Species assemblages, biomass and regional habitat characterisation across the offshore Kimberley region

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WAMSI Kimberley Marine Research Program

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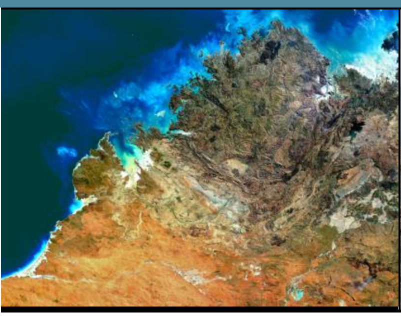
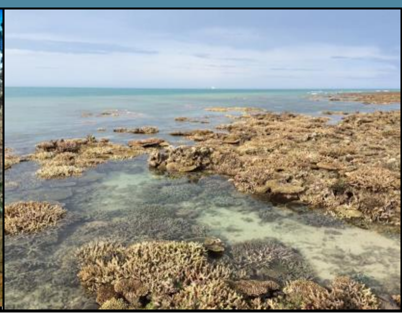

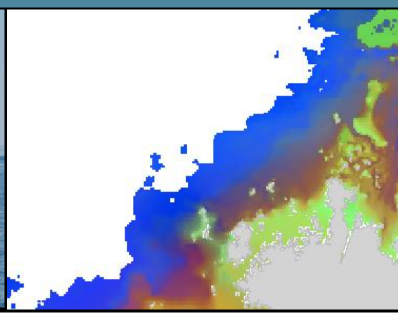

WAMSI Kimberley Marine Research Program

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: Exposed Acropora coral community at Holothuria Reef during the northern survey (Image: Karen Miller, AIMS)

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

Image 4: Figure 7 Map of the continuous seabed characterisation of the Kimberley survey area. (subproject 1.1.1.5)

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Contents

Executive Summary

Analysis of tow video and epibenthic sled collections matched to a wide set of environmental data at three locations in the Kimberley identified nine habitat/species assemblages, distributed as subsections within the IMCRA mesoscale Kimberley bioregion, that provide broad spatial characterisation of the region. There was a deeper offshore assemblage that ran the entire alongshelf 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 including of habitat forming sessile invertebrates, mostly sponges and octocorals. All assemblages had greater than 50% of coverage of mostly unconsolidated sediment habitats with no habitat forming or defining biota. 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 tow video. The result probably reflects the differing scales of the two methods (sleds 50-100m length, tow video transects 1500m) and the patchiness of the habitats and reinforces 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.

Management implications

The nine assemblage types identified provide the basis for considering whether the current marine park boundaries and their zoning provide adequate protection. 100% of the nine assemblages overlaps with state MPAs or commonwealth CMRs, mostly in IUCN category IV, however just 7 - 13% of assemblages 1,2,3 and 9 are within Sanctuary zones (nominally equivalent to IUCN category II). A breakdown of how the nine assemblage types are distributed across the various zoning categories, including Sanctuary areas and Special Purpose areas, in each of the state MPAs such that an assessment can be made by DBCA of the adequacy of the protection afforded to each assemblage type.

1 Introduction

Marine estate planning requires an understanding of the different habitats and species assemblages present in a region and the spatial extent of each habitat and assemblage type. The sampling undertaken to assess biodiversity in the Kimberley, described in 1.1.1.1, provides a good record of what habitats and species occur at a particular station and, aggregated up at the scale of each of our sampling locations, provides a measure of the total observed biodiversity. However, these data on their own do not indicate the structure of species assemblages and the habitats they occupy and how environmental variables may influence their spatial extent and distribution. 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.

2 Methods

2.1 Collection of tow video and epibenthic sled data

Habitat data were collected by towed video and scored in real time using the “tappity” method and an epibenthic sled was used to quantitatively sample epibenthic biota. These methods are described in detail in report 1.1.1.1 Chapter 3. Sampling design methods are described in Chapter 2.

2.2 Environmental data

The environmental variables used had been collated and mapped on a 0.01 degree grid for the entire Australian EEZ by a series of previous projects for the purpose of biodiversity distribution analysis and prediction. Initially, the CERF Marine Biodiversity Hub collated and mapped 26 variables (Pitcher et al. 2011); subsequently, these have been progressively updated and additional variables added (e.g. McLeod & Pitcher 2011; Pitcher et al. 2015; Pitcher et al. 2016). The most recent updated version (Pitcher et al. 2018) used here provided up to 41 environmental variables on a 0.01 degree grid (Table 1).

2.3 Treatment of tow video data

Towed video “tappity” score files recorded on RV Solander (AIMS) and RV Linnaeus (CSIRO) during 2014 and 2015 and 2016 voyages were matched against epibenthic sled tows taken in 2015 and 2016 in the Camden Sound, Eclipse Archipelago and Maret Island areas. Data were provided by AIMS in MS Access format and by CSIRO as CSV files. Data extraction and processing were done using UCanAccess (http://ucanaccess.sourceforge.net/site.html) via the RJDBC (Urbanek, 2018) package for Microsoft Access data and the default text processing for CSV files in R (2017)). For each sled track a bounding box was created using its most southern, western, northern and eastern coordinates. A buffer of 0.0075^o longitude and latitude was added to this bounding box to account for slight differences in the match up with the video tracks. For all sled matches the presence of each Tappity Benthic Substrate [SCode], Benthos [BCode] and observed Organisms code [OCode] within the bounding box were tallied and reported.

Each matched video track was exported for refined post processing and quality control by a benthic ecologist. A summary file was produced for all the matches which summed all the codes along the matched tracks. For the BCode and SCode a percent of track value was calculated. In the case of the OCode, a presence/absence measure, only the total number of observations was provided.

For all available video tracks in the 2014, 2015 and 2016 datasets a 0.01^o by 0.01^o grid for ACodes, BCodes and SCodes was produced. The coordinate for each observation was rounded to the nearest 0.01^o degree, this represented the centre of each grid cell, and the observation was assigned to that cell. The total number of codes and total number of observations for each grid cell was recorded. A separate grid cell file was produced for the ACodes, BCodes and OCodes. The distribution of grid cells with tow video data is shown in Figure 1.

Table 1 Environmental variables mapped to the Australian EEZ, available to the project

#	Variable	Description
1	GA_BATHY	Depth from bathymetry DEM – metres
2	GA_SLOPE	Slope derived from bathymetry DEM – degrees
3	GA_ASPECT	Aspect of slope derived from bathymetry DEM – degrees T
4	GA_MUD	Sediment % mud grainsize fraction, (Ø < 63 µm)
5	GA_SAND	Sediment % sand grainsize fraction, (63 µm < Ø < 2 mm)
6	GA_GRAVEL	Sediment % gravel grainsize fraction, (Ø > 2 mm)
7	GA_CRBNT	Sediment % carbonate ($CaCO_3$) composition, percent
8	RBN_BSTRESS	Seabed current stress, RMS mean – Nm^{-2}
9	RBN_BSTRESS_SR	Seabed current stress, Seasonal Range
10	CRS_NO3_AV	Nitrate bottom water annual average NO3 – µM
11	CRS_NO3_SR	Nitrate Seasonal Range
12	CRS_PO4_AV	Phosphate bottom water annual average PO4 – µM
13	CRS_PO4_SR	Phosphate Seasonal Range
14	CRS_O2_AV	Oxygen bottom water annual average O2 – ml L^{-1}
15	CRS_O2_SR	Oxygen Seasonal Range
16	CRS_S_AV	Salinity bottom water annual average S – ‰ (ppt)
17	CRS_S_SR	Salinity Seasonal Range
18	CRS_T_AV	Temperature bottom water annual average T – °C
19	CRS_T_SR	Temperature Seasonal Range
20	CRS_SI_AV	Silicate bottom water annual average Si – µM
21	CRS_SI_SR	Silicate Seasonal Range
22	SW_CHLA_AV	Chlorophyll annual average from SeaWiFS – mg m^{-3}
23	SW_CHLA_SR	Chlorophyll Seasonal Range
24	SW_K490_AV	Attenuation coefficient at wavelength 490nm annual average from SeaWiFS – m^{-1}
25	SW_K490_SR	Attenuation coefficient Seasonal Range
26	MT_SST_AV	Sea Surface Temperature annual average from Modis – °C
27	MT_SST_SR	Sea Surface Temperature Seasonal Range
28	VGPM_AV	Net Primary Production annual average from SeaWiFS – mg C m^{-2} d^{-1}
29	VGPM_SR	Net Primary Production seasonal range
30	EPOC_AV	Export Particulate Organic Carbon flux annual average from SeaWiFS – mg C m^{-2} d^{-1}
31	EPOC_SR	Export Particulate Organic Carbon seasonal range
32	PAR_AV	Photosynthetically Active Radiation (PAR) from MODIS – Einsteins m-2day-1
33	PAR_SR	Photosynthetically Active Radiation seasonal range
34	SW_BIR_AV	Benthic Irradiance annual average, BIR = PAR × exp(-K490 * Depth)
35	SW_BIR_SR	Benthic Irradiance Seasonal Range
36	TERAN_CHAN	Terrain channel, probability of membership of topographic shape "channel"
37	TERAN_PASS	Terrain pass, probability of membership of topographic shape "pass"
38	TERAN_PEAK	Terrain peak, probability of membership of topographic shape "peak"
39	TERAN_PIT	Terrain pit, probability of membership of topographic shape "pit"
40	TERAN_PLAN	Terrain plane, probability of membership of topographic shape "plane"
41	TERAN_RIDG	Terrain ridge, probability of membership of topographic shape "ridge"

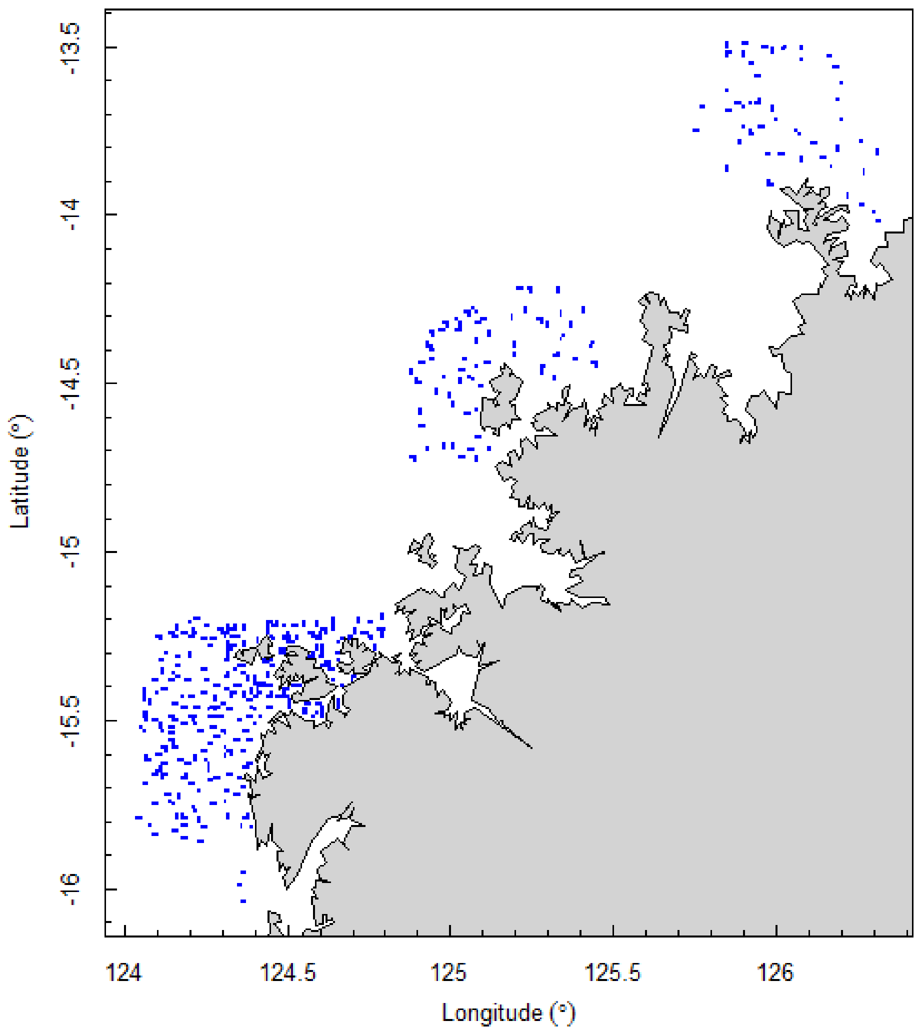

Figure 1 Map of locations of tow video data plotted on a 0.01 degree grid of the study region

2.4 Ecological modelling

The methods follow closely those used in Pitcher et al. (2017) to provide a regional habitat and species assemblage characterisation of the Pilbara region. The regional scale characterisation was achieved by analysing the new survey sled species sample data and the tow-video 'tappity' habitat data in an integrative analysis method, R package '`gradientForest`' (http://r-forge.r-project.org/projects/gradientforest/; Ellis et al 2012; Pitcher et al 2012). We used gradientForest to obtain evidence-based relationships between species compositional change (turnover) and multiple environmental gradients, which were then used to transform all environmental data layers to the same 'biological' scale (for details, see http://gradientforest.r-forge.r-project.org/biodiversity-survey.pdf). The transformed layers provide a multi-dimensional biological space that represents biotic composition as associated with the environmental variables. The biological space was mapped in geographic space to provide a continuous characterisation, and was also clustered to provide a classified assemblage map for the region. Multivariate analysis of variance was to guide selection of a statistically justifiable number of assemblages for the classification.

3 Results and Discussion

3.1 Animal and plant biomass

The range of biomass among sleds was similar between locations with sponges dominating the benthic biomass at all sites (Figure 2 and Figure 14). Some sleds had high biomass of cnidarians, especially around the Maret Islands and the Eclipse Archipelago. Echinoderm biomass was high in the nearshore sleds at all three locations.

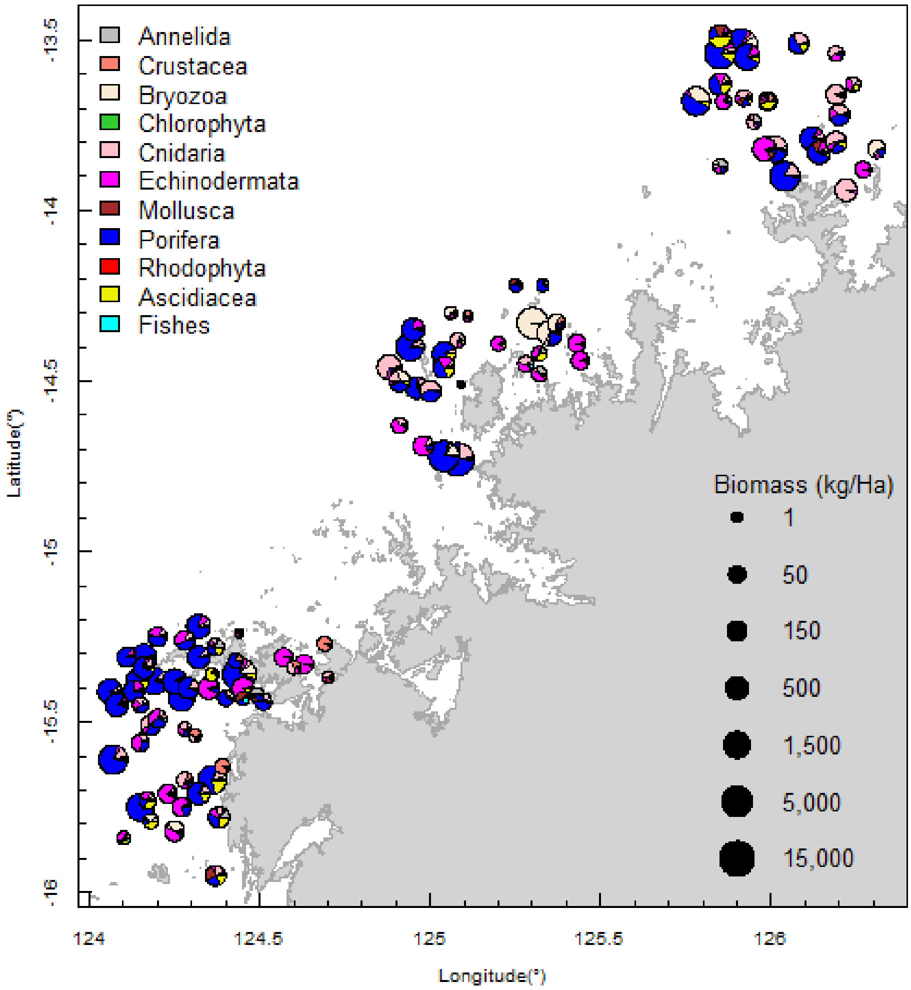

Figure 2 Map of the distribution of biomass of key taxa from epibenthic sled tows undertaken across the three study locations

3.2 Characterisation of benthic habitats

3.2.1 *Substrate type*

Characterisation of benthic habitats was carried out using tow video revealed differences in the amount of different habitat types between locations (Figure 3). Limestone reef and mud habitats were dominant at the Eclipse Archipelago with only a few offshore sandy sites while Maret Island sites were predominantly sandy. A mix of habitats was evident in Camden Sound with the northern section transitioning from mud onshore to reef offshore and in the south sites were predominantly sandy with occasional rocky patches.

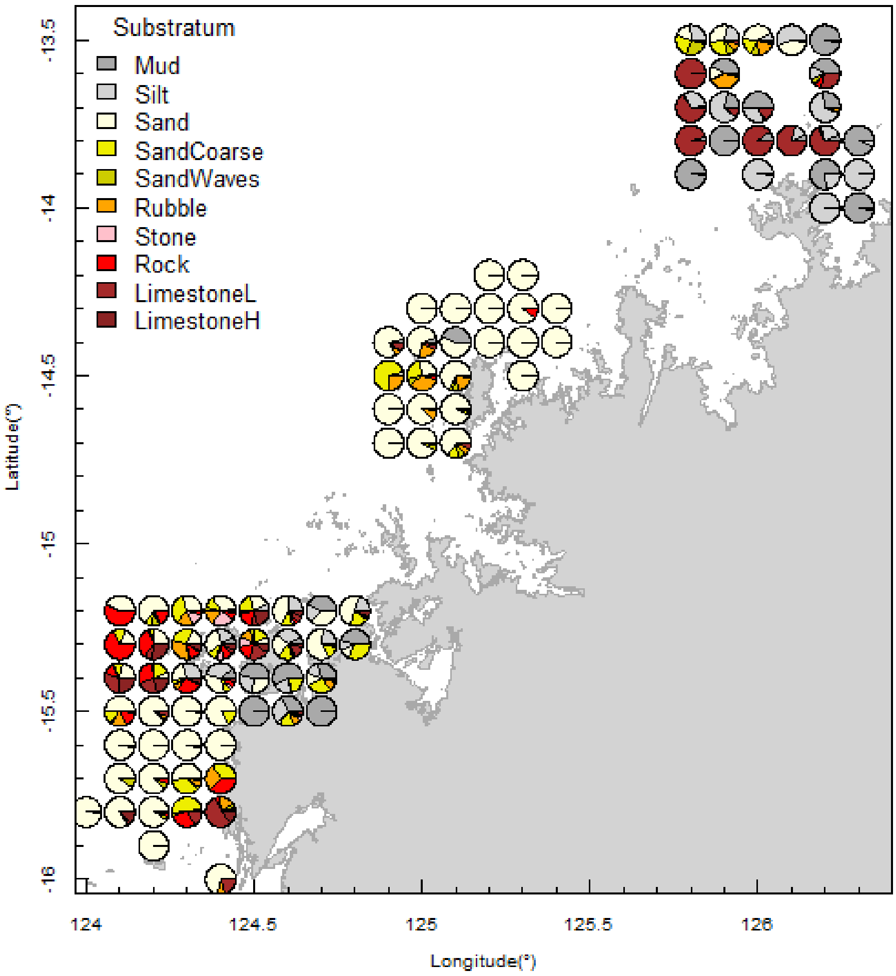

Figure 3 Map of the distribution of substrate types from tow video analysis across the three study locations. Note: for presentation purposes only the data from the tow-video locations (Figure 1) have been aggregated to 0.1 degree.

3.2.2 Biohabitat type

Sponge and octocoral biohabitat types occurred at all three study locations (Figure 4). These along with bioturbated sedimentary habitats made up the majority of sites. At all sites there were soft sediment sites with minimal bioturbation ("No Biohabitat"). There were few sites at any of the study locations which had significant amounts of primary producers (hard coral, macroalgae or seagrass).

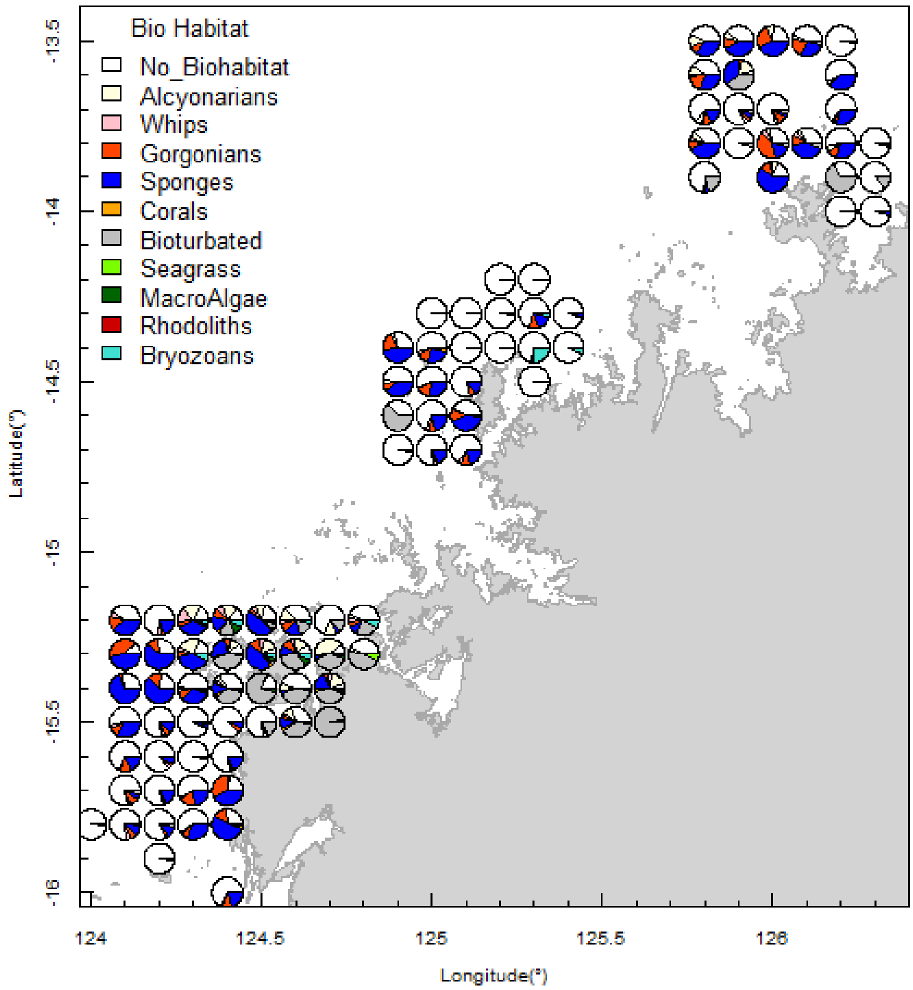

Figure 4 Map of the distribution of habitat forming benthos from tow video analysis across the three study locations. Note: for presentation purposes only the data from the tow-video locations (Figure 1) have been aggregated to 0.1 degree.

3.2.3 Non habitat forming animals

Hydroids, crinoids and echinoids dominated the animals seen on the tow video surveys at most sites (Figure 5). Fishes were also common in muddy habitats in the north-eastern part of Camden Sound.

3.3 Compositional turnover along environmental gradients

The relationships between species and habitat distributions in the sled samples and video transects and their environment, as determined by the gradientForest analysis are shown in Figure 6. These curves indicate the cumulative changes in biodiversity composition (or turnover) along multiple environmental gradients, based on aggregating outputs from models fitted to each species that quantified changes in species abundance along each environmental gradient determined to have influence. Steep parts of curves indicate strong changes in species composition, whereas flat parts indicate little compositional change — often, the changes are non-linear along environmental gradients. The curves are standardised by the R^2 performance of each species model and the importance of each environmental variable, so all are in common units of biological change associated with the environment. Environmental variables with greater influence are associated with larger changes in species composition (larger values on the Y-axis). For many of the variables, the influence on the sled species composition appeared to be stronger than on the video habitat. The black line indicates the combined cumulative changes across all datasets, based on weighting by species R^2 performance, the number of species and sites in each dataset and the density of observations for each dataset along each gradient. The combined cumulative curves represent empirical functions for transforming each of the regional environmental variables (measured on many disparate scales) to a common scale that represents gradients in biological composition associated with the environment.

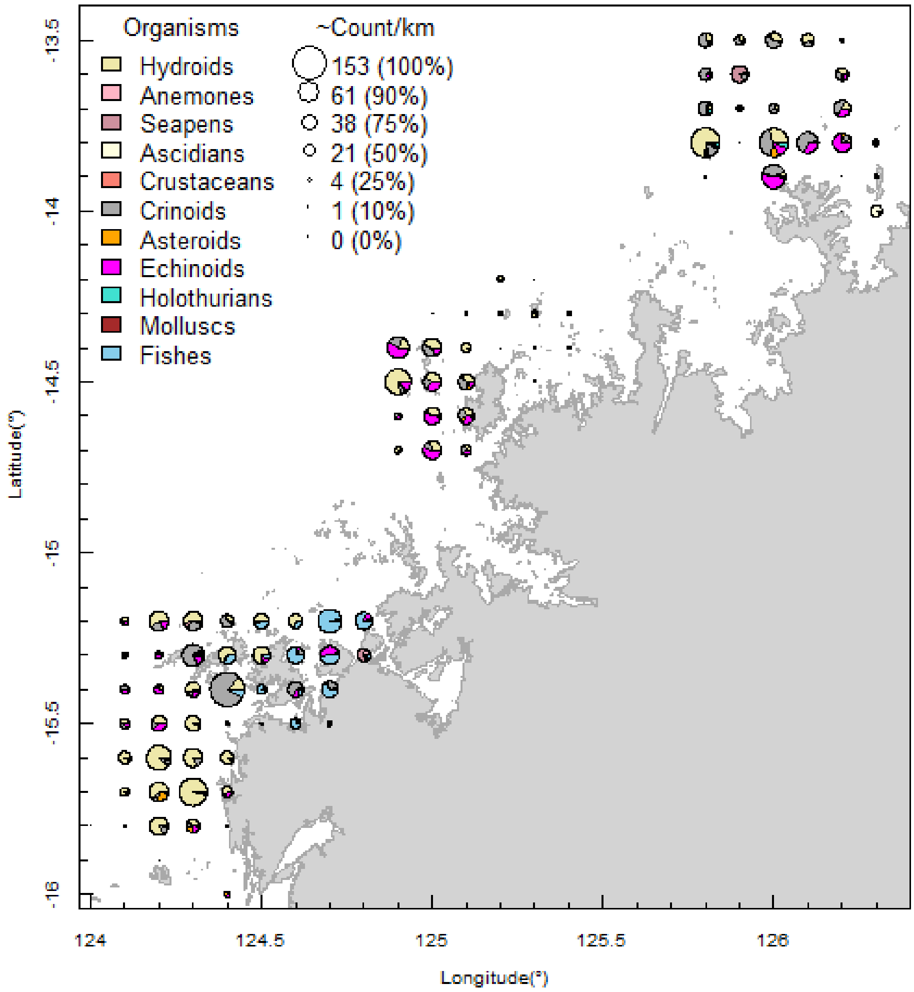

Figure 5 Map of the distribution of non-habitat forming biota from tow video analysis across the three study locations. Note: for presentation purposes only the data from the tow-video locations (Figure 1) have been aggregated to 0.1 degree.

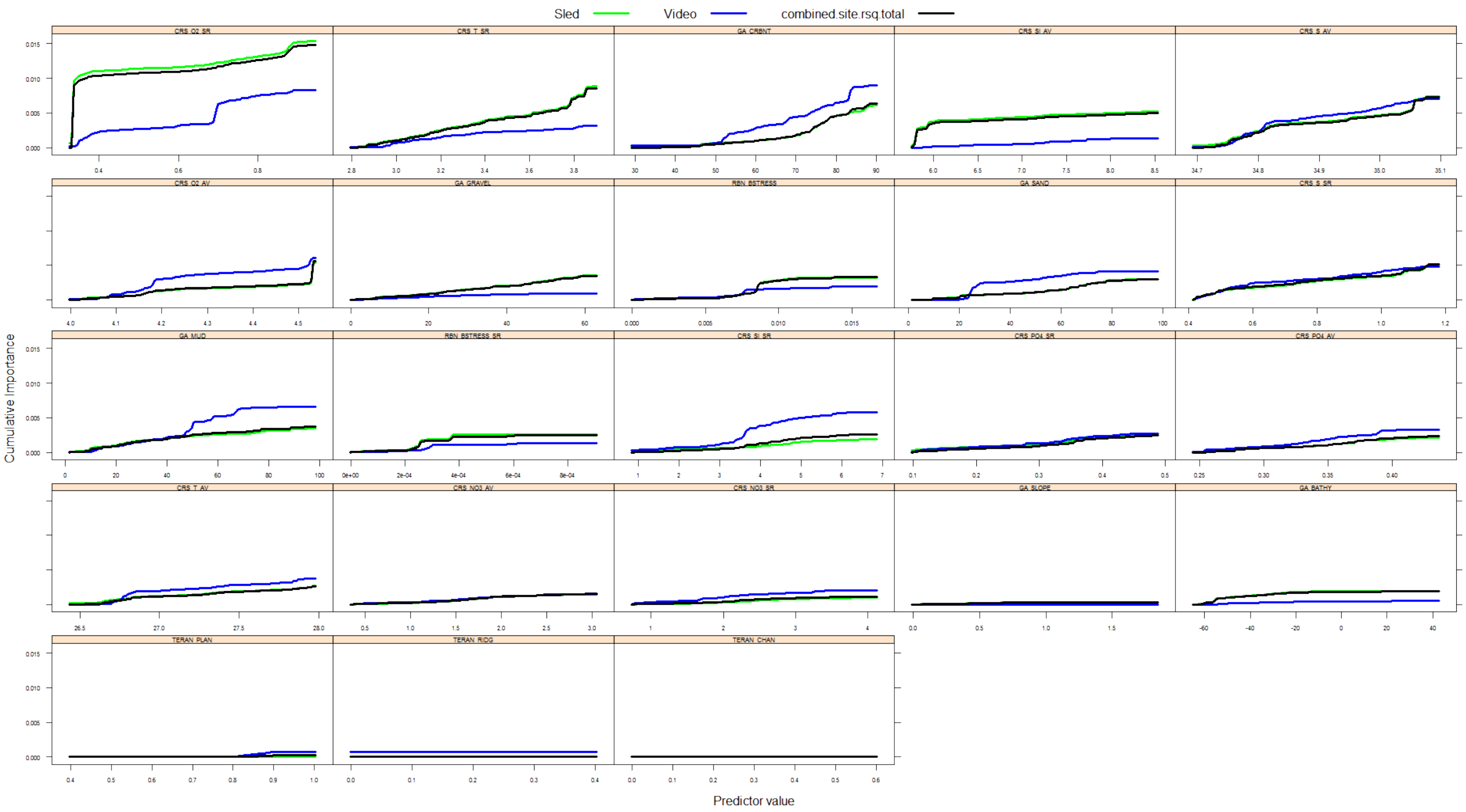

Figure 6 Relationships between change in species composition from the sled and video transect data and 23 environmental variables (in order of importance) in the Kimberley region study area. The y-axis is the cumulative compositional change associated with each environmental gradient. The abbreviations for the environmental variables are given in Table 1. Note, ocean colour derived variables were excluded because they were indeterminate in many shallow nearshore sites. Four variables were excluded due to unimportant influence on the response.

Transforming all environmental layers to the same 'biological' scale using the cumulative curves, provides a multi-dimensional biological space that reflects biodiversity composition associated with the environment and is used to provide a regional scale biophysical characterisation and predicted map of patterns of biodiversity composition for the region (see next section).

3.4 Regional characterisation

Regional spatial categorisation based on species assemblage characteristics, rather than just habitat types, is important for natural resource management. This is especially true in the case of large scale marine estate planning such as is occurring in the Kimberley. Such a categorisation can be used to ensure marine park zoning for different types of usage provides adequate protection for the full range of assemblage types represented.

A visual characterisation of the continuous regional scale biophysical patterns (Figure 7), based on the sled and tow video data from the three survey areas and an extensive spatial data set of environmental variables, shows some clear onshore/offshore patterns of biodiversity composition for the region as well as an alongshelf gradient in the inshore and intermediate areas.

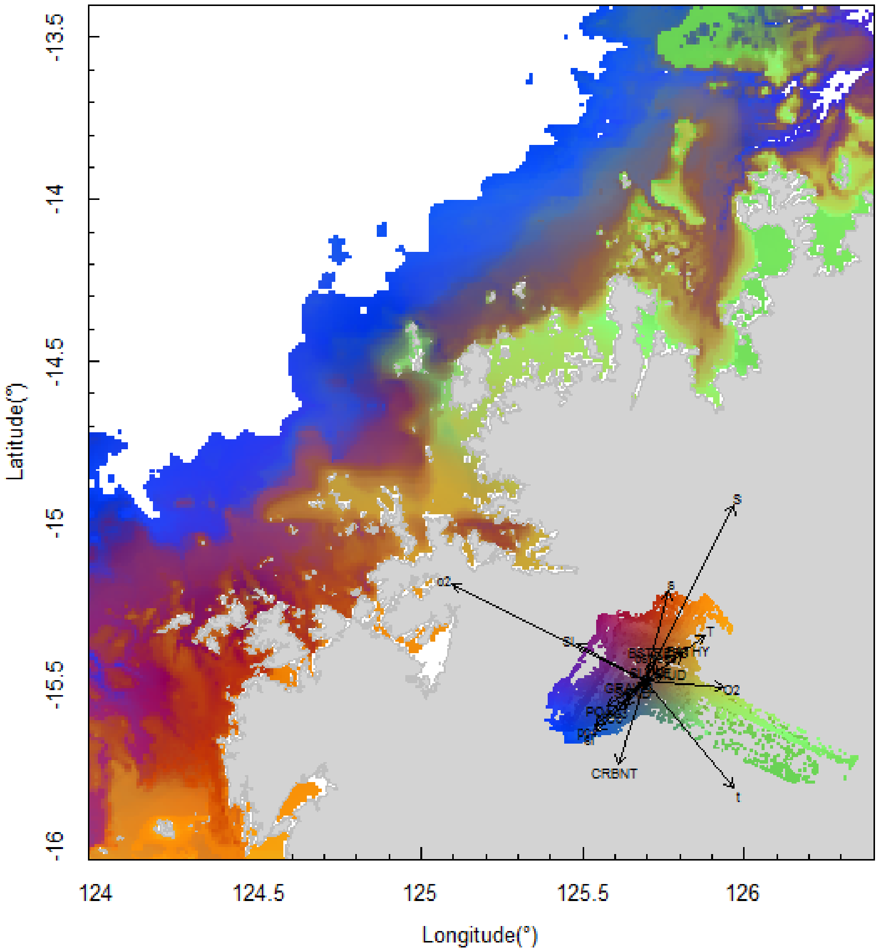

Figure 7 Map of the continuous seabed characterisation of the Kimberley survey area, showing expected changes in biodiversity composition associated with multiple environmental gradients. The biplot at bottom right shows the dimensions of the transformed biological space and variables principally associated with changes in composition. The key for the codes used in the biplot are given in Table 1.

Most management applications require a classified representation of assemblages. However, given that marine assemblages transition gradually (although often in a non-linear manner, Figure 6) and usually lack clear boundaries, dividing an area up into areas of significant spatial dissimilarity is not always optimal – identifying too few areas fails to adequately recognise important distinctions and identifying too many is impractical for management purposes. We used multi-variate analysis of variance (MANOVA) to help guide selection of the number of separate assemblages (Figure 8). Nine assemblages were the best fit for the sled data and in the case of the video data nine assemblages was substantively better than 6-8 and increasing this to as many as 14-16 assemblages contributed little additional benefit in terms of model fit. Based on the weighted mean F-ratio (Figure 8, thick grey numbered line), nine assemblages were selected as the best overall number.

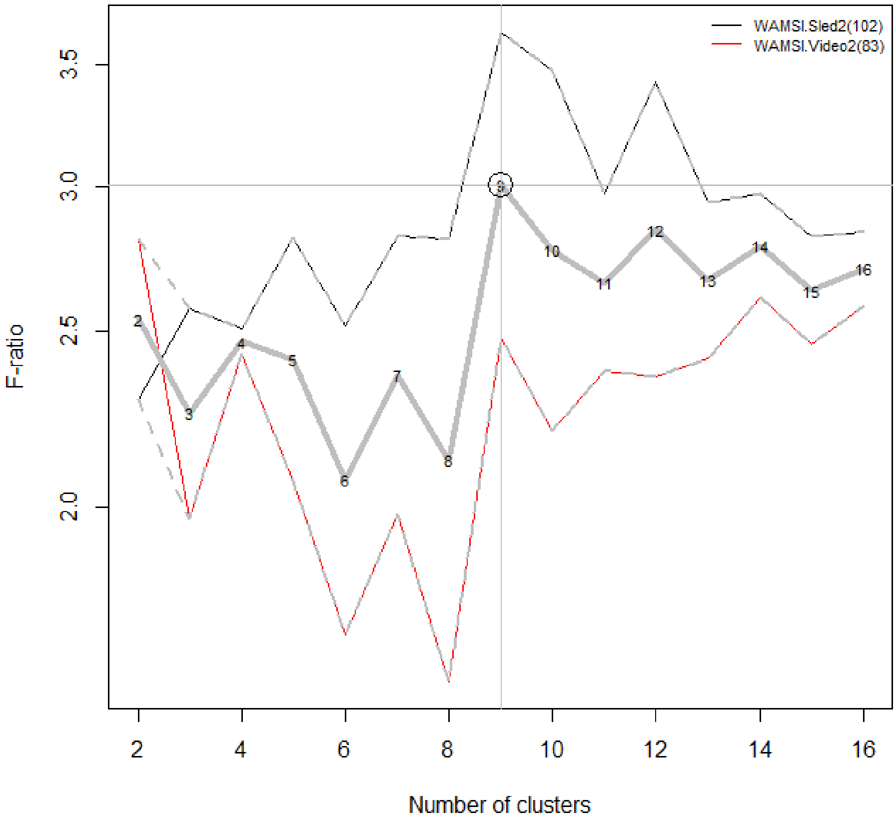

Figure 8 F-ratio results of multi-variate analysis of variance (MANOVA) illustrating variation in sled samples and video transect data explained by a range of clusterings (2–16) of the regional biological space.

The resultant map of nine discrete assemblages for the broader Kimberley region (Figure 9), encompassing the three areas surveyed in this project, shows there is an offshore assemblage made up of the deeper boundary along the extent of the three sampling areas from southwest to northeast (Cluster 1) and then a series of roughly across-shelf clusters which, broadly speaking comprise a northern set of assemblages (Clusters 2,3,4,5 and 6) and a southern set (Clusters 7, 8 and 9). There is some overlap, e.g. with Clusters 4 & 5, but the transition zone between the northern and southern areas is at about 14^{o} 45’S (Lamark Island and Augereau Island). In the southern section there is an inshore assemblage (Cluster 9) with a second assemblage type (Cluster 7) transitioning from onshore to offshore between Clusters 1 and 9. In the northern section there are two nearshore assemblages (Clusters 3 and 6) which then transition towards the offshore via Clusters 5 and 4 before joining the offshore assemblage (Cluster 1). The assemblage formed by Cluster 5 also occurs in the northern and southern overlap area.

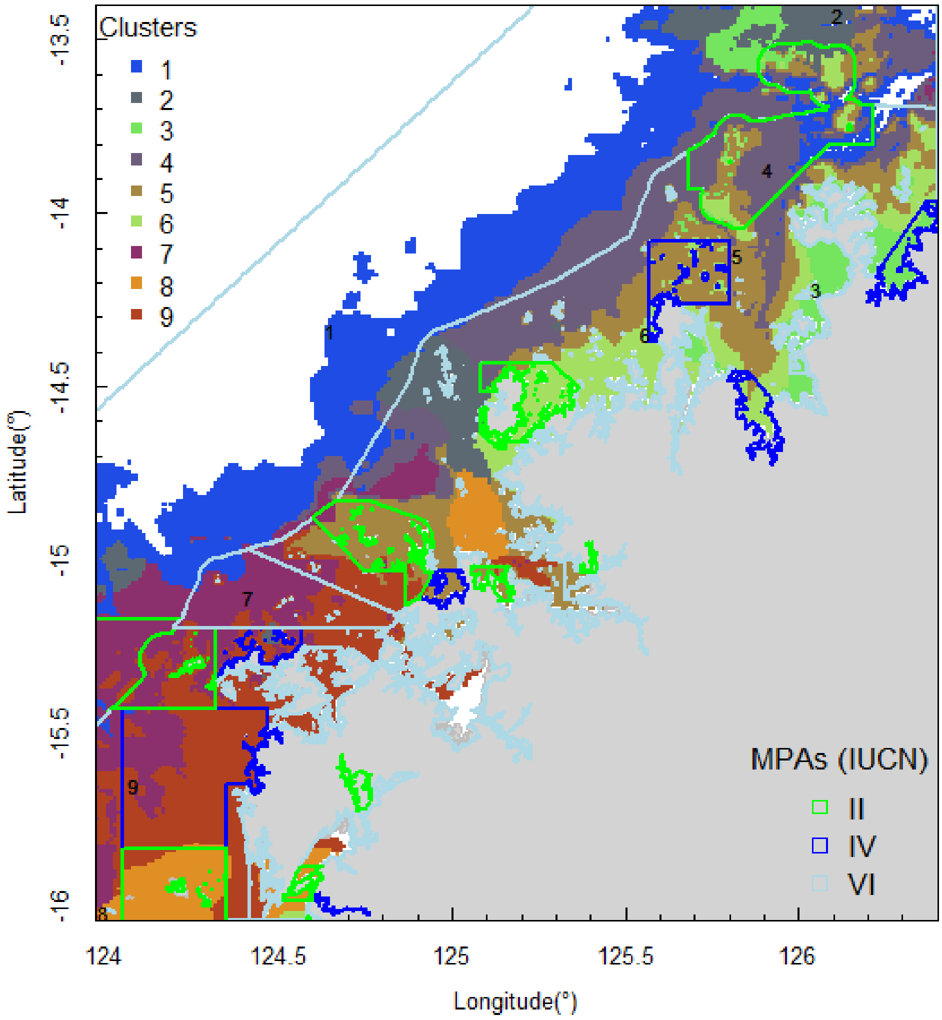

Figure 9 Map of the seabed characterisation of the Kimberley region into nine assemblage types. The location of Marine Protected Areas and their IUCN classification is overlaid for reference. WA MPA sanctuary zones are those marked as IUCN II and the Special Purpose zones are marked as IUCN IV. The IUCN category VI boundary reflects the fact that the entire coastal region is now an MPAwhole Kimberley MPA. Table 2 maps the nine assemblage types to each zoning type in each of the state MPAs.

The representation of these assemblages in State Marine Protected Areas (MPAs) and Commonwealth Marine Reserves (CMRs) is shown in Table 2 (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; just 7 - 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).

3.5 Characteristics of each assemblage type

The typical environmental, habitat, and biotic characteristics of each of the nine assemblage types is presented in Figure 10 to Figure 13 and summarised in Table 3. Table 4 lists the dominant species by biomass in each assemblage.

3.5.1 Environmental characteristics of assemblages

Figure 10 illustrates the typical range of values of each environmental variable across the nine assemblage types. Variables that showed strong gradients between assemblages included depth, seabed temperature, salinity, oxygen, silicate, phosphate and nitrate. Some variables were either relatively consistent between or had a broad range within assemblages (e.g. mud, gravel and sand). Others such as bottom stress were only predominant in one assemblage (8).

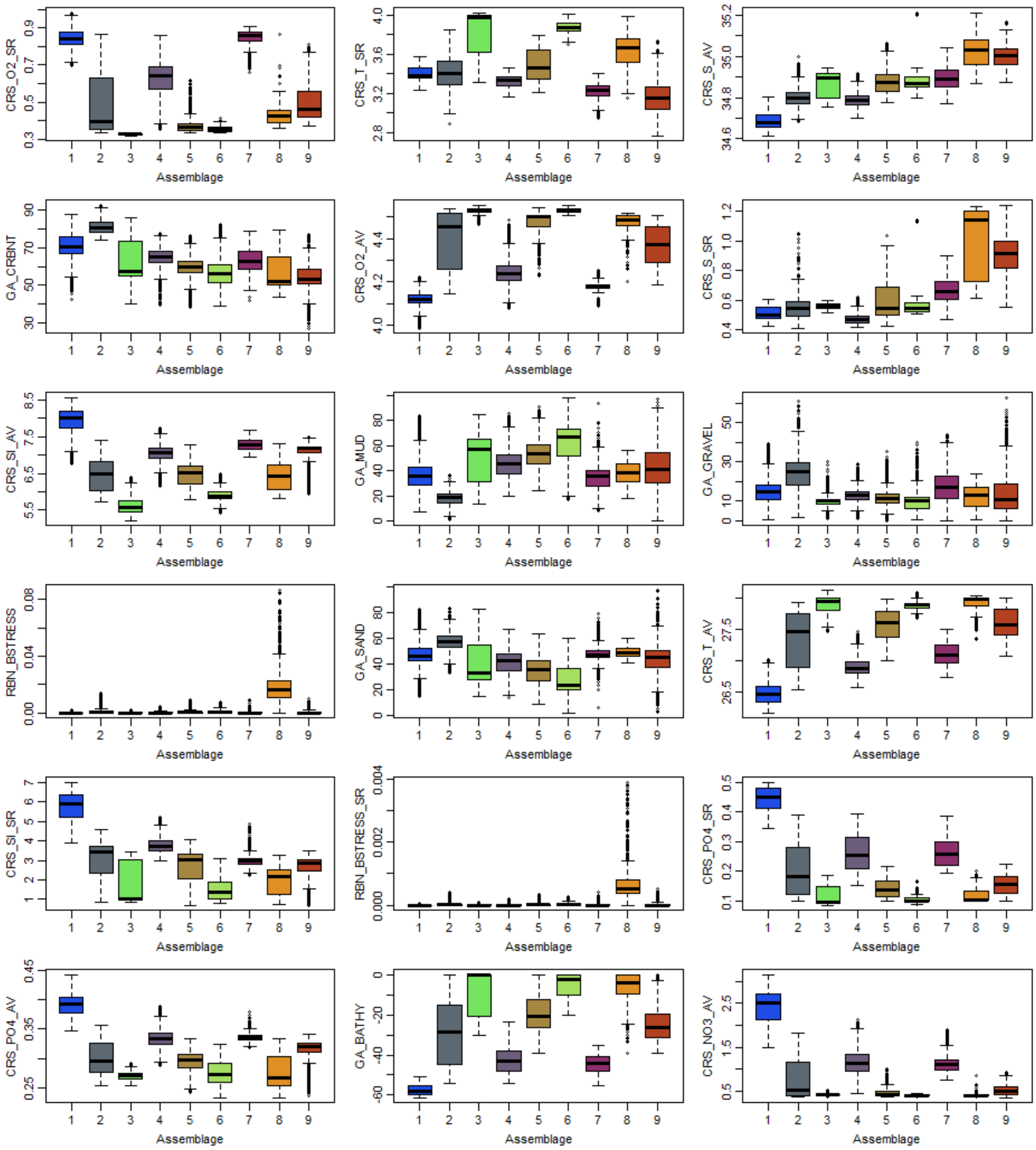

Figure 10 Boxplot summaries of the top 18 environmental variables for each of the nine discrete assemblages in the Kimberley study area. The box indicates the first and third quartiles and the horizontal bar indicates the median value; the whiskers indicate the 'normal' range of the data and small circles indicate outlying values. See Table 1 for full variable names and y-axis units of measurement.

3.5.2 Benthic biohabitat components of assemblages

With the exception of Assemblage 3, all assemblages typically had more than 50% of "No Biohabitat" (Figure 11) indicating large areas of principally unconsolidated sedimentary habitat with no habitat forming taxa present. Conversely Assemblage 3 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.

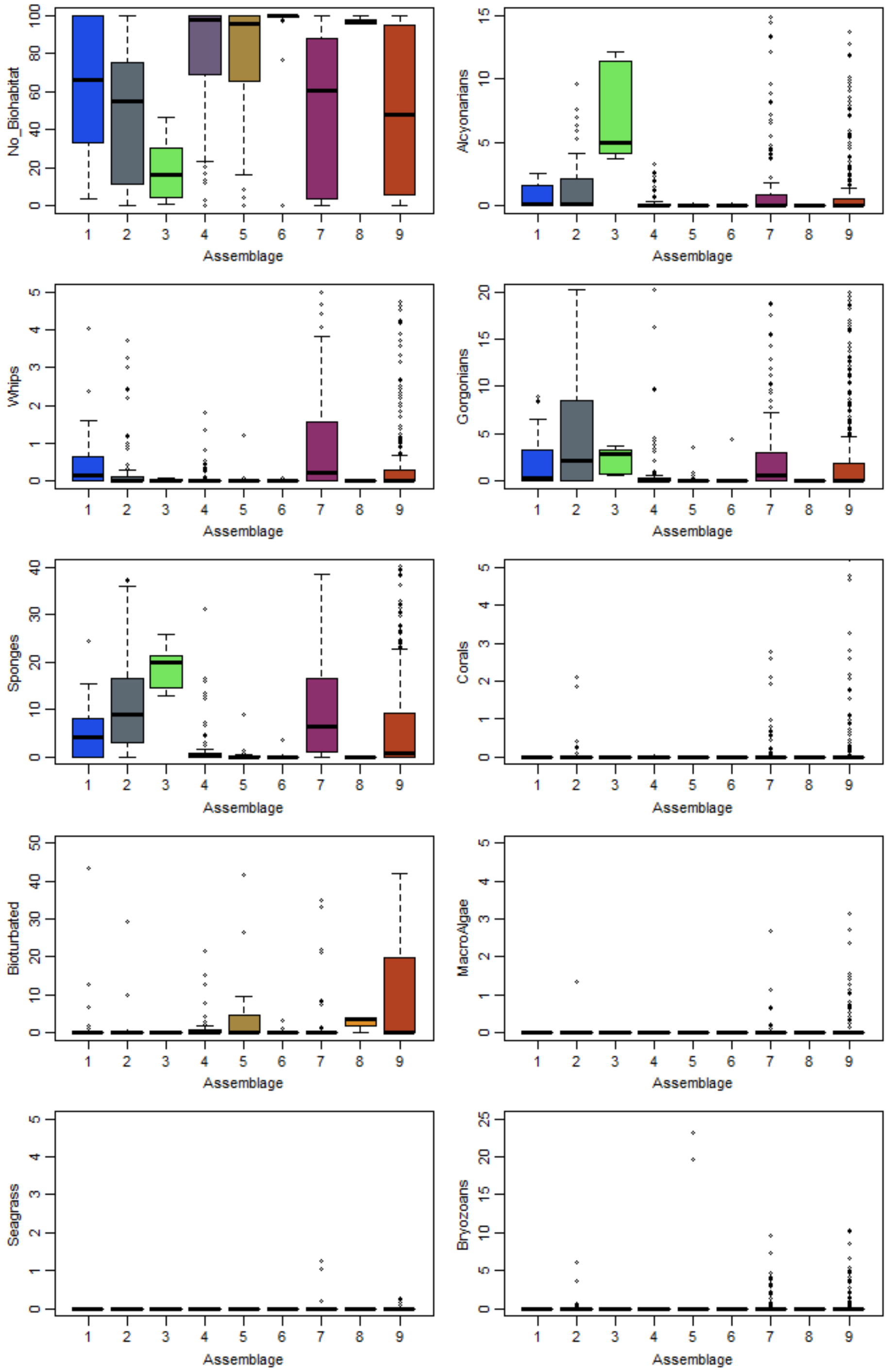

Figure 11 Boxplot summaries of bio-habitat % cover from tow video transects for each of the nine discrete assemblages in the Kimberley study area. The box indicates the first and third quartiles and the horizontal bar indicates the median value; the whiskers indicate the 'normal' range of the data and small circles indicate outlying values.

3.5.3 Benthic richness & biomass of assemblages

Species richness and biomass were highest in Assemblage 3 (northern, inshore), while the offshore Assemblages 1 and 2 were characterised by intermediate species richness and other assemblages by relatively low richness and low biomass (Figure 12). Assemblage 6 was least diverse.

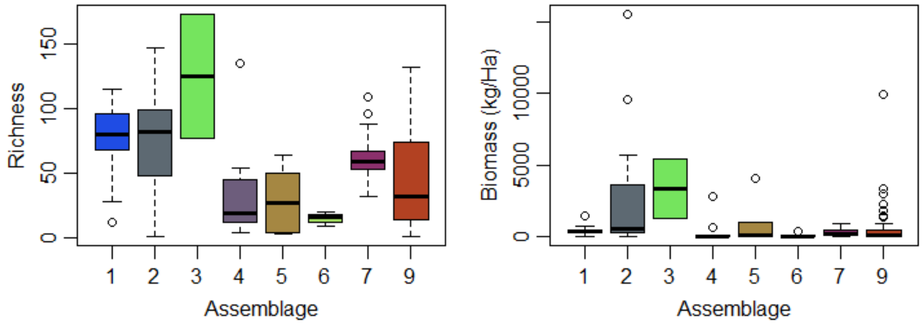

Figure 12 Boxplot summaries of richness and biomass as sampled by the sleds for each of the nine assemblages in the Kimberley study area. The box indicates the first and third quartiles and the horizontal bar indicates the median value; the whiskers indicate the 'normal' range of the data and small circles indicate outlying values. Note that there were no sled stations sampled in Assemblage 8.

3.5.4 Benthic taxa composition of assemblages

The northern inshore Assemblage 3 had the highest biomass overall (Figure 12) and when the contribution of individual taxa groupings are considered, Assemblage 3 also had the highest biomass of most groups (Figure 13) with the exception of malacostraca (crabs and shrimps), echinoids, hydroids and ophiuroids. These latter taxa tended to be more important in Assemblages with high levels of sediment habitat.

Table 2 Representation of mapped assemblages (Figure 9) in State MPAs and Commonwealth CMRs by IUCN category. Upper panel gives combined state and commonwealth MPA areas and lower panel provides the breakdown by each zoning type in the state marine parks.

Assemblage	Area km²	# Grid cells	State MPAs %				C'wlth CMRs %				TOTAL %			
			IA	II	IV	VI	IA	II	IV	VI	IA	II	IV	VI
1	5944.6	4968	0	7.70	0.116	6.19	0	0.19	0	85.80	0	7.89	0.116	91.99
2	1651.1	1379	0	11.47	2.184	38.98	0	0	0	47.37	0	11.47	2.184	86.35
3	1084.4	905	0	10.84	21.60	46.84	0	0	0	20.71	0	10.84	21.60	67.56
4	4453.4	3718	0	29.33	0.18	43.23	0	0	0	27.26	0	29.33	0.18	70.49
5	3632.2	3037	0	27.71	19.61	49.59	0	0	0	3.08	0	27.71	19.61	52.67
6	1933.5	1616	0	27.09	13.94	58.76	0	0	0	0.21	0	27.09	13.94	58.98
7	3070.1	2577	0	16.19	25.94	37.19	0	10.12	0	10.58	0	26.30	25.94	47.76
8	1208.1	1016	0	53.46	2.692	43.85	0	0	0	0	0	53.46	2.692	43.85
9	3743.8	3146	0	11.94	43.06	44.37	0	0.64	0	0	0	12.58	43.06	44.37

North Kimberley MPA proposed zoning / Assemblage number (areas in km²)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
General use area (VI)	269	678	533	2249	2098	1234	358	366	386
Sanctuary area (II)	477	202	146	1529	1228	614	38	0	51
Special purpose area (cultural heritage) (VI)	0	0	98	0	45	69	0	0	0
Special purpose area (recreation & conservation) (IV)	0	0	291	10	869	316	0	0	6
Camden Sound MPA proposed zoning									
General use area (VI)	17	0			48		378	84	1116
Sanctuary area (II)	0	0			0		591	628	687
Special purpose area (pearling) (VI)	0	2			5		50	0	829
Special purpose area (whale conservation) (IV)	7	0			0		821	33	2433
Special purpose area (wilderness conservation) (IV)	0	38			0		186	0	219
Horizontal Falls MPA proposed zonings									
General use area (VI)	97	2				28	659	93	411
Sanctuary area (II)	0	0				0	0	32	0
Special purpose area (recreation & conservation) (IV)*	0	0				0	0	0	0
Commonwealth Marine Reserves									
Multiple Use Zone (VI)	5308	832	280	1420	137	5	411		0
National Park Zone (II)	12	0	0	0	0	0	393		39

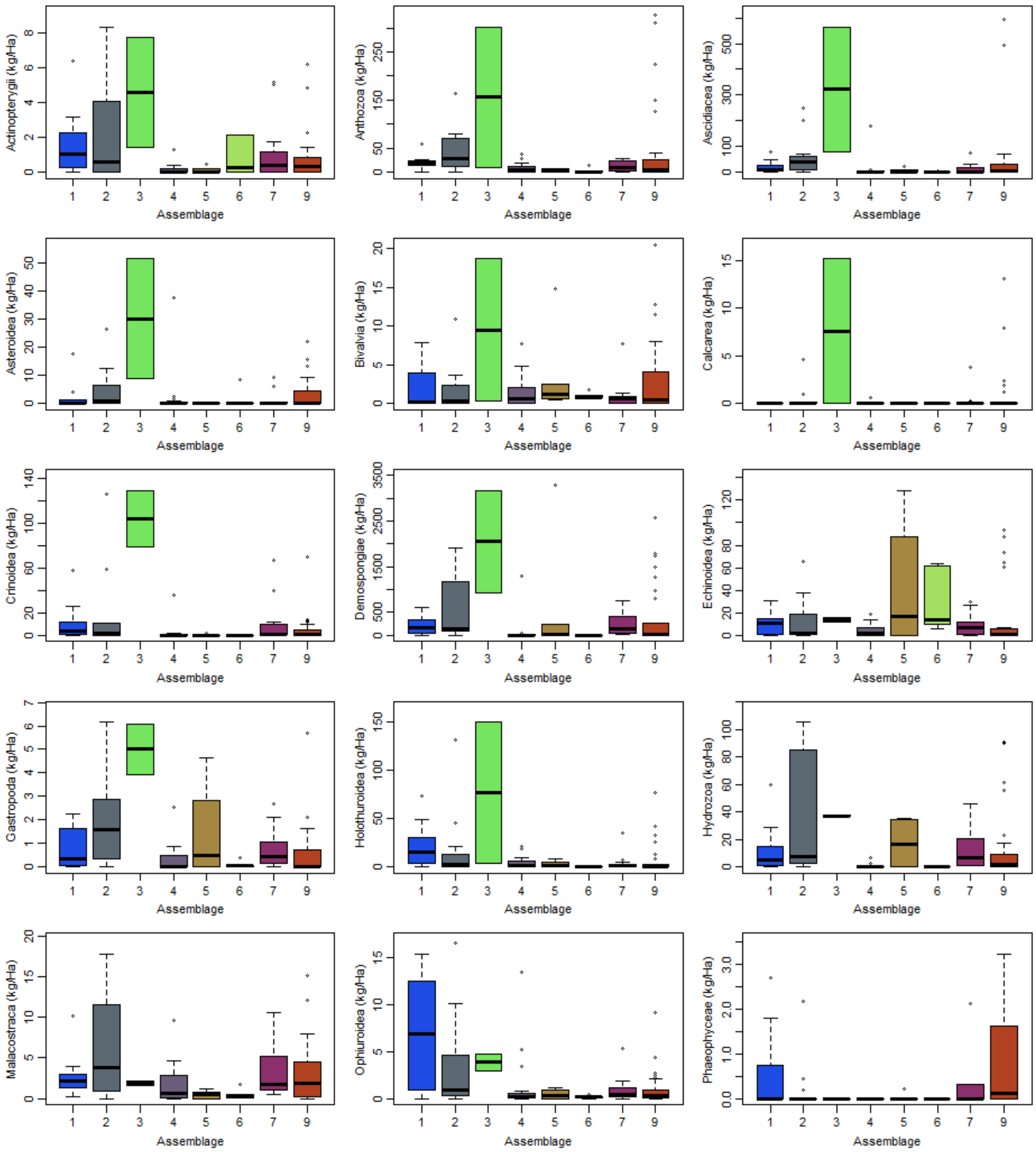

Figure 13 Boxplot summaries of benthic class level biomass for each of the nine assemblages in the Kimberley study area. The box indicates the first and third quartiles and the horizontal bar indicates the median value; the whiskers indicate the 'normal' range of the data and small circles indicate outlying values. Note that there were no sled stations sampled in Assemblage 8.

3.6 Distribution of sites and abundance of taxa across habitat and assemblage clusters.

Biodiversity characteristics vary in response to changes in substrate, habitat or environmental variables due to biological needs, preferences or obligate associations. These factors in part result in spatial variability in the distribution of animals and plants and the assemblages they form. This is evident in the above analyses which determine a set of nine assemblage types based on video surveys of habitat, species composition of animals and plants in sled samples and a large set of environmental and physicochemical variables. Elsewhere in this report (1.1.1.3) another set of six habitat groupings were established using just the tow video data and these were mapped onto each of the three survey areas examined in this project.

We used a multivariate approach to examine how usefully these six "habitat" groupings (1.1.1.3) explained the differences/similarities in biota abundance captured by sled. For these analyses biota was classified into eight broad taxonomic levels and sled stations were allocated among the six habitat groupings (or "clusters") according to their location. These are shown in Figure 14 and the location of the site relative to the nine assemblage groupings is also shown.

There were 58 stations classified into habitat cluster 1 (dense sponge and gorgonians) with 28 stations in Camden Sound and 15 stations each in Maret Islands and Eclipse Archipelago. Just two stations were in habitat cluster 2 (variable habitat including a lot of soft sediment and burrowers, some octocorals), one each in the Maret Islands and Eclipse Archipelago. There were seventeen stations in habitat cluster 3 (medium sponge and gorgonians), 12 in Camden Sound, four in the Maret Islands and one in the Eclipse Archipelago. Habitat cluster 4 (sparse gorgonians, sponges and whips) comprised 25 stations, with 11 in Camden Sound, five in the Maret Islands and nine in the Eclipse Archipelago. There were no sled stations in habitat cluster 5 (dense hard corals and macroalgae) and two stations in habitat cluster 6 (sparse to medium hard coral and bryozoa), one each of the Maret Islands and the Eclipse Archipelago. As such, only habitat clusters 1, 3 and 4 contained enough sled stations at each of the three locations for a reasonable analysis of patterns. It is also important to note that the sled stations were not uniformly distributed among the habitat or assemblage clusters. That is, replication in the analysis is unbalanced.

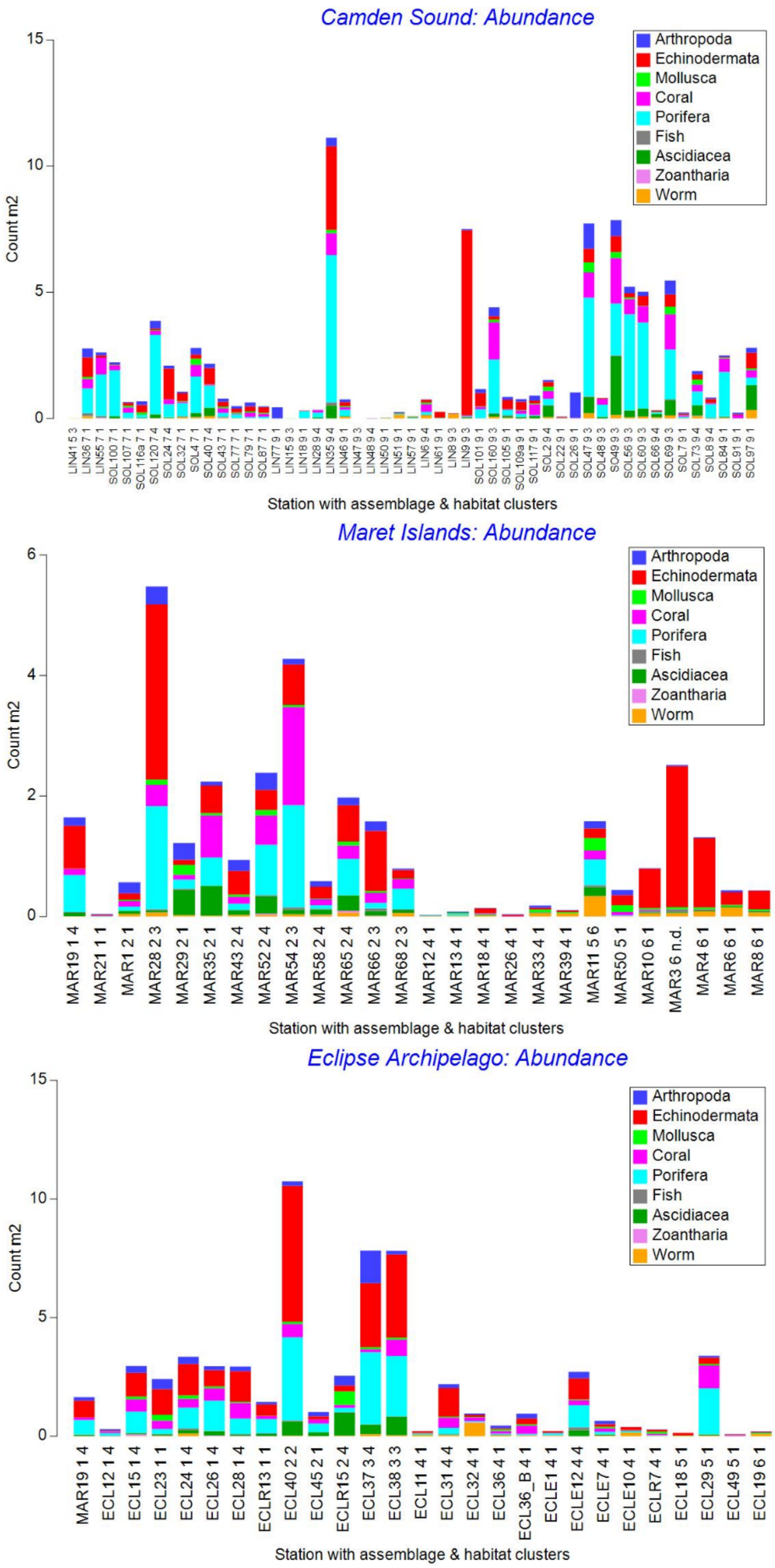

Figure 14 Distribution of sites and abundance of key taxa across the nine assemblage types identified at each of the three study locations. Colonial taxa that fragment easily such as Hydrozoans and Bryozoans are not included as they are not well represented by counts. The X-axis shows the station number, then above that the assemblage cluster number the sled station was located within (1-9) and above that the habitat classes (1-6) referred to in subreport 1.1.1.3.

Constrained ordination was used to relate the abundance of main groups with habitat clusters (Figure 15) and SIMPER analysis was used to identify the groups responsible for the multivariate patterns. There was a significant difference in abundance between habitat clusters 1 and 3, 1 and 4 and 3 and 4 (PERMANOVA, p<0.05). Sites grouped in habitat cluster 4 were most similar to each other in terms of abundance of main taxa (61% similarity) followed by sites in habitat cluster 1 (49%) and sites in habitat cluster 3 (41%) (SIMPER analysis). Average dissimilarity between habitat clusters 1 and 3 was 62% and was due to differences in location (PERMANOVA, p = 0.001, PERMDISP p = 0.304). Habitat cluster 3 had a three times higher abundance of sponges than habitat cluster 1, two times higher abundance of echinoderms and corals and slightly higher abundance of Arthropoda (mostly crustaceans). This was surprising given that habitat cluster 1 was based on the densest sponge and gorgonian habitats. The result probably reflects the patchiness of habitats and the difference in scale of the sleds which sampled the biota were 50-100 m long while the tow videos used to define the habitat clusters were 1500 m long. Average dissimilarity between clusters 1 and 4 was 50% and was due to difference in location or dispersion or a combination of both (PERMANOVA p = 0.001, PERMDISP p = 0.022). Sponges, echinoderms, corals, ascidians and arthropods were twice as abundant in habitat cluster 4 as in habitat cluster 1. Again this was the opposite of what was expected given habitat cluster contained the sparsest sponge and gorgonian communities. Clusters 3 and 4 were 51% dissimilar in location or dispersion (PERMANOVA p = 0.021, PERMDISP p = 0.049) with slightly higher abundance of sponges, echinoderms, corals and ascidians in sites classified in habitat cluster 3 than 4. This pattern was more in line with what was expected.

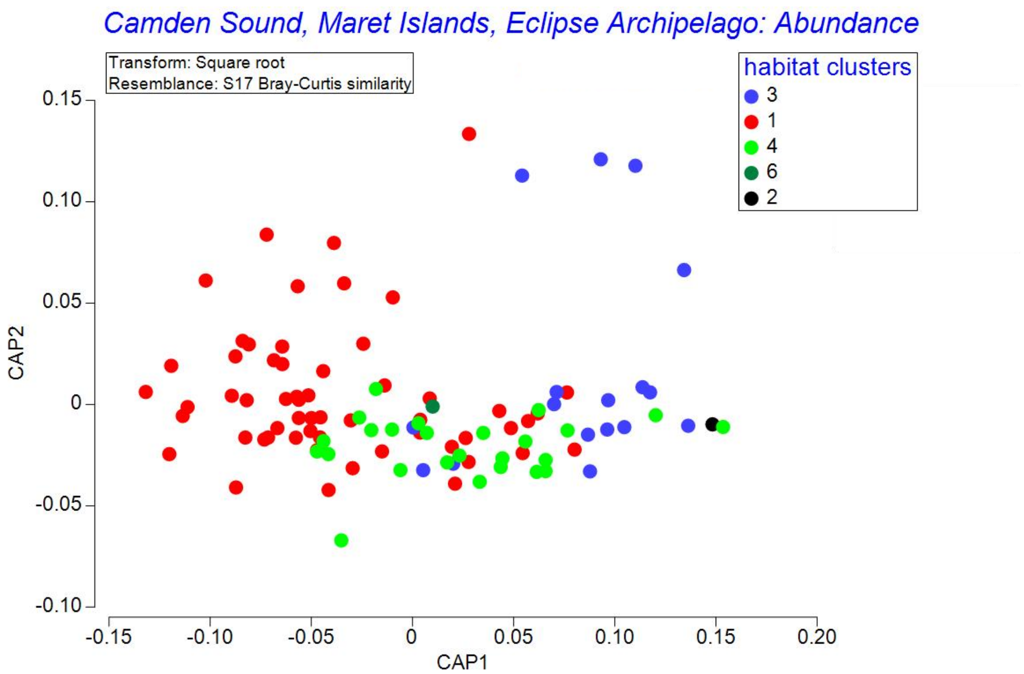

Figure 15. Distribution of sites across habitat clusters based on biota type and abundance at each station (see Figure 14) using Canonical Analysis of Principal coordinates (CAP).

In Camden Sound, 36 sites were classified in assemblage cluster 9, 14 sites in assemblage cluster 7 and one site in assemblage cluster 5. In the Maret Islands 11 sites were classified in assemblage cluster 2, six in assemblage 4, five in assemblage 6, and two in each of assemblage clusters 1 and 5. In the Eclipse Archipelago 10 sites were classified in assemblage cluster 4, eight in assemblage 1, three in assemblages 2 and 5, two in assemblage 3 and one in assemblage 6. Abundance of main groups of organisms was variable among habitat and assemblage clusters (Figure 14). In all three locations (Camden, Marets and Eclipse), all taxa were present in all clusters but their abundance differed among clusters and within stations grouped in the same cluster. The exception was assemblage 6 comprising a set of stations where sponges were absent.

We did not compare the nine assemblage clusters using multivariate analyses of biota abundance, as was done for the habitat clusters above, because the determination of the nine assemblage clusters was based on type and abundance (biomass) of sled biota (as well as video habitat data) and consequently the results of such analysis would not be independent.

Table 3 Summary table of characteristics of each assemblage category. See Appendix 1 for actual parameters for each character in each assemblage.

Characteristics	**Assemblage**								
Sled richness & biomass characteristics	1	2	3	4	5	6	7	8	9
Richness	mod. High	mod. High	High	mod. Low	mod. Low	mod. Low	mod. High	n.a.	mod. Low
Biomass	median	mod. High	High	mod. Low	median	mod. Low	median	n.a.	median
Sled biomass by taxonomic group									
Actinopterygii	mod. High	mod. High	High				mod. High	n.a.	mod. High
Anthozoa	mod. High	High	High	mod. Low		mod. Low		n.a.	
Ascidiacea	mod. High	mod. High	High			mod. Low		n.a.	
Asteroidea	mod. High	mod. High	High	mod. High	mod. High	mod. High	mod. High	n.a.	mod. High
Bivalvia	mod. High	mod. High	High	mod. High	mod. High	mod. High		n.a.	mod. High
Calcarea	Low	High	High	mod. Low	High	Low	High	n.a.	High
Crinoidea	mod. High	mod. High	High			Low	mod. High	n.a.	mod. High
Demospongiae	mod. High	mod. High	High	mod. Low		Low	mod. High	n.a.	
Echinoidea					mod. High	mod. High		n.a.	
Gastropoda	mod. High	mod. High	mod. High		mod. High	mod. Low	mod. High	n.a.	mod. High
Holothuroidea	High	mod. High	High	mod. High		mod. Low		n.a.	
Hydrozoa	mod. High	mod. High	High	mod. Low	mod. High	mod. Low	mod. High	n.a.	
Malacostraca	mod. High	mod. High	High		mod. Low	mod. Low	mod. High	n.a.	
Ophiuroidea	High	mod. High	High	mod. High		mod. Low	mod. High	n.a.	mod. High
Phaeophyceae	mod. High	mod. High	High	mod. High	mod. Low	Low	mod. High	n.a.	High
Video biohabitat characteristics									
No_Biohabitat	median	mod. Low	mod. low	median	median	median	mod. Low	mod. High	mod. Low
Alcyonarians	mod. High	mod. High	High	mod. High	Low	Low	mod. High	Low	mod. High
Whips	High	mod. High	median	mod. High	mod. High	mod. Low	High	Low	mod. High
Gorgonians	mod. High	mod. High	mod. High	median	median	median	mod. High	Low	mod. High
Sponges	median	mod. High	High	mod. Low	mod. Low	mod. Low	mod. High	Low	median
Corals	Low	High	Low	Low	Low	Low	High	Low	High
Bioturbated	mod. High	mod. High	Low	mod. High	mod. High	mod. High	mod. High	mod. High	High
Macroalgae	Low	Low	Low	Low	Low	Low	mod. High	Low	High
Seagrasss	Low	Low	Low	Low	Low	Low	Low	Low	median
Bryozoans	Low	Low	Low	Low	Low	Low	High	Low	High
Physical characteristics									
Nitrate CRS_NO3_AV	High	mod. Low	mod. Low	mod. High	mod. Low	Low	mod. High	Low	mod. Low
Nitrate seasonal range CRS_NO3_S	Wide				mod. Narrow		mod. Wide	mod. Narrow	Narrow

Oxygen CRS_O2_AV	High	mod. High	High		mod. High	High	mod. Low	mod. High	
Oxygen seasonal range CRS_O2_SR	Wide	mod. Narrow	Narrow		Narrow	Narrow	Wide	mod. Narrow	
Phosphate CRS_PO4_AV	High	mod. Low	Low		mod. Low	Low	mod. High	Low	
Phosphate seasonal range CRS_PO4_SR	Wide		Narrow	mod. Wide	mod. Narrow	Narrow	mod. Wide	Narrow	mod. Narrow
Salinity CRS_S_AV	Low	mod. Low	mod. High	mod. Low	mod. High		mod. High	High	High
Salinity seasonal range CRS_S_SR	mod. Narrow			Narrow			mod. Wide	Wide	Wide
Silicate CRS_SI_AV	High	mod. Low	Low		mod. Low	Low	mod. High	mod. Low	
Silicate seasonal range CRS_SI_SR	Wide		Narrow	mod. Wide		Narrow	mod. Narrow	Narrow	mod. Narrow
Seabed temperature CRS_T_AV	Low	mod. High	High	mod. Low	mod. High	High		High	mod. High
Seabed temperature seasonal range CRS_T_SR			Wide	mod. Narrow	mod. Wide	Wide	Narrow	Wide	Narrow
Depth GA_BATHY	Deep	mod. Shallow	Shallow	mod. Deep	mod. Shallow	Shallow	mod. Deep	Shallow	mod. Shallow
Carbonate GA_CRBNT	mod. High	High	mod. Low		mod. Low	mod. Low		Low	Low
Gravel GA_GRAVEL	mod. High	High	mod. Low			mod. Low	mod. High		mod. Low
Mud GA_MUD	mod. Low	Low	High		mod. High	High	mod. Low		
Mud GA_SAND		High	Low		mod. Low	Low	mod. High	mod. High	
Slope GA_SLOPE	mod. Low	mod. High			mod. High				mod. High
Seabed stress RBN_BSTRESS	mod. Low	mod. High			mod. High	mod. High		High	
Seabed stress seasonal range RBN_BSTRESS_SR	mod. Narrow	mod. Wide		mod. Narrow		mod. Wide		Wide	

Table 4 Top biomass species for each of the nine Kimberley assemblages. Note that sled samples were not undertaken in the area identified as assemblage 8.

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
372	1	53725	Chordata	Ascidiacea	-	-	2.3462998
290	1	10000021	Bryozoa	-	-	-	2.1840723
497	1	53739	Cnidaria	Hydrozoa	-	-	1.8110045
404	1	53730	Cnidaria	Anthozoa	Dendronephthya	sp.	1.5910913
1211	1	10003186	Porifera	Demospongiae	Stelletta	sp.	1.2551716
666	1	10000230	Echinodermata	Ophiuroidea	Euryale	aspera	1.2386990
498	1	10000276	Cnidaria	Scyphozoa	-	-	1.2236638
580	1	10006329	Echinodermata	Echinoidea	Prionocidaris	sp.	0.9999479
1306	1	10001707	Porifera	Demospongiae	Pseudoceratina	sp.	0.9879468
559	1	10000037	Echinodermata	Crinoidea	Comatula	pectinata	0.9245120
969	1	10006263	Porifera	Demospongiae	Echinodictyum	sp.	0.9111065
634	1	10000760	Echinodermata	Holothuroidea	Pseudocolochirus	axiologus	0.8835451
1073	1	10006231	Porifera	Demospongiae	Xestospongia	sp.	0.8727505
1238	1	10003189	Porifera	Demospongiae	Cinachyrella	sp.	0.8221000

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
2901	2	10000021	Bryozoa	-	-	-	3.6488149
3721	2	53725	Chordata	Ascidiacea	-	-	3.2325026
4971	2	53739	Cnidaria	Hydrozoa	-	-	2.8299855
1301	2	10000053	Porifera	Demospongiae	Ianthella	flabelliformis	1.5523182
1084	2	10000305	Porifera	Demospongiae	Xestospongia	testudinaria	1.4806796
4041	2	53730	Cnidaria	Anthozoa	Dendronephthya	sp.	1.3758401
1277	2	10000181	Porifera	Demospongiae	Aplysinopsis	sp. 1	1.2881640
1267	2	10000310	Porifera	Demospongiae	Hippospongia	sp. SS1	0.9822018
1300	2	10000175	Porifera	Demospongiae	Ianthella	basta	0.9504554
5591	2	10000037	Echinodermata	Crinoidea	Comatula	pectinata	0.9411682
963	2	10000032	Porifera	Demospongiae	Echinodictyum	cancellatum	0.8949216
1117	2	10001338	Porifera	Demospongiae	Crella	spinulata	0.8697746
1236	2	10000051	Porifera	Demospongiae	Cinachyrella	australiensis	0.8519476
929	2	10000047	Porifera	-	-	-	0.8273193
554	2	10000418	Echinodermata	Crinoidea	Comaster	multifidus	0.8152022

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
3722	3	53725	Chordata	Ascidiacea	-	-	5.3568011
9291	3	10000047	Porifera	-	-	-	4.3496444
5592	3	10000037	Echinodermata	Crinoidea	Comatula	pectinata	4.0115202
4972	3	53739	Cnidaria	Hydrozoa	-	-	3.6391961
972	3	10000248	Porifera	Demospongiae	Ectyoplasia	tabula	3.1434785
940	3	10006936	Porifera	Demospongiae	Axinella	sp.	2.9696549
2902	3	10000021	Bryozoa	-	-	-	2.9319967
1001	3	10000871	Porifera	Demospongiae	Higginsia	scabra	2.8720840
12771	3	10000181	Porifera	Demospongiae	Aplysinopsis	sp. 1	2.7152705
13011	3	10000053	Porifera	Demospongiae	Ianthella	flabelliformis	2.6719639
1091	3	10000242	Porifera	Demospongiae	Oceanapia	sp. KB1	2.6683318
468	3	10004206	Cnidaria	Anthozoa	Iciligorgia	sp.	2.6245476
6341	3	10000760	Echinodermata	Holothuroidea	Pseudocolochirus	axiologus	2.4757214
4042	3	53730	Cnidaria	Anthozoa	Dendronephthya	sp.	2.4258164
10731	3	10006231	Porifera	Demospongiae	Xestospongia	sp.	2.2317725
557	3	10009255	Echinodermata	Crinoidea	Comatella	maculata	2.2133737
958	3	10000187	Porifera	Demospongiae	Reniochalina	stalagmitis	2.1403282
1121	3	10000249	Porifera	Demospongiae	Iotrochota	sp. 2	2.0415856
961	3	10000126	Porifera	Demospongiae	Trikentrion	flabelliforme	1.9666550
956	3	10000833	Porifera	Demospongiae	Reniochalina	sp. 2	1.9659128
955	3	10006268	Porifera	Demospongiae	Reniochalina	sp.	1.9554627
12671	3	10000310	Porifera	Demospongiae	Hippospongia	sp. SS1	1.9546460
10841	3	10000305	Porifera	Demospongiae	Xestospongia	testudinaria	1.9508333
548	3	10005339	Echinodermata	Crinoidea	Comanthus	gisleni	1.9435457
1304	3	10000486	Porifera	Demospongiae	Ianthella	reticulata	1.9192372
1009	3	10000033	Porifera	Demospongiae	Acanthella	pulcherrima	1.8632117
1289	3	10000867	Porifera	Demospongiae	Luffariella	sp. SS10	1.8302244
549	3	10003050	Echinodermata	Crinoidea	Comanthus	parvicirrus	1.7652808
1005	3	10000197	Porifera	Demospongiae	Biemna	saucia	1.6573684
571	3	10000908	Echinodermata	Crinoidea	Zygometra	punctata	1.6478569
9631	3	10000032	Porifera	Demospongiae	Echinodictyum	cancellatum	1.6434088
1099	3	10013327	Porifera	Demospongiae	Oceanapia	sp. SS4	1.6290483
5541	3	10000418	Echinodermata	Crinoidea	Comaster	multifidus	1.6269106

1111	3	10000183	Porifera	Demospongiae	Chondropsis	sp. 1	1.6142630
12361	3	10000051	Porifera	Demospongiae	Cinachyrella	australiensis	1.5833126
941	3	10000253	Porifera	Demospongiae	Axinella	sp. KB1	1.5833126
1143	3	10000048	Porifera	Demospongiae	Antho	ridleyi	1.5149936
563	3	10009575	Echinodermata	Crinoidea	Amphimetra	tessellata	1.5147207
990	3	10000282	Porifera	Demospongiae	Raspailia	vestigifera	1.4568337
1166	3	10000208	Porifera	Demospongiae	Stylissa	flabelliformis	1.3933467
492	3	10000172	Cnidaria	Anthozoa	Subergorgia	suberosa	1.3910069
1239	3	10000199	Porifera	Demospongiae	Cinachyrella	sp. SS5	1.2573798
1078	3	10000511	Porifera	Demospongiae	Xestospongia	sp. KB1	1.2573798
9691	3	10006263	Porifera	Demospongiae	Echinodictyum	sp.	1.2232788
948	3	10000219	Porifera	Demospongiae	Phakellia	tropicalis	1.1814266
1234	3	10000241	Porifera	Demospongiae	Cinachyra	sp. BB1	1.1167961
489	3	10004209	Cnidaria	Anthozoa	Melithaea	sp. L	1.1167961
1098	3	10000858	Porifera	Demospongiae	Oceanapia	sp. SS13	1.1002930
437	3	10005383	Cnidaria	Anthozoa	Echinogorgia	sp. 13	1.0832265
407	3	10000207	Cnidaria	Anthozoa	Nephthyigorgia	kükenthali	1.0744697
1226	3	10000318	Porifera	Demospongiae	Geodia	sp. CERF1	1.0744697
1258	3	10004149	Porifera	Demospongiae	Psammocinia	bulbosa	1.0744697
1030	3	10000345	Porifera	Demospongiae	Callyspongia	sp. KB3	1.0033947
1129	3	10000179	Porifera	Demospongiae	Clathria	abietina	1.0033947
1103	3	10013285	Porifera	Demospongiae	Siphonodictyon	sp. KB2	0.9772654
984	3	10000601	Porifera	Demospongiae	Raspailia	clathrata	0.9496951
998	3	10002021	Porifera	Demospongiae	Thrinacophora	cervicornis	0.9496951
1217	3	10000490	Porifera	Demospongiae	Tribrachium	sp. SS1	0.9205153
622	3	10000001	Echinodermata	Holothuroidea	Colochirus	quadrangularis	0.8895264
993	3	10000243	Porifera	Demospongiae	Sollasella	sp. KB1	0.8765723
493	3	10000163	Cnidaria	Anthozoa	Carijoa	sp.	0.8564893
665	3	10000397	Echinodermata	Ophiuroidea	-	-	0.8471902

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
2903	4	10000021	Bryozoa	-	-	-	1.0952346
3723	4	53725	Chordata	Ascidiacea	-	-	0.8633028

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
4973	5	53739	Cnidaria	Hydrozoa	-	-	2.1176583
2904	5	10000021	Bryozoa	-	-	-	1.7723175
1087	5	10003185	Porifera	Demospongiae	Oceanapia	sp.	1.2069582
10732	5	10006231	Porifera	Demospongiae	Xestospongia	sp.	1.0943818
472	5	10000009	Cnidaria	Anthozoa	-	-	1.0544220
1305	5	10001724	Porifera	Demospongiae	Ianthella	sp.	0.9696411
1248	5	10000711	Porifera	Demospongiae	Dendrilla	sp. EG1	0.8709395
573	5	53715	Echinodermata	Echinoidea	-	-	0.8651885
3724	5	53725	Chordata	Ascidiacea	-	-	0.8613269

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
600	6	53732	Echinodermata	Echinoidea	Brissopsis	luzonica	2.7582115
2	6	53705	Annelida	-	-	-	1.0624406
4981	6	10000276	Cnidaria	Scyphozoa	-	-	0.9780907

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
4974	7	53739	Cnidaria	Hydrozoa	-	-	2.0665
2905	7	10000021	Bryozoa	-	-	-	1.8711144
3725	7	53725	Chordata	Ascidiacea	-	-	1.4932500
12362	7	10000051	Porifera	Demospongiae	Cinachyrella	australiensis	1.3480750
9632	7	10000032	Porifera	Demospongiae	Echinodictyum	cancellatum	1.3315959
13012	7	10000053	Porifera	Demospongiae	Ianthella	flabelliformis	1.1553454
579	7	53751	Echinodermata	Echinoidea	Prionocidaris	bispinosa	1.1464505
9581	7	10000187	Porifera	Demospongiae	Reniochalina	stalagmitis	1.0430540
10842	7	10000305	Porifera	Demospongiae	Xestospongia	testudinaria	0.9833458
1219	7	10000095	Porifera	Demospongiae	Erylus	sp. SS1	0.8905528
4721	7	10000009	Cnidaria	Anthozoa	-	-	0.8799868
1212	7	10000324	Porifera	Demospongiae	Stelletta	sp. KB1	0.8794942
12391	7	10000199	Porifera	Demospongiae	Cinachyrella	sp. SS5	0.8090303

	CL	CSIRO_CODE	PHYLUM	CLASS	GENUS	SPECIES	aveLOGnBiomass
3726	9	53725	Chordata	Ascidiacea	-	-	1.8770019
2906	9	10000021	Bryozoa	-	-	-	1.5404152
13013	9	10000053	Porifera	Demospongiae	Ianthella	flabelliformis	1.4025806
4975	9	53739	Cnidaria	Hydrozoa	-	-	1.3444958
4043	9	53730	Cnidaria	Anthozoa	Dendronephthya	sp.	1.0180636
9582	9	10000187	Porifera	Demospongiae	Reniochalina	stalagmitis	0.9844260

9633	9	10000032	Porifera	Demospongiae	Echinodictyum	cancellatum	0.9497974
12772	9	10000181	Porifera	Demospongiae	Aplysinopsis	sp. 1	0.9302381

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5 Appendices

Appendix 1

This appendix contains tables of parameters for each character assessed for each of the nine assemblages identified in the Kimberley survey area.

Table A2.1. Biophysical charcteristics of Kimberley assemblage number 1.

Sled richness & biomass characteristics
moderately high Richness (18.4-109.4 species)
median Biomass (69.9-1149.6 kg/Ha)
Biomass by taxonomic group
moderately high Sled biomass Actinopterygii (0.0599-5.11 kg/Ha)
moderately high Sled biomass Anthozoa (1.65-44.8 kg/Ha)
moderately high Sled biomass Ascidiacea (0.57-67 kg/Ha)
moderately high Sled biomass Asteroidea (0-12.2 kg/Ha)
moderately high Sled biomass Bivalvia (0-42.2 kg/Ha)
low Sled biomass Calcarea (0-0 kg/Ha)
moderately high Sled biomass Crinoidea (0.0126-45.3 kg/Ha)
moderately high Sled biomass Demospongiae (5.01-600 kg/Ha)
moderately high Sled biomass Gastropoda (0-5.3 kg/Ha)
high Sled biomass Holothuroidea (0.655-64 kg/Ha)
moderately high Sled biomass Hydrozoa (0.229-47.2 kg/Ha)
moderately high Sled biomass Malacostraca (0.523-7.72 kg/Ha)
high Sled biomass Ophiuroidea (0.0253-29.4 kg/Ha)
moderately high Sled biomass Phaeophyceae (0-2.34 kg/Ha)
Video biohabitat characteristics
median No_Biohabitat (8.4-100%)
moderately high Alcyonarians (0-2.3%)
moderately high Whips (0-1.8%)
moderately high Gorgonians (0-8.4%)
median Sponges (0-15.4%)
low Corals (0-0%)
moderately high Bioturbated (0-8.5%)
low MacroAlgae (0-0%)
Physical characteristics
high nitrate CRS_NO3_AV (1.76-2.93 µM)
wide nitrate seasonal range CRS_NO3_SR (2.38-4.25 µM)
low oxygen CRS_O2_AV (4.07-4.18 mL L^{-1})
moderately wide oxygen seasonal range CRS_O2_SR (0.754-0.896 mL L^{-1})
high phosphate CRS_PO4_AV (0.359-0.418 µM)
wide phosphate seasonal range CRS_PO4_SR (0.375-0.49 µM)
low salinity CRS_S_AV (34.6-34.8 ‰)
moderately narrow salinity seasonal range CRS_S_SR (0.459-0.585 ‰)
high silicate CRS_SI_AV (7.36-8.31 µM)
wide silicate seasonal range CRS_SI_SR (4.45-6.61 µM)
low seabed temperature CRS_T_AV (26.2-26.7 °C)
deep GA_BATHY (52.9-61 m)
moderately high carbonate GA_CRBNT (59-81.5 %)
moderately high gravel GA_GRAVEL (8.38-31 %)
moderately low mud GA_MUD (18.7-52.7 %)
moderately low slope GA_SLOPE (0.0061-0.184 °)
moderately low seabed stress RBN_BSTRESS (0.0176-1.28 $\times 10^{-3}$ Nm^{-2})
moderately narrow seabed stress seasonal range RBN_BSTRESS_SR (0.000723-0.0382 Nm^{-2})

Table A2.2. Biophysical charcteristics of Kimberley assemblage number 2.

Sled richness & biomass characteristics
moderately high Richness (24.8-144.2 species)
moderately high Biomass (52.5-11378.4 kg/Ha)
Biomass by taxonomic group
moderately high Sled biomass Actinopterygii (0-19.9 kg/Ha)
high Sled biomass Anthozoa (1.25-709 kg/Ha)
moderately high Sled biomass Ascidiacea (1.69-216 kg/Ha)
moderately high Sled biomass Asteroidea (0-16.6 kg/Ha)
moderately high Sled biomass Bivalvia (0-66 kg/Ha)
high Sled biomass Calcarea (0-8.93 kg/Ha)
moderately high Sled biomass Crinoidea (0-158 kg/Ha)
moderately high Sled biomass Demospongiae (5.04-7960 kg/Ha)
moderately high Sled biomass Gastropoda (0.083-5.12 kg/Ha)
moderately high Sled biomass Holothuroidea (0.0568-71.5 kg/Ha)
moderately high Sled biomass Hydrozoa (0.151-543 kg/Ha)
moderately high Sled biomass Malacostraca (0.166-17.6 kg/Ha)
moderately high Sled biomass Ophiuroidea (0.0413-12 kg/Ha)
moderately high Sled biomass Phaeophyceae (0-0.958 kg/Ha)
Video biohabitat characteristics
moderately low No_Biohabitat (0.2-99.5%)
moderately high Alcyonarians (0-6.3%)
moderately high Whips (0-2.4%)
moderately high Gorgonians (0-21%)
moderately high Sponges (0-37.4%)
high Corals (0-0.4%)
moderately high Bioturbated (0-0.3%)
low MacroAlgae (0-0%)
low Seagrass (0-0%)
high Bryozoans (0-0.4%)
Physical characteristics
moderately low nitrate CRS_NO3_AV (0.371-1.53 µM)
moderately high oxygen CRS_O2_AV (4.16-4.53 mL L^{-1})
moderately narrow oxygen seasonal range CRS_O2_SR (0.336-0.858 mL L^{-1})
moderately low phosphate CRS_PO4_AV (0.256-0.346 µM)
moderately low salinity CRS_S_AV (34.7-34.9 ‰)
moderately low silicate CRS_SI_AV (5.89-7.27 µM)
moderately high seabed temperature CRS_T_AV (26.7-27.9 °C)
moderately shallow GA_BATHY (0.132-52.1 m)
high carbonate GA_CRBNT (75.9-87.5 %)
high gravel GA_GRAVEL (11.5-42.7 %)
low mud GA_MUD (8.21-25.6 %)
high sand GA_SAND (41.7-71.5 %)
moderately high slope GA_SLOPE (0.0159-0.58 °)
moderately high seabed stress RBN_BSTRESS (0.0832-6.56 $\times10^{-3}$ Nm^{-2})
moderately wide seabed stress seasonal range RBN_BSTRESS_SR (0.00269-0.235 Nm^{-2})

Table A2.3. Biophysical charcteristics of Kimberley assemblage number 3.

Sled richness & biomass characteristics
high Richness (81.8-169.1 species)
high Biomass (1471.3-5228.9 kg/Ha)
Biomass by taxonomic group
high Sled biomass Actinopterygii (1.72-7.41 kg/Ha)
high Sled biomass Anthozoa (24.6-287 kg/Ha)
high Sled biomass Ascidiacea (103-539 kg/Ha)
high Sled biomass Asteroidea (11.2-49.5 kg/Ha)
high Sled biomass Bivalvia (1.3-17.8 kg/Ha)
high Sled biomass Calcarea (0.758-14.4 kg/Ha)
high Sled biomass Crinoidea (82-127 kg/Ha)
high Sled biomass Demospongiae (1040-3050 kg/Ha)
moderately high Sled biomass Echinoidea (11.7-15.5 kg/Ha)
high Sled biomass Gastropoda (4.04-5.95 kg/Ha)
high Sled biomass Holothuroidea (11.3-143 kg/Ha)
high Sled biomass Hydrozoa (36.5-37.6 kg/Ha)
high Sled biomass Ophiuroidea (3.04-4.68 kg/Ha)
low Sled biomass Phaeophyceae (0-0 kg/Ha)
Video biohabitat characteristics
moderately low No_Biohabitat (1.5-43.3%)
high Alcyonarians (3.8-12%)
median Whips (0-0.1%)"
moderately high Gorgonians (0.7-3.7%)
high Sponges (13.2-25%)
low Corals (0-0%)
low Bioturbated (0-0%)
low MacroAlgae (0-0%)
low Seagrass (0-0%)
low Bryozoans (0-0%)
Physical characteristics
moderately low nitrate CRS_NO3_AV (0.393-0.469 µM)
high oxygen CRS_O2_AV (4.49-4.54 mL L^{-1})
narrow oxygen seasonal range CRS_O2_SR (0.319-0.333 mL L^{-1})
low phosphate CRS_PO4_AV (0.26-0.281 µM)
narrow phosphate seasonal range CRS_PO4_SR (0.087-0.17 µM)
moderately high salinity CRS_S_AV (34.8-34.9 ‰)
low silicate CRS_SI_AV (5.34-6 µM)
narrow silicate seasonal range CRS_SI_SR (0.899-3.27 µM)
high seabed temperature CRS_T_AV (27.6-28 °C)
wide seabed temperature seasonal range CRS_T_SR (3.45-4.01 °C)
shallow GA_BATHY (0-26.1 m)
moderately low carbonate GA_CRBNT (49.3-82.5 %)
moderately low gravel GA_GRAVEL (5.14-17.6 %)
high mud GA_MUD (19.2-68.5 %)
low sand GA_SAND (21.6-70.9 %)

Table A2.4. Biophysical charcteristics of Kimberley assemblage number 4.

Sled richness & biomass characteristics
moderately low Richness (5.5-74.2 species)
moderately low Biomass (3-1172 kg/Ha)
Biomass by taxonomic group
moderately low Sled biomass Anthozoa (0-30.2 kg/Ha)
moderately high Sled biomass Asteroidea (0-11.2 kg/Ha)
moderately high Sled biomass Bivalvia (0-19.1 kg/Ha)
moderately low Sled biomass Calcarea (0-0.162 kg/Ha)
moderately low Sled biomass Demospongiae (0-351 kg/Ha)
moderately high Sled biomass Holothuroidea (0-19.1 kg/Ha)
moderately low Sled biomass Hydrozoa (0-3.59 kg/Ha)
moderately high Sled biomass Ophiuroidea (0-7.31 kg/Ha)
moderately high Sled biomass Phaeophyceae (0-1.05 kg/Ha)
Video biohabitat characteristics
median No_Biohabitat (14.9-100%)"
moderately high Alcyonarians (0-2.2%)"
moderately high Whips (0-0.5%)"
median Gorgonians (0-7.3%)"
median Sponges (0-13.3%)"
low Corals (0-0%)"
moderately high Bioturbated (0-58.6%)"
low MacroAlgae (0-0%)"
low Seagrass (0-0%)"
low Bryozoans (0-0%)
Physical characteristics
moderately high nitrate CRS_NO3_AV (0.658-1.65 µM)
moderately wide phosphate seasonal range CRS_PO4_SR (0.186-0.359 µM)
moderately low salinity CRS_S_AV (34.7-34.8 ‰)
narrow salinity seasonal range CRS_S_SR (0.426-0.51 ‰)
moderately wide silicate seasonal range CRS_SI_SR (3.3-4.39 µM)
moderately low seabed temperature CRS_T_AV (26.7-27.1 °C)
moderately narrow seabed temperature seasonal range CRS_T_SR (3.21-3.42 °C)
moderately deep GA_BATHY (32.1-51.6 m)
moderately narrow seabed stress seasonal range RBN_BSTRESS_SR (0.000616-0.0428 Nm^{-2})

Table A2.5. Biophysical charcteristics of Kimberley assemblage number 5.

Sled richness & biomass characteristics
moderately low Richness (3.2-60.5 species)
median Biomass (22.9-3313.9 kg/Ha)
Biomass by taxonomic group
moderately high Sled biomass Asteroidea (0-0.384 kg/Ha)
moderately high Sled biomass Bivalvia (0.476-11.7 kg/Ha)
high Sled biomass Calcarea (0-13.2 kg/Ha)
moderately high Sled biomass Echinoidea (0.0185-118 kg/Ha)
moderately high Sled biomass Gastropoda (0-4.17 kg/Ha)
moderately high Sled biomass Hydrozoa (0-35 kg/Ha)
moderately low Sled biomass Malacostraca (0-1.09 kg/Ha)
moderately low Sled biomass Phaeophyceae (0-0.166 kg/Ha)
Video biohabitat characteristics
median No_Biohabitat (4.4-100%)
low Alcyonarians (0-0%)
moderately high Whips (0-0.1%)
median Gorgonians (0-0.9%)
moderately low Sponges (0-1.3%)
low Corals (0-0%)
moderately high Bioturbated (0-53.2%)
low MacroAlgae (0-0%)
low Seagrass (0-0%)
high Bryozoans (0-19.7%)
Physical characteristics
moderately low nitrate CRS_NO3_AV (0.379-0.62 µM)
moderately narrow nitrate seasonal range CRS_NO3_SR (0.785-1.1 µM)
moderately high oxygen CRS_O2_AV (4.38-4.53 mL L^{-1})
narrow oxygen seasonal range CRS_O2_SR (0.338-0.429 mL L^{-1})
moderately low phosphate CRS_PO4_AV (0.253-0.32 µM)
moderately narrow phosphate seasonal range CRS_PO4_SR (0.101-0.188 µM)
moderately high salinity CRS_S_AV (34.8-35 ‰)
moderately low silicate CRS_SI_AV (5.98-7.02 µM)
moderately high seabed temperature CRS_T_AV (27.2-27.9 °C)
moderately wide seabed temperature seasonal range CRS_T_SR (3.26-3.76 °C)
moderately shallow GA_BATHY (0-31.3 m)
moderately low carbonate GA_CRBNT (49.1-72.2 %)
moderately high mud GA_MUD (31.2-70.8 %)
moderately low sand GA_SAND (21.7-50.5 %)
moderately high slope GA_SLOPE (0.024-0.846 °)
moderately high seabed stress RBN_BSTRESS (0.0391-3.34 $\times 10^{-3}$ Nm^{-2})

Table A2.6. Biophysical charcteristics of Kimberley assemblage number 6.

Sled richness & biomass characteristics
moderately low Richness (9.8-19.5 species)
moderately low Biomass (17-298.4 kg/Ha)
Biomass by taxonomic group
moderately low Sled biomass Anthozoa (0-10.3 kg/Ha)
moderately low Sled biomass Ascidiacea (0.0994-4.29 kg/Ha)
moderately high Sled biomass Asteroidea (0-6.34 kg/Ha)
moderately high Sled biomass Bivalvia (0.704-1.66 kg/Ha)
low Sled biomass Calcarea (0-0 kg/Ha)
low Sled biomass Crinoidea (0-0 kg/Ha)
low Sled biomass Demospongiae (0-0 kg/Ha)
moderately high Sled biomass Echinoidea (6.98-62.8 kg/Ha)
moderately low Sled biomass Gastropoda (0-0.295 kg/Ha)
moderately low Sled biomass Holothuroidea (0-0.233 kg/Ha)
moderately low Sled biomass Hydrozoa (0-0.545 kg/Ha)
moderately low Sled biomass Malacostraca (0.0829-1.37 kg/Ha)
moderately low Sled biomass Ophiuroidea (0.0166-0.367 kg/Ha)
low Sled biomass Phaeophyceae (0-0 kg/Ha)
Video biohabitat characteristics
median No_Biohabitat (79.1-100%)
low Alcyonarians (0-0%)
moderately low Whips (0-0%)
median Gorgonians (0-4%)
moderately low Sponges (0-3.3%)
low Corals (0-0%)
moderately high Bioturbated (0-1%)
low MacroAlgae (0-0%)
low Seagrass (0-0%)
low Bryozoans (0-0%)
Physical characteristics
low nitrate CRS_NO3_AV (0.386-0.428 µM)
high oxygen CRS_O2_AV (4.51-4.54 mL L^{-1})
narrow oxygen seasonal range CRS_O2_SR (0.336-0.387 mL L^{-1})
low phosphate CRS_PO4_AV (0.255-0.309 µM)
narrow phosphate seasonal range CRS_PO4_SR (0.0959-0.126 µM)
low silicate CRS_SI_AV (5.68-6.24 µM)
narrow silicate seasonal range CRS_SI_SR (0.898-2.73 µM)
high seabed temperature CRS_T_AV (27.7-27.9 °C)
wide seabed temperature seasonal range CRS_T_SR (3.79-3.98 °C)
shallow GA_BATHY (0-17.2 m)
moderately low carbonate GA_CRBNT (45.7-74.2 %)
moderately low gravel GA_GRAVEL (2.79-21 %)
high mud GA_MUD (29.4-85.9 %)
low sand GA_SAND (10.6-51.9 %)
moderately high seabed stress RBN_BSTRESS (0.0777-3.94 $\times 10^{-3}$ Nm^{-2})
moderately wide seabed stress seasonal range RBN_BSTRESS_SR (0.00336-0.156 Nm^{-2})

Table A2.7. Biophysical charcteristics of Kimberley assemblage number 7.

Sled richness & biomass characteristics
moderately high Richness (35.2-100.5 species)
median Biomass (44.8-771.3 kg/Ha)
Biomass by taxonomic group

moderately high Sled biomass Actinopterygii (0-5.05 kg/Ha)
moderately high Sled biomass Asteroidea (0-7.35 kg/Ha)
high Sled biomass Calcarea (0-1.56 kg/Ha)
moderately high Sled biomass Crinoidea (0.0496-49.3 kg/Ha)
moderately high Sled biomass Demospongiae (12.7-623 kg/Ha)
moderately high Sled biomass Gastropoda (0.0515-2.33 kg/Ha)
moderately high Sled biomass Hydrozoa (0.734-43 kg/Ha)
moderately high Sled biomass Malacostraca (0.668-9.71 kg/Ha)
moderately high Sled biomass Ophiuroidea (0.0515-13.1 kg/Ha)
moderately high Sled biomass Phaeophyceae (0-2.82 kg/Ha)
<u>Video biohabitat characteristics</u>
moderately low No_Biohabitat (0-99%)
moderately high Alcyonarians (0-14.5%)
high Whips (0-8.1%)
moderately high Gorgonians (0-12.9%)
moderately high Sponges (0.1-44.6%)
high Corals (0-1%)
moderately high Bioturbated (0-8%)
moderately high MacroAlgae (0-0.2%)
low Seagrass (0-0%)
high Bryozoans (0-3.3%)
<u>Physical characteristics</u>
moderately high nitrate CRS_NO3_AV (0.852-1.54 µM)
moderately wide nitrate seasonal range CRS_NO3_SR (0.858-2.17 µM)
moderately low oxygen CRS_O2_AV (4.16-4.21 mL L^{-1})
wide oxygen seasonal range CRS_O2_SR (0.732-0.898 mL L^{-1})
moderately high phosphate CRS_PO4_AV (0.327-0.348 µM)
moderately wide phosphate seasonal range CRS_PO4_SR (0.204-0.351 µM)
moderately high salinity CRS_S_AV (34.8-35 ‰)
moderately wide salinity seasonal range CRS_S_SR (0.503-0.806 ‰)
moderately high silicate CRS_SI_AV (7.02-7.5 µM)
moderately narrow silicate seasonal range CRS_SI_SR (2.48-3.65 µM)
narrow seabed temperature seasonal range CRS_T_SR (3.09-3.36 °C)
moderately deep GA_BATHY (37.4-52.1 m)
moderately high gravel GA_GRAVEL (7.24-29.5 %)
moderately low mud GA_MUD (22.4-50.3 %)
moderately high sand GA_SAND (37.2-55.9 %)

Table A2.8. Biophysical charcteristics of Kimberley assemblage number 8. Note that there were no sled stations within assemblage 8.

Sled richness & biomass characteristics
n.a.
Biomass by taxonomic group
n.a.
Video biohabitat characteristics
Moderately high No_Biohabitat (96.1-99.5%)
low Alcyonarians (0-0%)
low Whips (0-0%)
low Gorgonians (0-0%)
low Sponges (0-0%)
low Corals (0-0%)
moderately high Bioturbated (0.5-3.9%)
low Caulerpa (0-0%)
low Rhodoliths (0-0%)
low Bryozoans (0-0%)
Physical characteristics
low nitrate CRS_NO3_AV (0.388-0.427 µM)
moderately narrow nitrate seasonal range CRS_NO3_SR (0.801-1.07 µM)
moderately high oxygen CRS_O2_AV (4.45-4.51 mL L^{-1})
moderately narrow oxygen seasonal range CRS_O2_SR (0.358-0.464 mL L^{-1})
low phosphate CRS_PO4_AV (0.236-0.314 µM)
narrow phosphate seasonal range CRS_PO4_SR (0.0992-0.169 µM)
high salinity CRS_S_AV (34.9-35.2 ‰)
wide salinity seasonal range CRS_S_SR (0.644-1.22 ‰)
moderately low silicate CRS_SI_AV (5.87-7.2 µM)
narrow silicate seasonal range CRS_SI_SR (0.766-2.69 µM)
high seabed temperature CRS_T_AV (27.8-28 °C)
wide seabed temperature seasonal range CRS_T_SR (3.39-3.83 °C)
shallow GA_BATHY (0-20.3 m)
low carbonate GA_CRBNT (45.1-73.7 %)
moderately high sand GA_SAND (43.9-56.6 %)
high seabed stress RBN_BSTRESS (1.84-52.6 $\times 10^{-3}$ Nm^{-2})
wide seabed stress seasonal range RBN_BSTRESS_SR (0.0581-2.27 Nm^{-2}

Table A2.9. Biophysical charcteristics of Kimberley assemblage number 9.

Sled richness & biomass characteristics
moderately low Richness (3.3-129.3 species)
median Biomass (4.5-3091 kg/Ha)
Biomass by taxonomic group
moderately high Sled biomass Actinopterygii (0-7.5 kg/Ha)
moderately high Sled biomass Asteroidea (0-76.9 kg/Ha)
moderately high Sled biomass Bivalvia (0-42 kg/Ha)
high Sled biomass Calcarea (0-9.7 kg/Ha)
moderately high Sled biomass Crinoidea (0-33.6 kg/Ha)
moderately high Sled biomass Gastropoda (0-3.37 kg/Ha)
moderately high Sled biomass Ophiuroidea (0-3.27 kg/Ha)
high Sled biomass Phaeophyceae (0-6.28 kg/Ha)
Video biohabitat characteristics
moderately low No_Biohabitat (0-100%)
moderately high Alcyonarians (0-7.9%)
moderately high Whips (0-4.5%)
moderately high Gorgonians (0-15.7%)
median Sponges (0-31.6%)
high Corals (0-1%)
high Bioturbated (0-99.2%)
high MacroAlgae (0-1.4%)
median Seagrass (0-0%)
high Bryozoans (0-2.7%)
Physical characteristics
moderately low nitrate CRS_NO3_AV (0.388-0.784 µM)
narrow nitrate seasonal range CRS_NO3_SR (0.75-1 µM)
moderately narrow phosphate seasonal range CRS_PO4_SR (0.103-0.2 µM)
high salinity CRS_S_AV (34.9-35.1 ‰)
wide salinity seasonal range CRS_S_SR (0.694-1.13 ‰)
moderately narrow silicate seasonal range CRS_SI_SR (1.47-3.22 µM)
moderately high seabed temperature CRS_T_AV (27.2-28 °C)
narrow seabed temperature seasonal range CRS_T_SR (2.88-3.54 °C)
moderately shallow GA_BATHY (1.48-35.6 m)
low carbonate GA_CRBNT (45.1-67.1 %)
moderately low gravel GA_GRAVEL (1.32-31.1 %)
moderately high slope GA_SLOPE (0.0238-1 °)