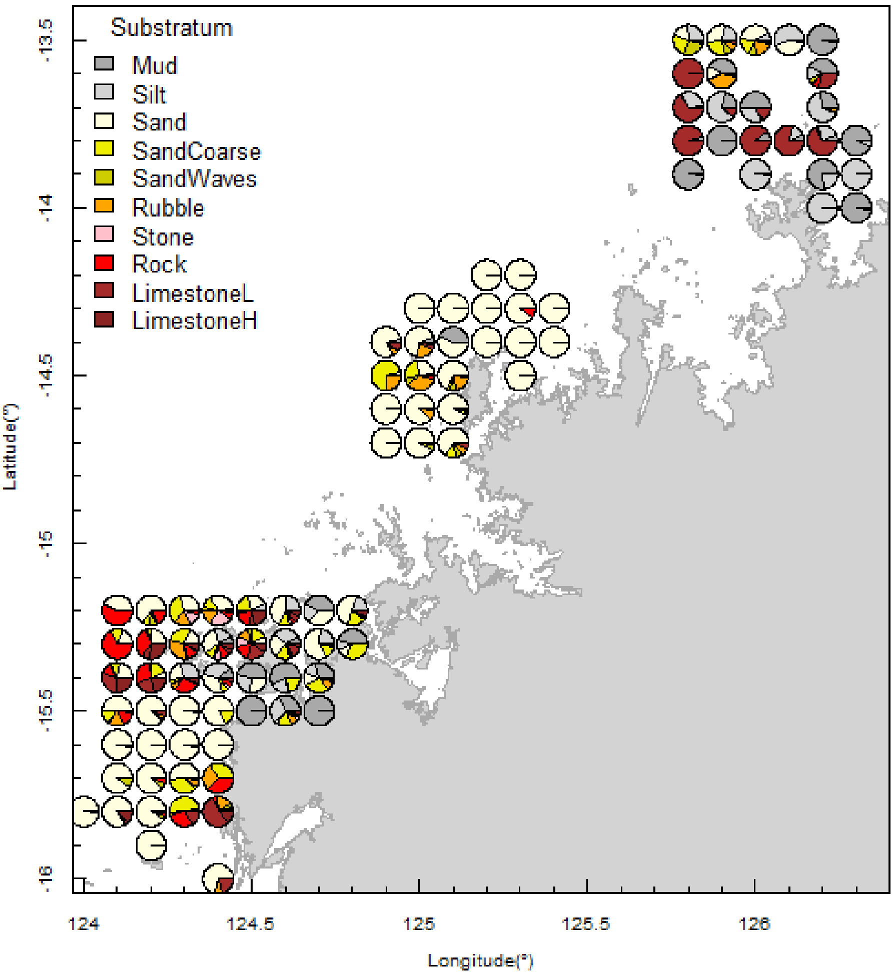

Figure 19. Map of the distribution of substrate types from tow video analysis across the three study locations. Note: for presentation purposes only the data from the tow-video locations have been aggregated to 0.1°

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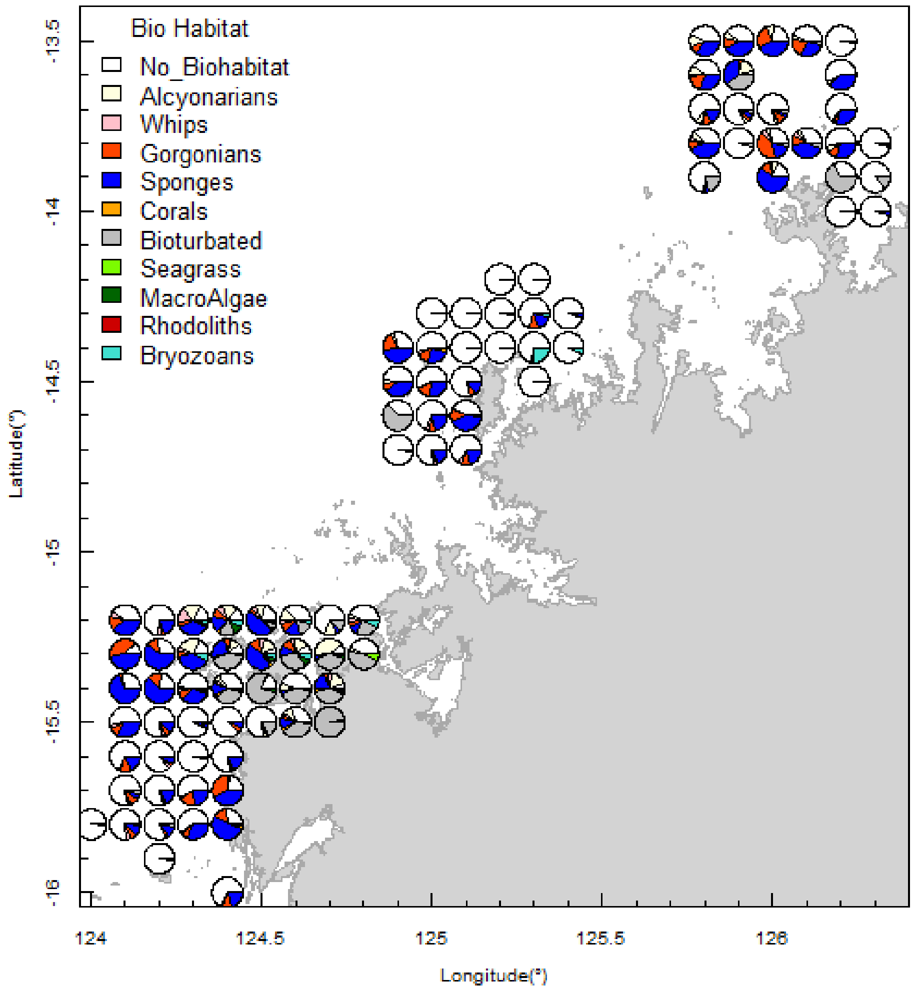

Figure 20. Map of the distribution of habitat forming benthos from tow video analysis across the three study locations. Note: for presentation purposes only the data from the tow-video locations have been aggregated to 0.1°.

A visual characterisation of the continuous regional scale biophysical patterns, based on the sled and tow video data from the three survey areas and an extensive spatial dataset of environmental variables, revealed some clear onshore/offshore patterns of biodiversity composition for the region as well as an along-shelf gradient in the inshore and intermediate areas. The representation of these assemblages in State Marine Protected Areas (MPAs) and Commonwealth Marine Reserves (CMRs) is shown in Figure 21 below), by IUCN category. Overall, 100% of each of the nine assemblages overlaps with the combination of state MPAs and commonwealth CMRs, mostly in general-use zones (IUCN category VI); however; 8 -13% of assemblages 1, 2, 3, and 9 are within more highly protected sanctuary zones (IUCN category II). The remainder are in various special purpose use zones, most of which provide habitat protection (IUCN IV).

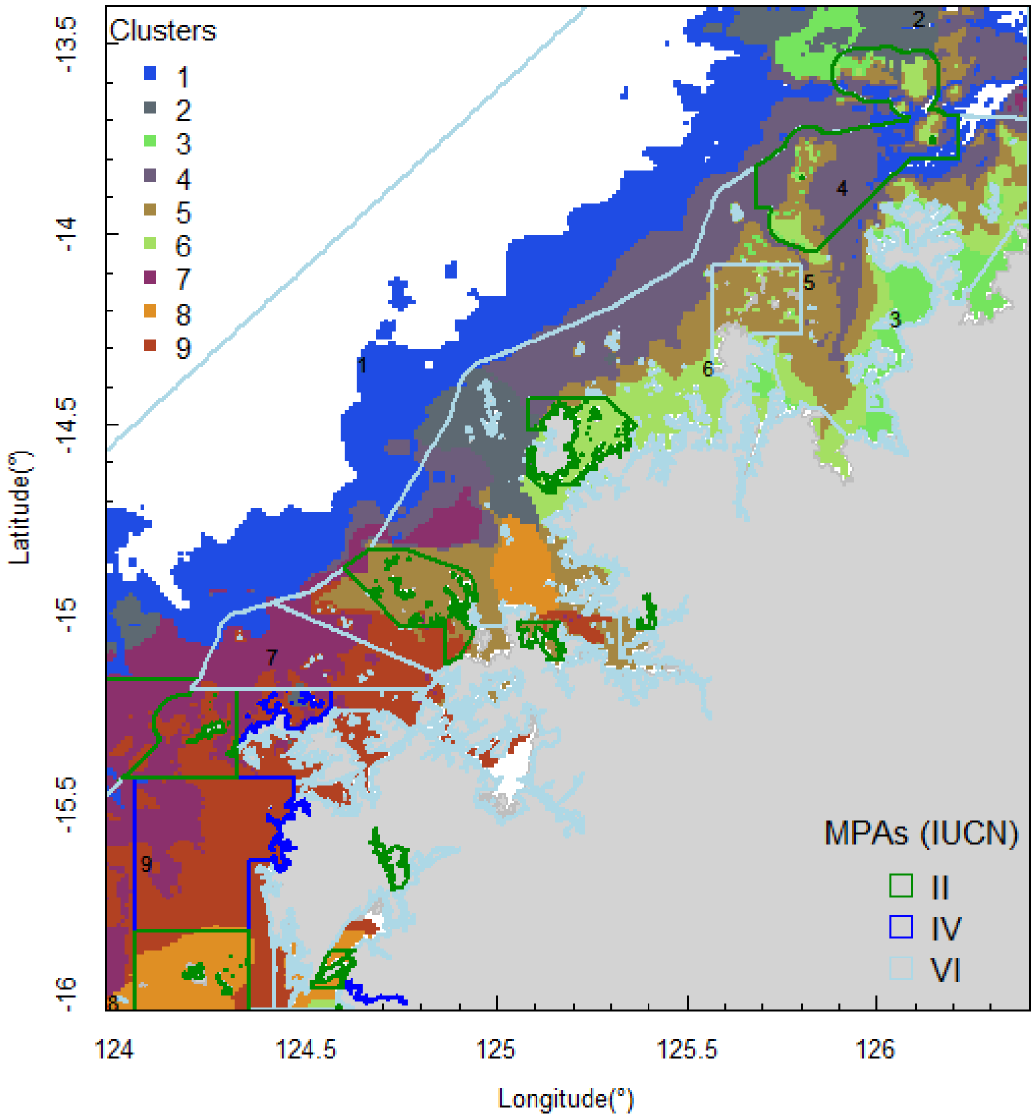

Figure 21. Map of the seabed characterisation of the Kimberley region into nine assemblage types. The location of Marine Protected areas and their IUCN classification is overlayed for reference. See subreport 1.1.1.5 for detail on assemblage composition.

7 Prediction of species distributions (see subreport 1.1.1.6)

Analysis of species data from epibenthic sled samples and habitat morphotypes from tow video, against a suite of environmental variables, at three locations in the Kimberley provided broader regional distribution maps for 160 species and 21 habitat components. Individual species exhibited a wide variety of distribution patterns: e.g. inshore, offshore, northern, southern, wide-spread or localised and patchy. These data provide a synopsis of the current ecological condition of the region, and also strengthen understanding of linkages between ecological attributes and the environmental processes that affect them.

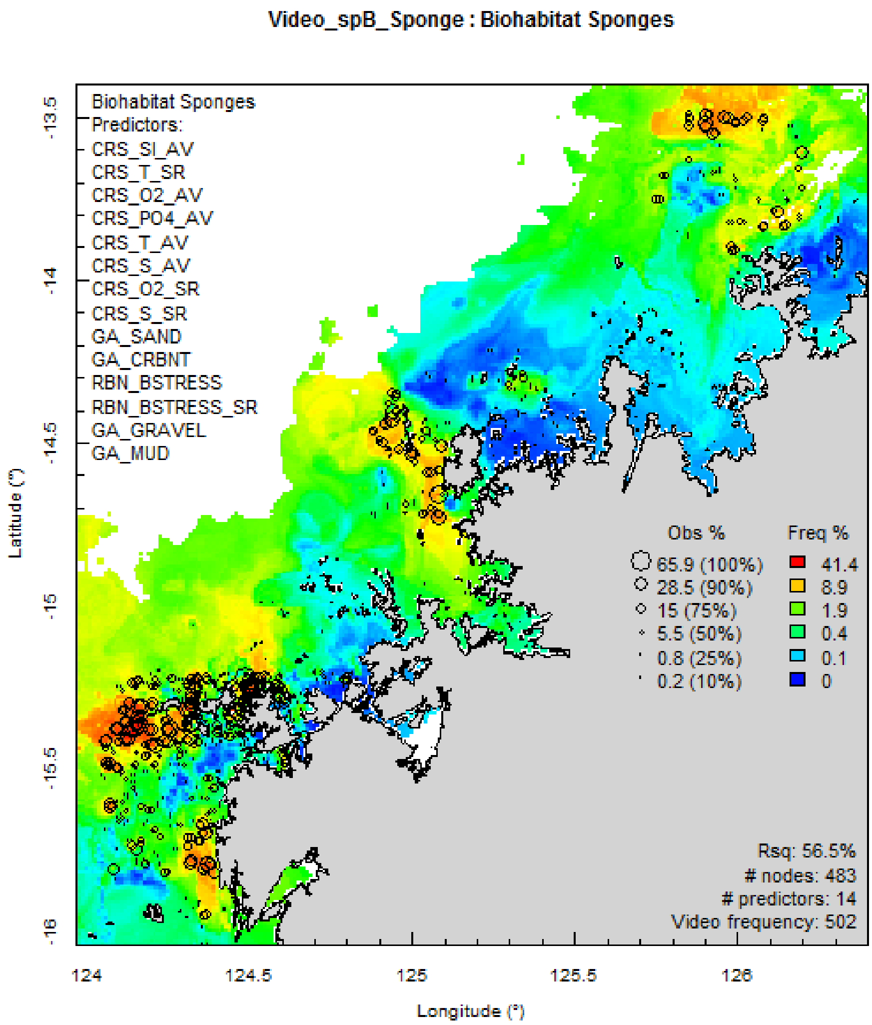

Figure 22. Predicted distribution of sponges throughout the study region based on video transects.

There are predicted distributions given for 50 species/taxa of sponges shown in Figure 22 with *Axinella* sp. having the highest level of predictability (R square = 42%). This species had a markedly shallow, northerly distribution and predictors included bathymetry and temperature. Other species also show quite heterogeneous distributions with strong spatial patterns or concentrated distributions. A number of species including *Stelletta* sp., *Raspalia australensis* and *Pseudoceratina* sp. have a predominantly offshore distribution while *Stelletta* sp SS11 has a more southern distribution. *Arcarnus thielei* and *Axinella aruensis* have distributions mostly centred on the area between Bigge Island and the Coronation Islands.

The outputs from this study can be used to support a range of spatial planning, monitoring, assessment and management applications across the region, including for conservation, assessments of current uses, and provide a foundation for evaluating future proposed activities or developments — or the potential consequences of global drivers such as climate change — thus providing lasting benefits. The outputs will also enable spatial analyses of the overlap of human uses with multiple levels of biodiversity, permitting ecological risk assessments and, for some types of uses, fully quantitative assessments of their sustainability.

8 Species – Habitat Associations (see subreport 1.1.1.7)

The aim of this analysis was to describe species distribution patterns and to seek to explain them on the basis of environmental drivers, principally habitat type and factors such as depth and substrate type which shape habitats. We examined differences in marine benthic communities between three study regions (Camden Sound; Bonaparte

Archipelago and the Eclipse Archipelago) using data collected from a towed epibenthic sled. There was no significant latitudinal trend or differences with depth among benthic assemblages (across a relatively narrow depth range, ~30 m). However, there was a significant difference among Southern and Central assemblages from mud and rocky substrates and a significant interaction between depth and substrate, indicating an inconsistent response by species to these factors. Species richness in shallow stations was lower than in deeper stations. The shallow stations were also more variable than deeper stations and mud stations were more variable than rocky stations.

The analysis of species distributions broadly confirmed the validity of the nine spatial habitat/species assemblages identified and mapped in 1.1.1.5. Clustering of the 50 most abundant taxa at each location identified groups of species that co-varied among substrate and depth stations. In Camden Sound 19 coherent species groups were identified, eight in the Maret Islands and 12 in the Eclipse Archipelago. Each group of species tended to occur only at a limited subset of stations although some species or group of species were more station specific than others. A combination of depth and substrate type explained the separation of species clusters. The surveys confirmed the expected correlation between reef habitats and species richness indicating that hard substrate and habitat complexity are important determinants of diversity. The large number of species assemblage groupings within each of the three regions suggests that species are patchily distributed and is consistent with the species accumulation curves (see Figure 17), indicating the surveys probably under-sampled the diversity of species and species assemblages. This reinforces the need for large spatial scale protection measures such as the marine parks and reserves that have been established in the Kimberley. Better knowledge of the relationships between habitat forming sessile invertebrates and mobile animals remains a gap in the Kimberley and closing it would lead to an improved understanding of the patterns found in this study.

9 Shallow coral habitat distributions (see subreport1.1.1.8)

Two additional surveys were conducted from RV Solander (e.g. Figure 23), in collaboration with Wunambal Gaambera and Dambimangari sea rangers, to assess very nearshore fringing reef and rocky shoreline habitats inshore of the deeper water expeditions. The shallow water surveys, in 1-15m water depths, were accessed using small auxiliary vessels and sampled using drop cameras. It is clear from the Project’s surveys, in combination with the results of recent work by the WA Museum (see subreport 1.1.1.8, Appendix 4) and ongoing drop camera assessments along the coast by DBCA, that Scleractinian corals feature as a component of shallow benthic habitats throughout the Kimberley.

Figure 23. Map showing fringing reef sampling locations during and RV Solander cruise in collaboration with Wunambal Gaambera rangers

Coral reef habitats with dense live coral cover, some with species diversity equivalent to well recognised offshore coral reef ecosystems, have been observed in southern, central and northern locations across the region and have been best documented around outer coastal islands (see Figures 24, 25). While the Bonaparte Archipelago in the central region remains the location of maximum documented species diversity, historical records indicate locations of moderate to high diversity can also occur to the north and south as well as very near the mainland. Consequently, it is reasonable to infer that coral habitats with moderate to high diversity exist throughout the region in WA coastal waters. While a number of larger coral reef type platforms are known, the presence of smaller patches of reef or coral-dominated habitat on rocky substrate is pervasive and may represent the majority of coral habitat in the region.

The surveys made during this Project suggest that corals are likely to be present on much of that rocky shoreline which is prevalent along the Kimberley coast, if the elevation in relation to tidal heights is appropriate. The observations made from the Eclipse Archipelago to Camden Sound indicate that mid- and upper reef flat coral abundance is frequently <5-10%, with macroalgae the major habitat component. Both abundance and diversity rise when the corals are less exposed further seaward, but also including intertidal ponds and rock pools at all elevations, However the outer reef flat and crest region provide large and more continuous areas of substrate that support the highest levels of diversity and coral cover. Observations on tidal exposure of the coral dominated habitats indicate that in many locations this rich coral zone tends to commence on the seaward margins where the substrate lies lower than 1m below LAT, with reef crest habitats at 0.6m LAT or lower often characterised by high coral abundance and diversity.

Figure 24. Exposed *Acropora* dominated coral community at Beagle Island in the southern region of the Project study area. Predicted tidal height at nearby Adele Island was approximately 0.3m.

Figure 25. Wildcat Reef exposed domal coral habitat during the southern survey. Image taken during a morning low tide when the predicted tidal height at nearby Degerando island (Port 62930, Hydrographic Service RAN) was 0.9m.

The results of this and other recent complementary studies confirm the Kimberley coastal region as a significant coral province. A narrow band of coral exists on many of the intertidal and subtidal rocky shore areas, even along mainland shores, however the areal extent of coral habitat remains uncertain. The width of those coastal fringing habitats could be hundreds of meters, but habitat where coral cover exceeded 10-15%, was measured in this study to vary from 10m to 200m e.g. Figure 26. This would suggest that, even if several thousand kilometres of rocky shore supports a dense lower intertidal and subtidal coral habitat, it may be a narrow or a diffuse element whose extent totals a few hundred square kilometres.

Very high coral diversity was observed at a few locations within the outer reef flat zone and from the reef crest to several meters below LAT. However, the coral dominated habitat on the inshore fringing reef and rocky shelf areas surveyed in the current project did not extend beyond 10-15m depths, due to the absence of hard substrate at the base of the reef drop offs and perhaps less favourable environmental parameters, including the marked attenuation of surface sunlight.

Scleractinian corals were occasionally recorded to 30m during the offshore towed video surveys, but were generally absent or contributed <1% to the biota in habitats deeper than 10-15m below LAT. This suggests that management of benthic primary producers in the coastal waters of the Kimberley should focus on intertidal and subtidal waters <15m deep. An indicative distribution of these habitats, based on mapping the likely 15m depth contour, is shown in Figure 27. The observation that major coral habitats are likely to be exposed at tidal heights between 0.6-1.0m, suggests that such areas would be detectable by remote sensing at tide height which occur reasonably often. With the increasing frequency and spatial resolution of satellite, it will be increasingly possible to map the major coral areas, or at least identify their shallower edges, from space. Given the scale of the Kimberley and expense of ship based surveys, a remote sensing approach has great promise for detection of the most extensive coral habitats, which may take priority for conservation measures in the future.

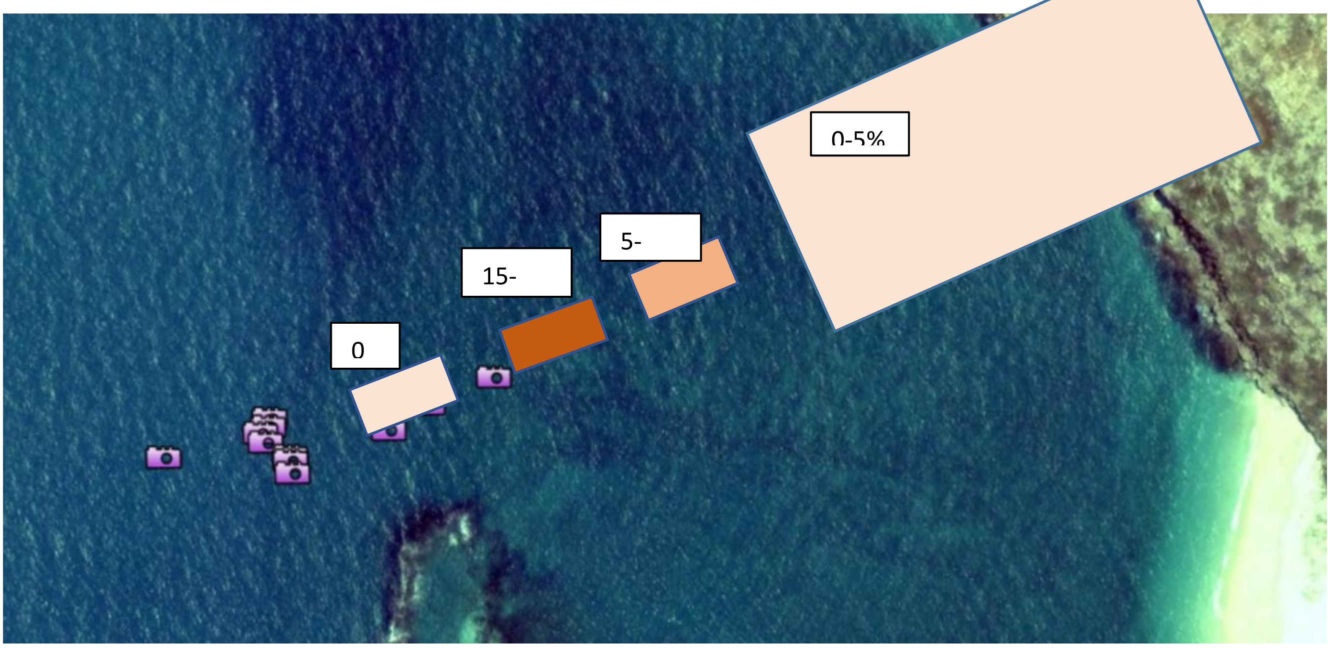

Figure 26: Cape Voltaire area, Transect example- relative hard coral cover along drop camera transect from the shore to fringing reef edge drop off area, overlaid on a Google Earth satellite image. Warmer colours along the transect reflect zones of higher coral cover.

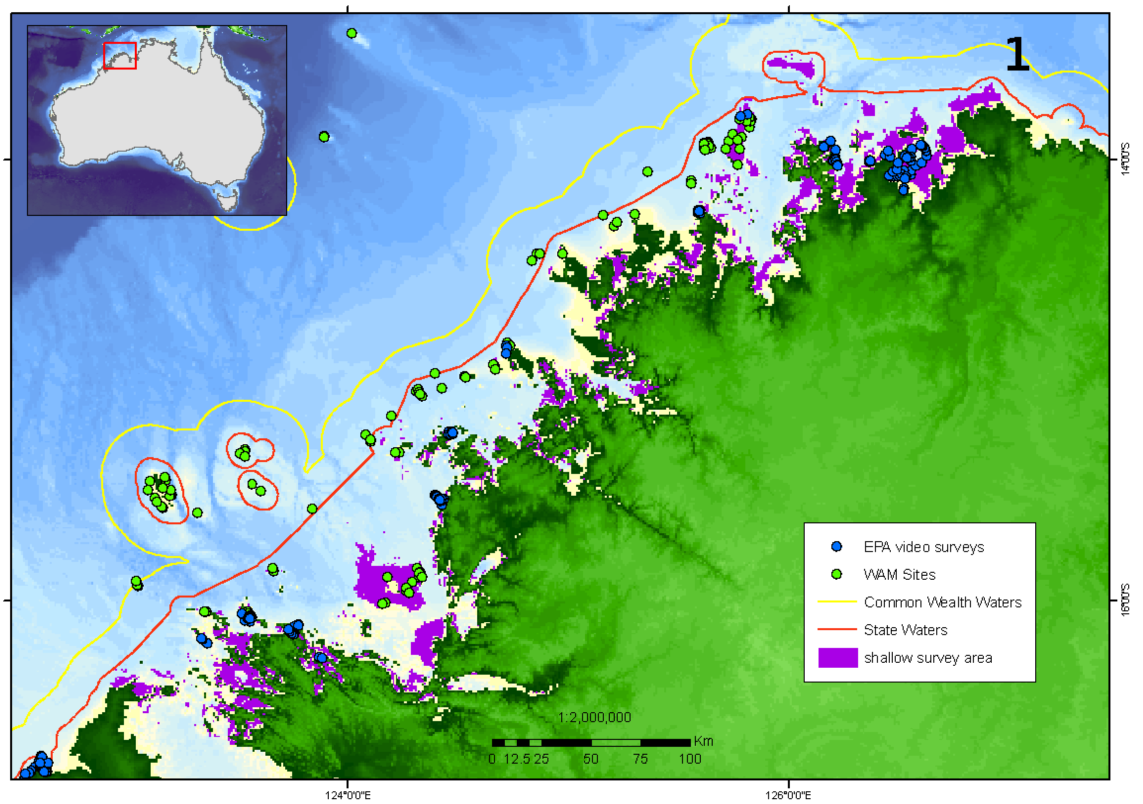

Figure 27. Map of coastal waters along the Kimberley, with shallow water areas most likely to support benthic primary producers, including hard corals, shown in purple.

As a general rule, large areal extent of coral habitat was not apparent as a preeminent environmental value of the Kimberley reef systems. Rather, the key feature of inshore coral habitats there is the occurrence in a broad variety of sometimes unusual and largely undisturbed environmental settings, in addition to the more typical coral-reef like habitats observed on larger reef platforms around the coastal islands.

When considering representative examples of coral habitat within the proposed Greater Kimberley Marine Park area, it is clear that corals will be part of almost any spatial planning area selected for management and conservation. However, there are regional and local differences in abundance and diversity, influenced by depth, underlying geomorphology, exposure to currents and waves and so forth. The WA Museum reported distinct inshore-offshore, intertidal-subtidal and subregional patterns of community structure in their study of coastal islands and inshore reefs. Taken together these studies suggest conservation of areas that include inshore-offshore gradients, such as archipelagos, with a variety of environmental settings, such as sheltered and exposed shorelines, should be effective in ensuring a representative sample of coral habitats and species, as well as genetic diversity between sites within the area. The recently declared North Lalang-garram Marine Park is one good example likely to meet those needs

Nonetheless, additional marine park areas are likely to be needed at more local scales within the Greater Kimberley Marine Park. While many of the Kimberley coral species are widely distributed and form a subset of the broader Indo-Pacific coral taxa, genetic evidence from the recent WAMSI connectivity project (Berry et al, 2017) indicated corals typically exhibited localised population structure, with evidence for limitations to routine dispersal on scales of 10s of kilometres or less. Consequently, they suggest conservation would be most effective with protected areas of similar scale large (10–20 km). They also found evidence that King Sound, subject to strong tidal flows and seasonal salinity effects, could be a barrier to dispersal. While the presence of coral habitat on islands and submerged reefs is likely to provided important stepping stones for dispersal across this barrier over multiple generations. this finding raises the question of whether other large sounds within the Greater Kimberley Marine Park, such as Prince Regent Sound, may form additional dispersal barriers. Conversely it is uncertain if the widespread occurrence of coral populations along rocky shorelines provides a mechanism to overcome them within ecological time scales. Answering that question will help demarcate functional coral habitat provinces of the Kimberley coast and aid in locating additional areas for protection.

10 References

Berry O, Underwood J, McMahon K, Travers M, Richards Z, Moore G, Hernawan U, DiBattista J, Evans R, Gilmour J (2017) Ecological Connectivity of Kimberley Marine Communities. Executive Summary Report of Project 1.1.3 prepared for the Kimberley Marine Research Program, Western Australian Marine Science Institution, Perth, Western Australia, 17pp.

Collins LB, Stevens A, O'Leary M, Bufarale G, Kordi M Solihuddin T. (2015). Reef Growth and Maintenance. Final Report of Project 1.3.1 of the Kimberley Marine Research Program Node of the Western Australian Marine Science Institution, WAMSI, Perth, Western Australia, 246pp.

Fearns, P., Greenwood, J., Chedzey, H., Dorji, P., Broomhall, M., King, E., Cherukuru, N., Hardman-Mountford, N., Antoine, D., (2017) Remote Sensing for Environmental Monitoring and Management in the Kimberley. Final Report of Project 1.4. Prepared for the Kimberley Marine Research Program, Western Australian Marine Science Institution, Perth, Western Australia, 89 pp.

Kendrick GA, Vanderklift M, Bearham D, Mclaughlin J, Greenwood J, Säwström C, Laverock B, Chovrelat L, Zavala-Perez A, De Wever L, Trapon M, Grol M, Guilbault E, Oades D, McCarthy P, George K, Sampi T, George D, Sampi C, Edgar Z, Dougal K, Howard A (2016) Benthic primary productivity: production and herbivory of seagrasses, macroalgae and microalgae. Report of 2.2.4 prepared for the Kimberley Marine Research Program, Western Australian Marine Science Institution, Perth, Western Australia, 61 pp.

Keesing, J.K. (2014) Marine biodiversity and ecosystem function in the King George River region of north-western Australia. Unpublished report to the Total Corporate Foundation. 141 pages. CSIRO, Australia.

Moilanen, A. and Kujala, H., 2014. Zonation spatial conservation planning framework and software v. 4.0, User Manual. Helsinki, Finland: University of Helsinki.

Wilson B (2013). The biogeography of the Australian north west shelf: environmental change and life's response. First edition. Elsevier, Sydney. 425p.

11 Appendices

Appendix 1. Management questions

This project directly addresses the following questions outlined in the Kimberley Marine Research Program Science Plan.

Key Question

Informed Response

1. What is the distribution, extent, species composition, condition and conservation significance of the major benthic marine habitats (e.g. beaches, coral reefs, filter-feeders, etc)? Where are the marine biodiversity 'hotspots'?

Highest diversity was on rocky substrates in a range of depths.

Fine scale spatial models enabled the extent some key habitat types to be determined.

2. What environmental factors are 'driving' the above distribution patterns? (What controls where communities live and can we predict their distribution based on the drivers?)

Important variables for sled richness included: sediments, nutrients, bottom temperature, turbidity, productivity, sea surface temperature

3. Which habitats have significant conservation value and how are they distributed?

High diversity filter feeding habitat on rocky subtidal areas. A number of separate assemblages were identified at various scales. Some of the assemblages identified are outside current MPA sanctuary zones.

Nine benthic assemblage types identified provide the basis for considering whether the current marine park boundaries and their zoning provide adequate protection. Between 78.5% and 100% of the nine assemblages overlaps with state MPAs or commonwealth CMRs, mostly in IUCN category IV, however less than 20% of six assemblages are within IUCN category II zones.

At the broadest scale, northern filter feeding habitats should be represented in future MPA sanctuary zones.

Larger fringing reef areas with high coral abundance and diversity on seaward margins, notably occurring on the coastal islands such as. Examples include Maret Islands, Beagle Islands, and others

Examples of terraced intertidal areas, supporting algae and corals on exposed reef platforms during low tide. Examples include Montgomery Reef, islands in the Bonaparte Group and Long Reef.

4. How do the major habitats interact?

Substrate type and depth are key influences of habitat distributions and transitions. The influence of tides, with associated currents and turbidity is a knowledge gap.

5. How do geomorphology, sediment composition and turbidity influence habitat and biodiversity distribution?

Geomorphic complexity is associated with diversity, while sediment composition influences the presence of sessile biota such as sponges, which tend to settle on hard substrate, while infauna and some mobile taxa, for example echinoderms, are able to utilise unconsolidated seabed areas.

Turbidity may have a range of influences, for example be correlated with sedimentation rates that affect species differentially, but a key influence is on light penetration. High turbidity in the region tends to restrict the amount

of light reaching the seabed, restricting benthic primary producers to shallower margins less than 30m deep and predominantly less than 15m deep.
6. What taxa are good surrogates (indicators) for the benthic biodiversity of major habitats? And what broader environmental variables are useful drivers of biodiversity? Sponges, echinoderms and bryozoans were the dominant taxa in the heterotrophic habitats. Scleractinian corals and algae predominant on intertidal and shallow subtidal areas. It remains to be determined if particular taxa in these group represent good surrogates
7. How representative is the biodiversity in the sanctuary zones of the proposed MPAs? The current zoning of Lalang-garram Maine Park, and in particular in combination with the northern section, now declared as North Lalang-garram Marine Park, is likely to provide good representativeness.. Additional sanctuary zones further north would improve overall representativeness.
8. What are the key characteristics of benthic habitats used by tracked sea turtles (including key features, distinguishing attributes and dominant invertebrate fauna) See subsequent turtle report 1.1.1a
9. Which key invertebrate fauna in the areas are turtles eating most? See report 1.1.1a
10. What are the key biodiversity attributes that can be used to predict “turtle hotspots” at a Kimberley regional-scale? See report 1.1.1a
What do Indigenous rangers/TOs see as important in their sea country? This question was not within the scope of this study.
What is this project adding to our understanding of bathymetry across the Kimberley? A greatly improved bathymetry in the three areas surveyed, (southern - 4,166 km^2, central - 1,824 km^2, northern - 2,513 km^2). The results have highlighted the undersea, drowned river channel legacy of the Holocene transgression
How can managers use this information - we may know where things are, but what does this tell us about how to manage the park? ● How fragile/unique is what's there? ● Where would be good spots for anchors/moorings? ● Which habitats are most vulnerable to human activity - and how do these activities impact? The regional and local scale characterisation of habitat distributions facilitates selection of representative areas and subsequent spatial planning for management at local scale.
Characteristics of the fauna There were almost double the number of sponge species collected compared to the next most speciose groups: crustacea and molluscs (426 species versus 229 and 211 respectively).
Crustacea A total of 229 species or OTUs belonging to 45 families and 131 genera were identified.

The majority of species collected belong to the order Decapoda (87%), as would be expected from the sampling methods. Decapods are the most speciose group of crustaceans and include crabs and shrimp.

Rare species dominate the dataset with 59% and 20% of the species collected from only one or two stations, respectively, and only 11% of species found at 10 or more stations.

In total 85 species identified from these expeditions were not reported previously from the inshore Kimberley (summarised by Hosie et al. 2015).

Sixteen species are considered to be the first records within Western Australian waters.

Newly discovered species include *Paranaxia keesingi* Hosie & Hara, 2016, the stalked barnacle *Smilium* sp. nov. and the shrimp *Odontozona* sp. nov.

The faunal composition reflects habitats dominated by non-scleractinian sessile organisms and/or soft sediments, with few coral reef associated crustaceans found.

The most commonly collected species was the porcelain crab *Petrolisthes militaris,* found at 55 stations. Ecologically this species is a generalist in terms of habitat preference and is very common in the intertidal and shallow subtidal in tropical Western Australia.

Molluscs

Four potential new species.

New records for Australia and/or WA are still being tallied but none have been found as yet.

The sample lots were dominated by two classes: gastropods and bivalves, with sparse but important records from the other classes.

The muricids (Muricidae) were the most commonly encountered family of gastropod, found across all expeditions and within this family, the species *Chicoreus cervicornis*, *C. banksii* and *Vokesimurex multiplicatus* were present in all three areas.

Highest familial diversity was found during Expedition 1 (44/64 or 69%), followed by Expedition 3 (41/64 or 64%) and then Expedition 2 (26/64 or 41%).

Generic diversity largely reflects familial diversity trends with Expedition 1 (78/113 or 69%), followed by Expedition 3 (62/113 or 55%) and then Expedition 2 (40/113 or 35% genera).

Comparison of Expedition 1 and Expedition 3 reveal only 26/52 or 50% of observed families were shared, implying that 50% of familial diversity observed was unique to each expedition area.

Venerid clams, which include many commercially important species, were the dominant bivalve family on Expeditions 1 and 3, but were completely absent from Expedition 2.

The results are consistent with the interpretation of extremely patchy molluscan diversity, perhaps as a result of high habitat heterogeneity and the need for more sampling to fully characterize the biodiversity of such a rich area.

Porifera

The majority of the species collected belong to the class Demospongiae (98%) with a total of 429 species or OTUs recorded. The demosponges are known to be the most diverse sponge class, globally accounting for 83% of sponge diversity (van Soest et al. 2012).

Seventy two species were only collected from the 1st expedition (Camden Sound), 16 species from the 2nd (Maret Islands) and 19 species from the 3rd (Eclipse). Ecological characteristics of the different areas may account for this, or patchy species distributions.

The known shallow water sponge fauna of the Kimberley was summarised by Fromont and Sampey (2014) who reported 342 sponge species from the region. The WAMSI expeditions have increased this number by 20% (84 additional species). The overall collection from these locations reflects a typical Indo Pacific tropical sponge fauna. For example, *Ianthella* species, *Xestospongia testudinaria*, and species of *Spheciospongia* are commonly found in this region.
Fishes Most of the fauna comprises widespread species from Northern Australia with typical Indo-West Pacific affinities. The collection comprises around 100 species. The most common species (12 individuals) was *Liocranium pleurostigma*. The collection of 8 seahorses *Hippocampus* spp. is a notable important addition to our knowledge of these difficult to collect fishes. Some specimens are almost certainly new Western Australian and/or Australian records. Others are known to be undescribed taxa and are currently under revision by both WA Museum and external experts.
Soft corals The collected assemblages from these locations reflects a general North West Shelf octocoral fauna, and a typical Indo-Pacific tropical octocoral fauna for muddy/sandy environments with moderate water movement and low wave action. The relatively high abundance of sea whips and sea fans and octocoral genera known to live predominantly in turbid and sandy environments, such as *Studeriotes, Nephthyigorgia, Carijoa, Iciligorgia*, *Solenocaulon*, and *Plumarella penna,* as well as the absence of the genus *Lobophytum* and the low abundance of genera such as *Sinularia* and *Sarcophyton* support these findings. Some species generally described as rare or not often reported in shallow tropical waters, such as *Studeriotes* and *Nephthyigorgia*, appeared to be relatively abundant.
Hard corals A total of 107 specimen lots were examined and represented 30 species. All of the hermatypic corals recorded in these surveys are known from the Kimberley (Richards, Sampey and Marsh, 2014). Azooxanthellate solitary scleractinian genera dominated the collections – particularly from the genus *Truncatoflabellum* which accounted for 44% of specimens. Three of the four *Truncatoflabellum* species have been previously recorded in Western Australia (Cairns 1998) and the fourth species requires further investigation to confirm the species identity. All of the known *Truncatoflabellum* species recorded are known to have an upper depth distribution of 11-40m and a lower depth distribution of 155-136m depth. The finding of *T. veroni* at 32.8m however is slightly shallower than the shallowest depth record in Cairns 1998 of 40m. Among the azooxanthellate corals were 16 *Caryophyllia* specimens, of which there are at least four different species. For *Tubastrea coccinea*, the known depth distribution in Cairns (1998) is 0.3-20m, hence this datasets extends the lower depth distribution of this species in Western Australia to 55.4m.

Echinoderms

A total of 205 species of echinoderms were collected (26 asteroids, 35 crinoids, 20 echinoids, 54 holothuroids and 70 ophiuroids).

Diversity was highest at the Eclipse Islands (154 species), despite the number of stations (26 stations) being the similar at the Maret Islands (28 stations) and much less than in Camden Sound (51 stations).

The number of individuals collected was highest at the Eclipse Archipelago with very high densities of crinoids and ophiuroids in particular.

Overall echinoderm diversity appears to increase from south to north.

The collection of 205 species from the central Kimberley includes an additional 66 species to those recorded by Sampey and Marsh (2015), increasing the total known echinoderm diversity for the Kimberley by 17%.

There are three new, undescribed species of asteroids and ophiuroids and four new species of holothuroids in this collection.