Identification of Demosponges, Echinoderms and Molluscs from the Ningaloo Deepwater Surveys – 2006 to 2008 Expeditions.

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Introduction.

This project aimed to identify the species comprising the deeper water benthic communities off the Ningaloo reef tract. Collection methods allowed for sampling of benthic invertebrates on hard substrata between depths of 18 to 144 metres. Soft sediment invertebrates were not included in this study.

Prior to this study an examination of towed video footage supplied by the Australian Institute of Marine Science (AIMS) suggested that sponge communities were diverse and variable in these Ningaloo environments (Fromont, unpub. data). Little was known about the fauna that occurred in these depths and the collaborative study lead by AIMS (WAMSI Node 3, Project 1, subproject 3.1.1: Deepwater communities at Ningaloo Marine Park) and reported on here was planned to address this significant knowledge gap.

The Ningaloo reef system lies in tropical waters and extends approximately 290 kilometres from North West Cape to Red Bluff, Western Australia (CALM, 2004). In the northern section, offshore of the reef, is a rapid drop off in bottom depth and a narrow shelf (Le Provost et al., 2000). Further south below Pt. Cloates the shelf widens. Ningaloo Reef is the largest fringing coastal reef system in Australia (Taylor and Pearce, 1999).

A set of protocols was established for sampling the biota in a quantitative manner, and detailed methods were outlined for the preservation of specimens of each phyla collected. All species of all phyla were collected. Taxonomists in the WA Museum's Aquatic Zoology department, or affiliated to other Australian Museums, identified the dominant sponges, echinoderms and molluscs collected in the study. Specimens of other taxa collected are held in the WA Museum for future identification.

Standardised field collecting methods and preservation protocols allowed for the biodiversity data to be directly comparable between stations and collecting years in 2007 and 2008 (methods were still being developed in 2006 and are not consistent with the latter years). This data is available to be compared and analysed with other datasets obtained in WAMSI Node 3, Project 1 such as broadscale habitat classifications from towed video, bathymetry and acoustic surveys, and demersal fish assemblages. This overall synthesis of data will greatly improve the knowledge of species distributions and habitat characteristics in the region.

The primary aims of this component of the study were to contribute to the following management questions:

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

Methods.

Station selection. Sampling stations were determined by AIMS staff with reference to acoustic generated maps and video footage that indicated different habitat types in the area. Distribution of the organisms within these areas would indicate whether the fauna differed within or between the mapped habitats.

Data collection. Sled tows. Sampling was quantitative with sled tows standardised as much as possible to sample 50 metre lengths of the substrate with latitude, longitude and depth recorded at the start and end of each tow. These tows were intended to collect a representative subset of biota from different habitats. It was difficult to sample highly consolidated outcropping reef, which occurred in some areas, as the sled could bounce on this substrate and therefore not consistently collect the biota. Soft sediment habitats were not sampled for benthic biodiversity.

Each identifiable taxon collected was weighed if greater than 100 grams wet weight, the numbers of individuals of each taxon were counted and voucher specimens preserved. The priority taxa in the project were the filter feeders, specifically the Porifera, because of their suspected high frequency of occurrence in the region, the lack of knowledge of the species occurring there, and lack of information about their distribution and abundance.

Vouchered specimens of each taxon have been formally accessioned into the WA Museum collections.

Specimen collection. Weights (as surrogates for biomass/dominance). The sled cod-end was weighed from a standard fixed-lifting point both empty and full so the overall catch-weight could be determined. Total sponge catch was weighed for each tow, sponges were separated into morphospecies and weighed separately for each station. The dominant morphospecies (≤10) were determined by weight or by volume judged by eye. Where weight was <100 g, it was recorded as such as no scales were available on board that could record weights of less than 100 g. The weights of other sessile organisms collected were recorded (if dominated by another phyla, e.g. cnidaria, rhodoliths, bryozoa etc) such that an overall weight was recorded for each taxon group. Cnidarians, ascidians, echinoderms, molluscs, crustaceans, fishes, worms, hydroids, bryozoans and algae were separated from each other and weighed if their weight exceeded 100 g.

Voucher Specimens of Sponges. A voucher specimen representative of the size and shape of each sponge morphospecies was selected and the remaining specimens were discarded. Voucher specimens were labelled with a field number and name and photographed with a scale bar and label. Details were recorded in a field notebook. Voucher specimens were preserved in 75% ethanol and some large specimens were frozen.

Specimen preservation – other phyla. Echinoderms were divided into classes: asteroids, crinoids, echinoids, ophiuroids, holothurians. Where there were multiple specimens of morphospecies of asteroids and crinoids, some were preserved in 75% ethanol and some were fixed in 10% formalin. Ophiuroids were frozen flat. Where there were multiple specimens of each morphospecies of echinoids, most were preserved in 75% ethanol, and some were fixed in 10% formalin or frozen.

Molluscs were divided into classes: bivalves, cephalopods and gastropods. Gastropods were divided into nudibranchs/opisthobranchs and prosobranchs. Bivalves and gastropods (non-opisthobranchs) were relaxed in an aqueous solution of magnesium chloride isotonic with seawater and labelled. Opisthobranchs and nudibranchs were relaxed in the refrigerator and photographed with a scale-bar and label. All molluscs were then frozen. Dead-taken molluscs were also collected to assist with determination of species distributions and identifications but only live specimen data is incorporated into this report.

Crustaceans were divided into orders: amphipods, decapods, isopods and stomatopods (when time permitted), labelled and frozen. Fish and algae were labelled and frozen. All other groups were labelled and preserved in 75% ethanol.

Laboratory processing. Only the dominant sponges, based on the wet weights determined in the field, have been identified. Species identifications and wet weights were recorded for each sampling year. All molluscs were identified to family and some were identified to species where time permitted. The number of individuals per taxon was recorded for each sampling year. All echinoderms were identified with the majority being identified to species. Some taxa of ophiuroids were not identified to species due to difficulties in their identification and these represent mixed species. Crinoids were not counted but have been identified to family, genus or species levels. Some Cnidaria were identified from the 2006 collections but not the 2007 and 2008 collections. Species names were standardised according to the current accepted scientific and common names using the appropriate Australian Faunal Catalogues. All raw data spreadsheets are been made available to AIMS.

Data analyses. Datasets of the dominant sponge species, echinoderm species (minus crinoids) and mollusc species and families datasets were analysed in PRIMER v6.1.11. Count data was used for all phyla as weight data was available only for sponges.

For the purposes of analysis the collecting stations were grouped into four areas within the Ningaloo region:
1. Muiron Islands,
2. Northern section from Point Murat to Point Cloates including sites in the vicinity but slightly north of North West Cape,
3. Central section from Point Cloates to Amherst Point and
4. Southern section from Amherst Point to Red Bluff.

The latter three divisions were based on the bottom topography of the Ningaloo reef tract which has a narrow shelf in the north, a gentle sloping and wider shelf within an embayment centrally, and a more northwest facing aspect to the coastline in the south.

Collection depths were stratified into four groupings: <30 metres, 30-60 metres, 60-99 metres and >100 metres. These categories assisted with determining if species composition changes across the shelf as a consequence of increasing depth.

To provide a broad understanding of the differences in the invertebrate assemblages in the four areas and depth categories outlined above, datasets were averaged by area and depth and the averages converted to presence/absence. A zero-adjusted Bray-Curtis similarity measure was used to generate a resemblance matrix so that stations without invertebrates were not excluded from the analyses. The absence of sponges, echinoderms or molluscs may provide important information on the habitat of the area. Non-metric multi dimensional scaling (nMDS) and hierarchical cluster analyses using average distances were performed. Similarity profiles (SIMPROF) based on 999 permutations was used to determine the significance of groups. SIMPER was performed on the presence absence dataset and run using areas and depth categories as factors; the Bray-Curtis similarity and 90% cutoff were used.

To provide more detailed information on the relationships of the fauna collected at each station the sponge dataset was examined for all stations using the same procedures as above. To provide some insight into the information gained by identifying taxa to species, as opposed to a higher taxonomic classification such as family, the mollusc dataset was analysed in two ways, using all taxa collected and identified to family and secondly, only the subset of mollusc taxa that have been identified to species.

Results.

Total counts. A total of 145 stations were sampled by sled for collection of benthic invertebrates (Appendix 1). Forty-nine stations were examined in 2006, 12 in 2007 and 84 in 2008. A total of 155 taxa of dominant sponges, 227 taxa of echinoderms, and 236 mollusc taxa were identified (Appendices 2-4).

Sponges. Eighty of the 145 stations sampled (55%) contained dominant sponge species. A sponge was considered to be dominant based on weight, i.e. when the total weight for a species was >1 kg at a station. An additional 46 stations (32%) had sponge species present that were <1 kg in weight, that is non-dominant by weight, and only 19 stations (13%) had no sponges present.

Echinoderms. Echinoderms were found in 120 of the 145 stations sampled (83%). A total of 227 echinoderm taxa were collected (218 species and 9 unresolved taxa). This included 61 species of asteroids, 34 species of crinoids, 40 species of echinoids, 22 species and 1 unresolved taxa of holothurians, and 61 species and 8 unresolved taxa of brittle stars.

One species, *Astroboa nigrofurcata* Döderlein, 1927, was recorded from the collections but the station data for this specimen was missing.

Molluscs. Molluscs were recorded from 97 stations (67% of all stations). A total of 69 families were recorded from all live-taken mollusc material examined. From these families, a total of 236 taxa were identified, including 145 species. Bivalve species accounted for 33.5% of the molluscan taxa identified (79), 65.7% were gastropods (155) and one cephalopod and one scaphopod were recorded**.**

Data analyses.

Sponges. Multi-dimensional scaling plots of dominant sponge species for all stations indicated five groupings (Figure 1: groups a-e, Table 1). These five groups had little overlap in their dominant sponge species, except for *Caulospongia amplexa*, which was found in both groups c and d6, and *Petrosia (Petrosia)* sp. SS2, which was found in group d4 and e. Two of the five station groupings contained stations from the same area and/or depth e.g. group b, which contained only northern stations in <60 m depth and which do not appear to be represented in a sanctuary zone, and group e which contained only southern stations in <100 m depth. Group c contained stations from three of the four areas, although the stations were all >30 m depth, and group d contained the majority of stations (Table 1, Figure 2). Both of these groups were represented in both sanctuary and general use zones. Six sub-groups could be recognised within group d and these sub-groupings tended to contain stations from the same area and/or depth except d6, which contained mostly northern and southern stations from all depths. In general, these sub-groups had representation across a number of zone types in the park including sanctuary zones (Figure 2). These results suggest that species composition is variable across the Ningaloo reef tract with some species restricted to particular depth regimes and to particular areas in the region.

The sponge data was also analysed using the average sponge species abundance for each area and depth category to determine if similar patterns were observed from a simplified dataset (Figure 3). These nMDS plots showed some clustering of stations from similar depths but this was not clearly defined, suggesting that average abundances are not detecting species differences associated with depth. More clearly defined groups were observed for the area categories with all points from a given area lying adjacent to other points from that same area. All the southern stations grouped together and the northern stations formed two closely associated clusters. The Muiron Island stations grouped with one of the central areas. Sampling effort differed across the four areas with least sampling at the Muirons (Figure 3). Examination of selected sponge species abundances indicated that these varied across areas, which is a similar result to the dataset of all stations. The analysis based on averages found some species contributed to the groupings that had not been detected from the full dataset, e.g. *Spheciospongia* cf. *papillosa* in the southern area, *Desmacidon* sp. Ng1 and *Haliclona (Haliclona)* sp. Ng1 in the northern area and *Xestospongia* sp. Ng1 in the central area. All other significant species in this dataset were also detected in the full dataset. Some of the species were found in very large numbers e.g. *Axinella* sp. Ng3 at the Muiron Island stations (Figure 4).

Sled tows in 2006 differed from those in 2007 and 2008 so weight of species per sled tow could not be directly compared across all years. The 10 most dominant sponge species determined from biomass in 2007 and 2008 are given in Table 2. Dominant sponge species determined by abundance in all three years are given in Table 3. The six species with high biomass but not high in abundance are large sponges: *Geodia* sp. SS2, *Asteropus* sp. SS2, *Jaspis* sp. SS4 and *Asteropus* sp. SS1 are all massive, bulky sponge species with large spicules and solid, generally incompressible morphology. *Sarcotragus* sp. SS3 does not have a spicule component and is a fibre sponge of massive dimensions that incorporates a large amount of sand and foreign material into its skeleton. The six species with high abundances that did not have high biomass (*Axinella* sp. Ng3, *Haliclona (Haliclona)* sp. Ng1, *Monanchora* sp. Ng1, *Sigmaxinella* sp. SS1, *Caulospongia amplexa* and *Echinodictyum clathrioides*) are all branching or cup-shaped sponges that do not have the large spicules found in the high biomass species, consequently they will have lighter overall weight. The four species that had both high biomass and abundance (*Petrosia (Petrosia)* sp. SS2, *Ecionemia* sp. SS1, *Ecionemia* sp. Ng1 and *Spheciospongia* cf. *papillosa*) are massive sponges, the latter three with large spicules and the former with numerous small spicules dominating the skeletal architecture.

Of the 155 taxa identified only 31 could be given a known species name at present, and some of these require comparison with type material (those with the species name prefixed with ‘cf.’, Appendix 2). The rest of the species were only able to be assigned to a genus and given a species number. These are most likely poorly known species described in old taxonomic literature or are new to science. The 155 taxa recorded were assigned to 38 families and 65 genera.

The sponge species collected in this study were compared with species collected in related studies recently undertaken by the WA Museum in collaboration with CSIRO (deepwater >100 m off Ningaloo reef tract, M^{c}Ennulty et al., in prep) and WA Fisheries (Exmouth Gulf <30 metres, Kangas et al., 2007). Only 27 of the species collected in this study were also found in the deeper stations off Ningaloo, and only five species were found in shallow depths in Exmouth Gulf (Appendix 2).

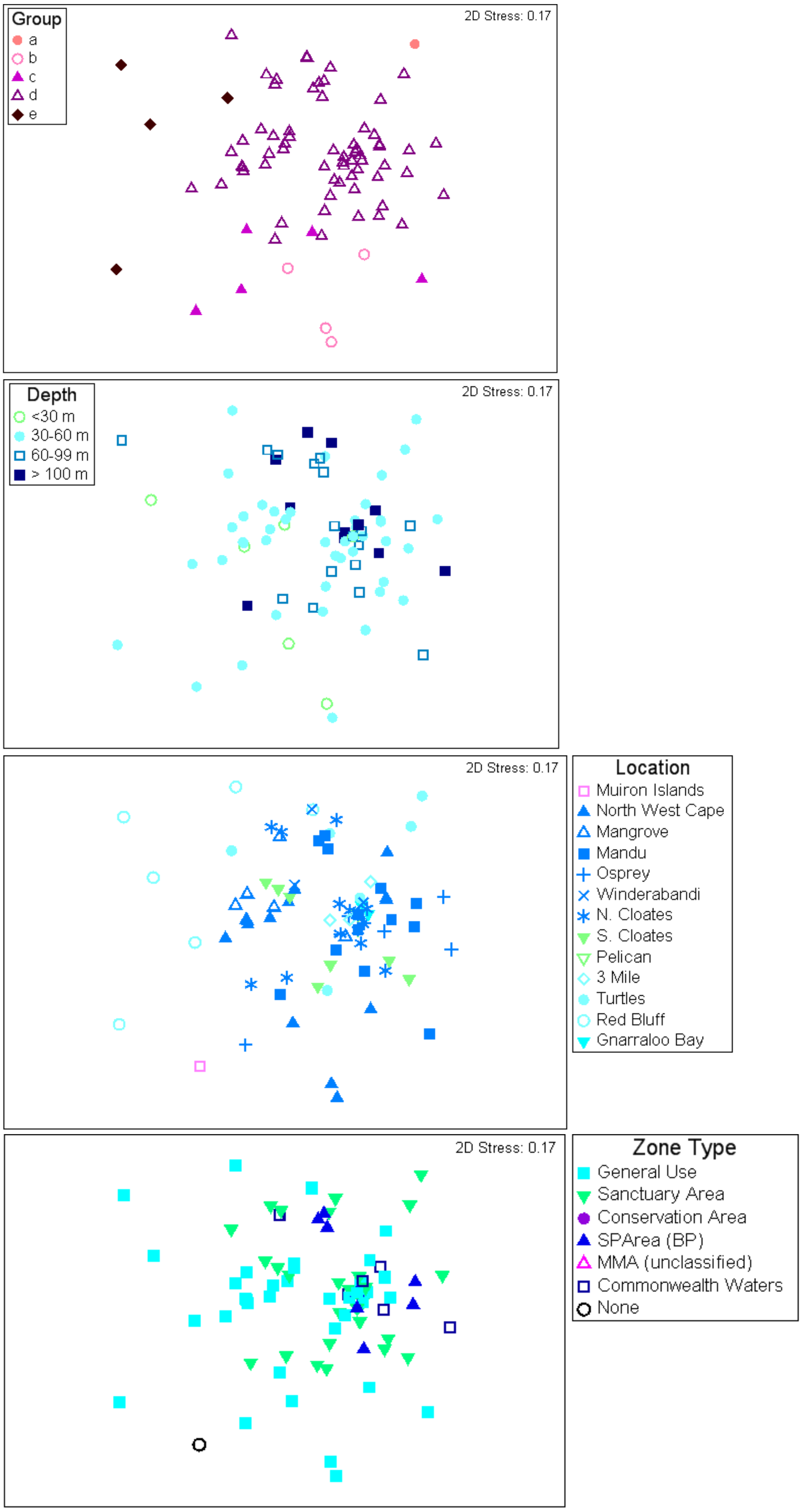

Figure 1. Multi-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of dominant sponge species abundance for all stations showing the SIMPROF groups (significant $p < 0.05$ at 20% similarity), depth, area and zone type groupings within Ningaloo reef tract. Locations are colour coded by area, Muiron Islands: pink, Northern: blue, Central: green, and Southern: aqua.

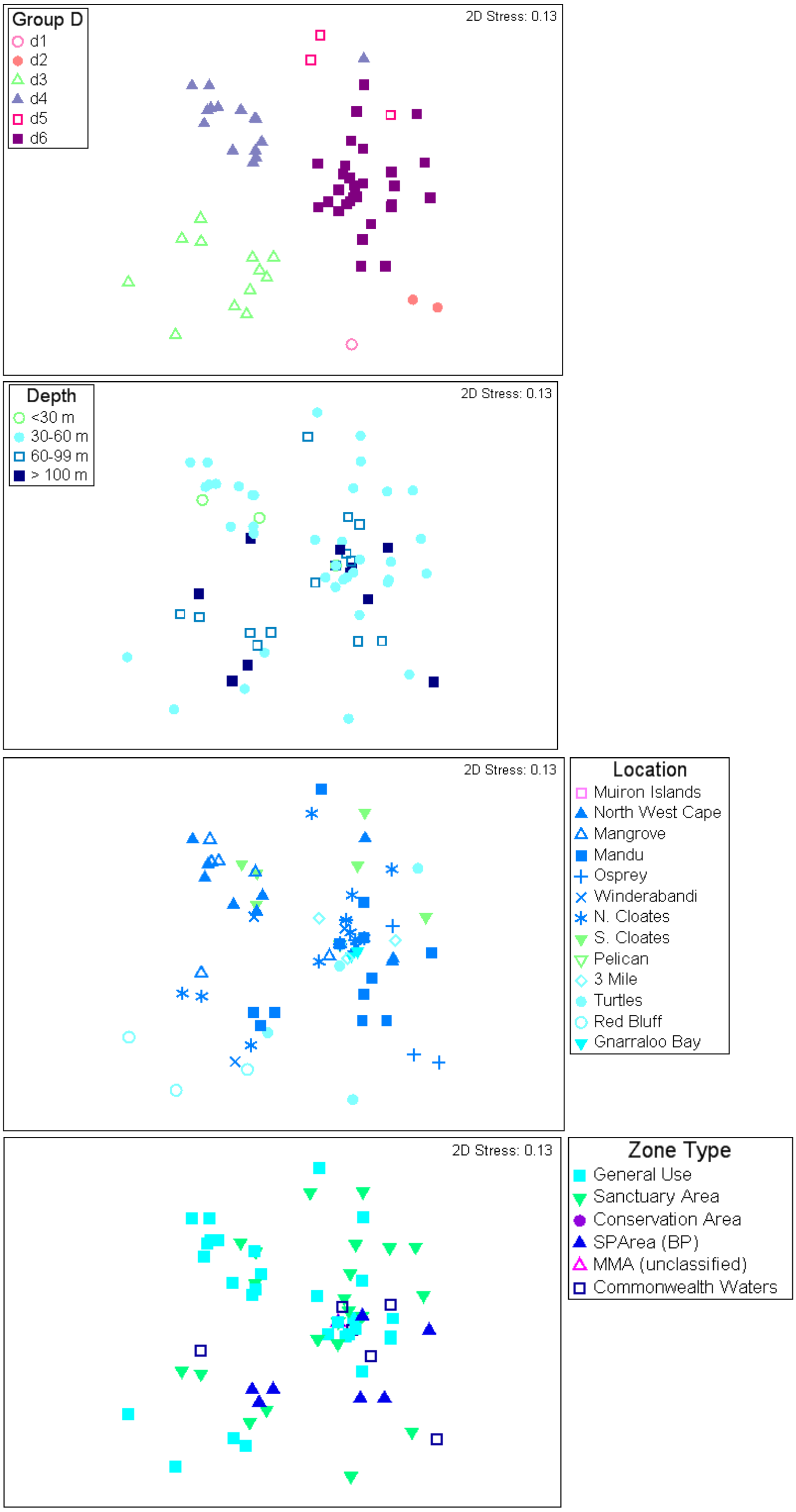

Figure 2. Two-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of sponge species from each station - group d only. SIMPROF Groups are shown at 30% similarity.

Table 1. Sponge cluster groups for all species from all stations.
Group d6 – many of the samples had no dominant sponge species i.e. >1 kg weight.

Group	Station No.
a	D095
b	D053 - 54, 59-60
c	D014, 19, 28, 30, 49
d1	D097
d2	D005, 17
d3	D055, 83, 98, 103, 108, 118-20, 127, 130-132
d4	D051-52,56,62-63,113-115,117,128,139-141,145-146
d5	D021,33,35
d6	D001-4,6-13,15-16,18,20,22-27,29,31-32,34,36-48, 57-58,61,64-80,82,85-94,96,100-102,105-107,109-112,116,121-126,129,133-138,142-144
e	D081,84,99,104

Stations with sponges present (species all < 1 kg)
D002, D004, D008, D010, D011, D012, D013, D015, D022, D024, D025, D026, D029, D036, D037, D038, D040, D041, D042, D043, D044, D046, D047, D048, D065, D066, D067, D070, D072, D073, D075, D079, D082, D088, D089, D092, D093, D106, D110, D112, D116, D124, D125, D134, D137, D142

Stations with sponges absent
D020, D023, D061, D068, D074, D080, D085, D086, D087, D090, D091, D094, D096, D101, D105, D107, D123, D136, D138

Group	Area and Depth	Dominant species in each group
a	southern, 30-60 m	8 species all equal dominance
b	northern, <60 m	*Sigmaxinella* sp. SS1, *Iotrochota acerata*
c	3 northern, 1 each Muiron Island and central, > 30m	*Axinella* sp. Ng3, *Caulospongia amplexa*
d1	southern, 30-60 m	no dominant species collected
d2	northern only (Turtles), 30 - 60 m, >100 m	*Caulospongia plicata*
d3	northern & southern, >30 m	*Ecionemia* sp. SS1, *Ecionemia* sp. Ng1
d4	northern & central, mostly 30-60m	*Petrosia (Petrosia)* sp. SS2, *Haliclona (Haliclona)* sp. Ng1
d5	northern only, 30-100 m	*Raspailia (Parasyringella)* sp. Ng1
d6	mostly northern & southern, all depths	*Monanchora* sp. Ng1, *Caulospongia amplexa*
e	all southern, <100 m	*Biemna* sp. SS2, *Petrosia (Petrosia)* sp. SS2, *Axinella* sp. Ng3

Group a species
Coelosphaera (Coelosphaera) sp. SS3
Crella (Yvesia) sp. Ng1
Ecionemia sp. SS3
Holopsamma sp. Ng1
Psammocinia sp. SS1
Psammoclema sp. Ng1
Spongia (Heterofibria) sp. Ng1
Strongylamma sp. SS1

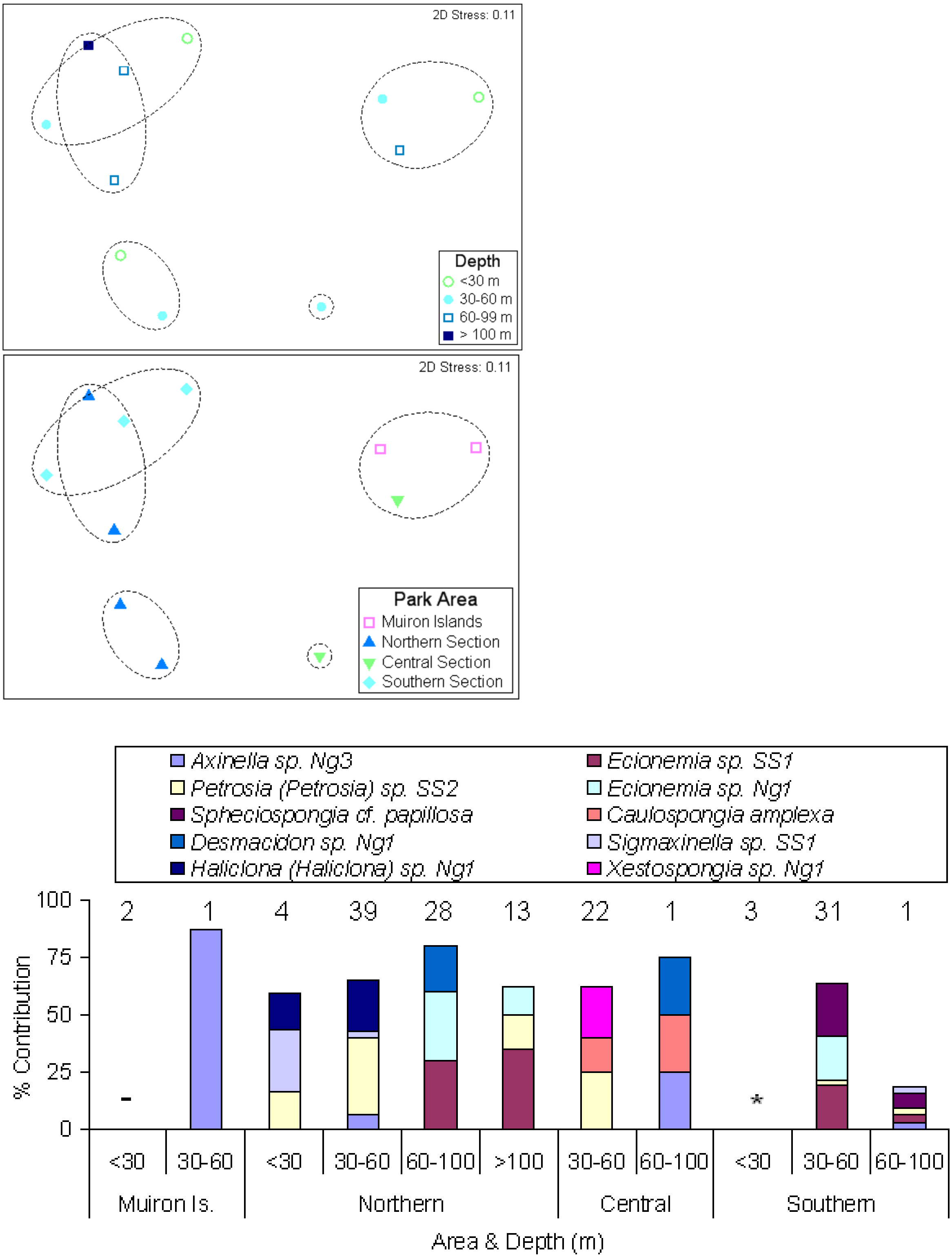

Figure 3. Multi-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of the average sponge species abundance for each area and depth category. Groups are significant, $p < 0.05$, with SIMPROF at 25% similarity. The top 10 species that contributed to the similarity within each area and depth are displayed (* similarities zero, i.e. no species in common for stations within this category). The number at the top of each column is the number of stations sampled at that area and depth.

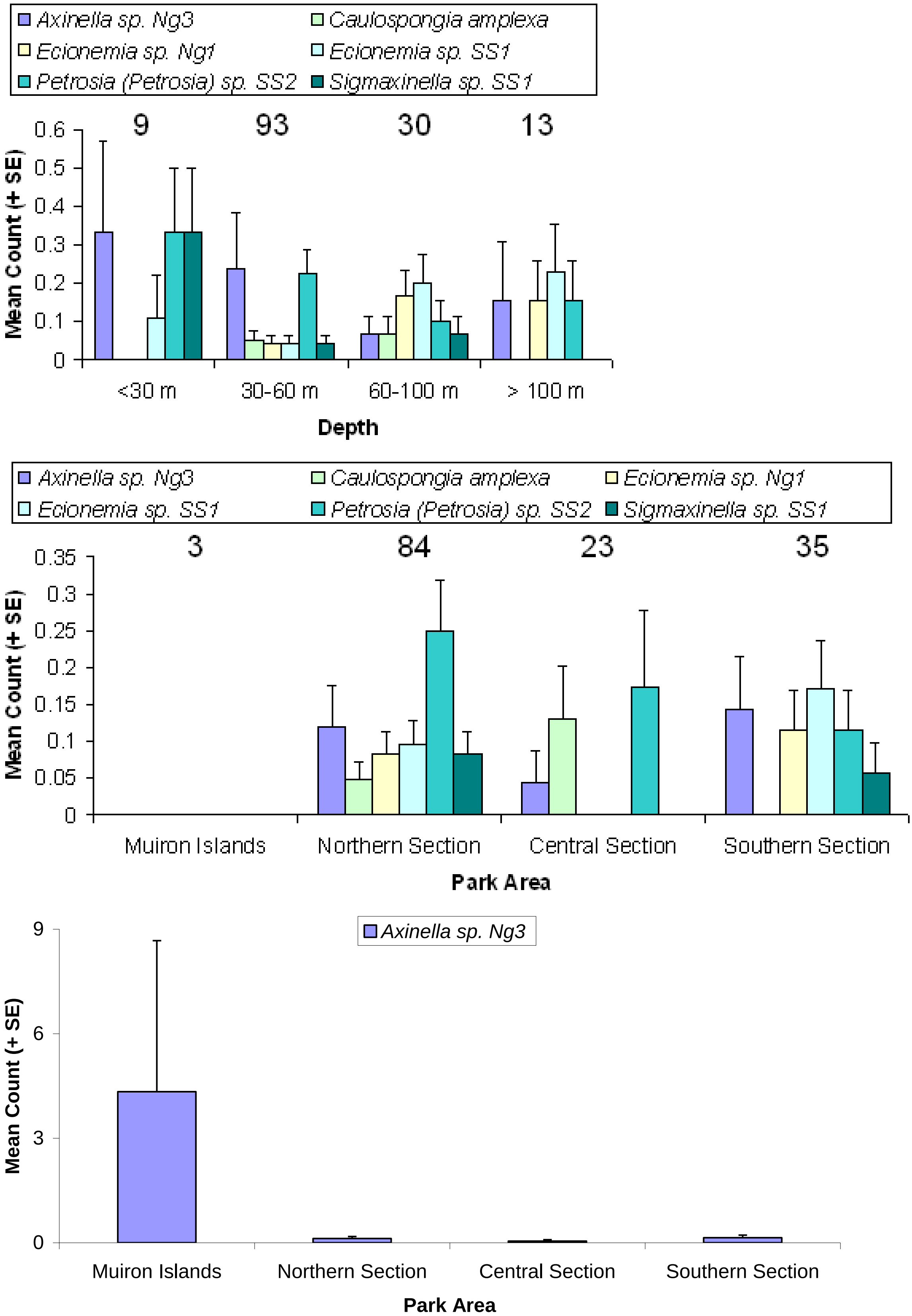

Figure 4. Average counts for selected sponge species. (*Axinella* sp. Ng3 values not entered on middle graph as this species was in very high abundance at Muiron Islands and does not allow other abundances to be seen when included. Ideally needs to go on a graph with a scale break, which can't be done in Excel).

Table 2. Overall top 10 species of sponges by weight.

Top 10 - Biomass	Weight (kg)
Petrosia (Petrosia) sp. SS2	356.8
Geodia sp. SS2	137.4
Ecionemia sp. Ng1	120.2
Asteropus sp. SS2	98.6
Biemna sp. SS1	78.7
Spheciospongia cf. *papillosa* (Ridley & Dendy, 1886)	62
Ecionemia sp. SS1	60.9
Jaspis sp. SS4	53.9
Sarcotragus sp. SS3	34.9
Asteropus sp. SS1	33

Table 3. Overall top 10 species of sponges by count.

Top 10 - Counts	Count
Axinella sp. Ng3	29
Petrosia (Petrosia) sp. SS2	29
Ecionemia sp. SS1	14
Haliclona (Haliclona) sp. Ng1	13
Ecionemia sp. Ng1	11
Monanchora sp. Ng1	10
Spheciospongia cf. *papillosa* (Ridley & Dendy, 1886)	10
Sigmaxinella sp. SS1	9
Caulospongia amplexa Fromont, 1998	7
Echinodictyum clathrioides Hentschel, 1911	6

Echinoderms.

The echinoderm data was analysed using average species abundances as no weights were determined for echinoderms (Figure 5). These nMDS plots showed four groups of stations but these did not closely align with similar depths. As with the sponges, there were clear groupings associated with area and this is evident as a gradient on the plot from the northern, through the central to the southern sites. The Muiron Island sites are to the right in the plot but closely aligned with the central and southern areas. Stations in the northern area grouped together, although the <30 m depth category formed a separate group due to the dominance of *Tripneustes gratilla* in the shallow depths.

The ten species that contributed to the similarity within area and depth categories are given in Figure 5. Some species were found in most areas, e.g. the brittle star *Ophiothrix (Ophiothrix) ciliaris*, which lives in sponges, was found in all four areas but only at >30 m depth. The sea star *Heteronardoa diamantinae* dominated at stations deeper than 60 m depth in the northern section, while the urchin *Prionocidaris baculosa* was found at the Muirons, northern and central areas at deeper than 30 m, but not in the southern area. The urchin *Lovenia elongata* was found at the Muirons, central and southern areas between 30-60 m depth, but not in the northern area. The brittle star *Ophiocoma* cf. *doederleini* was only found at 30-60 m depth in the northern area and *Ophiothrix (Keystonea) smaragdina*, which lives in sponges, was only found in the northern and southern areas. The holothurian *Colochirus quadrangularis* was only found in the southern area at >30 m depth and the brittle star *Ophiothrix (Keystonea) martensi* was only found in the central and southern areas. Note that sampling effort differed across the four areas with least sampling at the Muirons.

Five of the 10 species that contributed to the similarity within each area and depth were also some of the most abundant echinoderm species collected in this study (Table 4). These were the brittle stars *Ophiothrix (Keystonea) smaragdina, Ophiothrix (Ophiothrix) ciliaris, Ophiothrix (Keystonea) martensi,* the urchin *Prionocidaris baculosa* and the seastar *Heteronardoa diamantinae.* The other five most abundant species collected in this study were the brittle stars *Ophiactis savignyi, Ophiothela danae*, which is found on gorgonians, and *Gymnolophus obscura,* which is parasitic on crinoids, and the urchins *Acanthocidaris maculicollis*, found in sponges, and *Clypeaster virescens* which is parasitic on crinoids.

The echinoderm species collected in this study were compared with species collected in three studies previously undertaken in the region, deepwater >100 m off Ningaloo reef tract (WA Museum in collaboration with CSIRO, M^{c}Ennulty et al., in prep), Exmouth Gulf <30 m depth (WA Museum and WA Fisheries, Kangas et al., 2007), and shallow reef fieldwork (WA Museum, Appendix 3). Only 38 of the 227 species collected in this study were also found in the deeper stations off Ningaloo, 26 of the species were found in shallow depths in Exmouth Gulf, and most species overlap was with the shallow reef study with 87 species in common between these two surveys. This suggests that the deepwater fauna (>100 m) is different from the mid-depth areas sampled in this study. The shallow water reef echinoderms tend to be widely occurring Indo-Pacific species and the middle depths sampled in this study have a North West shelf faunal component (L. Marsh, pers. comm.) not usually found in shallow diving depths (<30 m).

Taxonomic characterisation of the echinoderm species identified in this study has indicated the presence of a significant number of new species. The urchin *Rhynobrissus* sp. was relatively common in deeper depths (around 100 m) and occurred in approximately equal abundance to *Rhynobrissus tumulus* and *R. hemiasteroides* (A. Miskelly, pers. comm).

Six of the species in the sea star family Ophidiasteridae are undescribed species (one species in the genus *Fromia*, one in the genus *Ophidiaster*, and four in the genus *Tamaria* (L. Marsh, pers. comm). One goniasterid appears to be an undescribed genus and species, and eight other species of sea star are also probably new species: *Astromesites* sp., *Astropecten* sp., aff. *Perissogonaster* sp., *Stellaster* sp., *Goniodiscaster* sp., *Asterodiscides* sp., *Pteraster* sp., and *Allostichaster* sp. (L. Marsh, pers. comm).

The number of ophiuroid species in this study is an underestimate as several problematic species complexes in the genera *Amphiura*, *Ophiactis*, *Ophiothrix* and *Macrophiothrix* have only been identified to genus. There are several ophiuroids that are likely to be new species including a common *Ophiocoma* species that appears to be an intermediate between *O. doederleinii* (annulated arm spines) and *O. brevipes* (small arm spines). Two specimens of a fissiparous six-armed *Ophiomyxa* were found as well as an undescribed species of *Ophionereis* that is part of a complex of shelf-dwelling species occurring from WA to Tonga. There are likely further new species amongst the ophiuroid material identified to genus (T. O'Hara, pers. comm).

Three holothurian species could only be identified to genus and one phyllophorid probably belongs to a new genus and is a new species. Of the few holothurian species collected, several are probably undescribed as they could not be identified from available literature. One species of holothurian, *Ohshimella ehrenbergi* is recorded for the first time from Australia. This was first described from the Red Sea and is known from the Indian Ocean and the Xisha Islands in the South China Sea. *Actinopysa miliaris* is recorded from WA for the first time. The greatest depth of six species (*Actinopysa miliaris, Holothuria (Halodeima) edilus, Actinocucumis typica, Plesiocolochirus violaceus, Cladolabes acicula* and *C. schmeltzii*) is increased by > 20 metres (L. Marsh, pers. comm).

In addition,this study found new distributional ranges for some sea star species. For instance, two continental shelf species *Luidia savignyi* and *Leiaster glaber* are recorded from Australia for the first time although the latter species was also found in the deepwater (>100 m depth) study with CSIRO (Appendix 3). *Acanthaster brevispinus* is newly recorded from Western Australia. This species is found on soft substrates and is not a coral predator (L. Marsh, pers. comm). The brittle star *Ophiomastix elegans* had been reported only twice before, from Indonesia and Keeper Reef, Great Barrier Reef but has now been collected in this study, a first record for Western Australia (T. O'Hara, pers. comm). Some interesting and unusual ophiuroid species were also found. The rare sexually dimorphic *Ophiosphaera insignis* was found three times, always with a dwarf male placed over the mouth of the female. Two species that are parasitic or commensal on crinoids were common, the colourful *Ophiomaza cacaotica* and the rare *Gymnolophus obscura* (T. O'Hara, pers. comm).

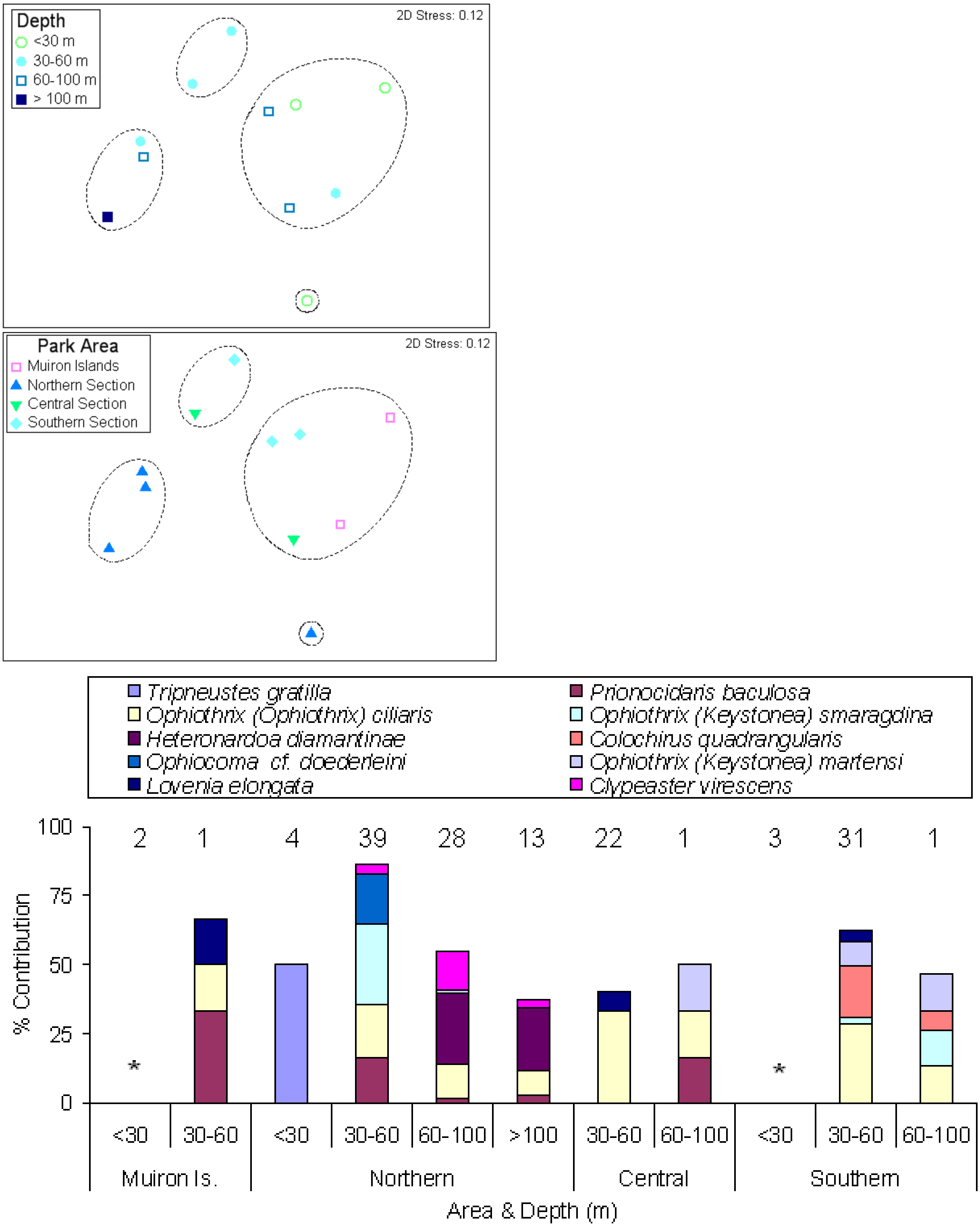

Figure 5. Multi-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of the average echinoderm species abundance for each area and depth category. Groups are significant, $p < 0.05$, with SIMPROF at 22% similarity. The top 10 species that contributed to the similarity within each area and depth are displayed (* similarities zero, - no species collected). Numbers at the top of each group are the number of stations included in that group.

Table 4. Overall top 10 abundant echinoderms.

Top 10	Count
Ophiothrix (Keystonea) smaragdina Studen, 1883	136
Ophiothrix (Ophiothrix) ciliaris (Lamarck, 1816)	119
Ophiactis savignyi (Müller & Troschel, 1842)	85
Ophiothela danae Verrill, 1869	35
Ophiothrix (Keystonea) martensi Lyman, 1874	35
Clypeaster virescens Doderlein, 1885	32
Acanthocidaris maculicollis (De Meijere, 1904)	29
Prionocidaris baculosa (Lamarck, 1816)	21
Heteronardoa diamantinae Rowe, 1976	20
Gymnolophus obscura (Ljungman, 1867)	19

Molluscs.

The mollusc data was analysed using the complete dataset, which consisted of a number of taxa identified only to family (Figure 6), with a subset of these identified to species (Figure 7). Both analyses used average abundances as no weights were recorded for molluscs. The nMDS plots of average family abundances showed two clusters of stations that did not closely align with depth or area categories (Figure 6). The top ten families that contributed to the similarity within area and depth categories are given in Figure 6. Some families contributed to the similarity in all four areas at depths >30 m, e.g. the Muricidae, while other families dominated in fewer areas e.g. the sand dwelling Mactridae occurred in the southern area at <60 m depth, and hard-substrate oysters of the Ostreidae were only found in the central and southern areas.

When the species dataset was examined four clusters were found across depth and area categories (Figure 7) suggesting that the higher taxonomic resolution to the level of species was giving important additional information. The four clusters generated did not align with depth categories but as for the sponges and echinoderms they did align with area categories. All the northern stations grouped together with one central area, while two of the southern stations grouped together and the other with the central area and a Muiron Islands category. One Muiron Islands category was separated from all other clusters.

When the top 10 species that contributed to the similarities were listed (Figure 7) some of these dominated only in a particular area and depth, e.g. the bivalve *Spondylus* sp. cf. *S. asperrimaus* at 30-60 m depth at the Muiron Islands, and the scallop *Scaeochlamys* sp. 1 at depths >30 m in the northern area. The gastropod *Xenophora cerea* was dominant in the northern area between 30-60 m depth and *Cypraea cernica* and *Latirus turritus* in the central area between 30-100 m depth. *Oliva ornata* was only found in the southern area and *Chicoreus cervicornis* in the northern area, as was *Bursa granularis* and *Pterynotus acanthopterus.* Only *Tudivasum* sp. cf. *T. spinosa* was found in more than one area, occurring in both the Muiron Islands and central area.

Five of the 10 species that contributed to the similarities within each area and depth also belonged to some of the most abundant molluscan families found in this study (Table 6). The remaining five most abundant species were *Cronia* *avellana, Barbatia (Acar) plicata, Tutufa bufo, Coralliophila radula* and *Glycymeris persimilis.*

The three most abundant mollusc families were the Ark shells, the muricids and the trochids (Table 5). The trochids comprise a very speciose family in Australia. Most species are herbivores with a very few feeding on sponges and one or two species being nestling filter feeders in sand. Muricids are carnivores and largely predators on other organisms such as molluscs, barnacles or worms, and the arcids are filter feeding bivalves, of which some are epifaunal on soft substrates. Ark shells can be very abundant when a suitable habitat is available e.g. sponge or coral. Others are byssally attached to hard substrates and some of these are almost infaunal occurring in overgrown crevices of massive corals.

The 236 mollusc taxa collected in this study were compared with live-taken taxa collected in four studies previously undertaken in the region, Ningaloo Reef < 20 m depth (WA Museum as part of CReefs), deepwater >100 m off Ningaloo reef tract (WA Museum in collaboration with CSIRO, M^c^Ennulty et al., in prep), Exmouth Gulf <30 m depth (WA Museum and WA Fisheries, Kangas et al., 2007), and shallow reef fieldwork (WA Museum, Appendix 4). Only 14 of the 236 taxa collected in this study were recorded from <20 m on Ningaloo Reef; 14 species were in common with deeper stations off Ningaloo, 14 were found in shallow depths in Exmouth Gulf, and four on Ningaloo reef. However, this last study only incorporates three families, the Pectinidae, Veneridae, and Volutidae. Although these comparisons are restricted due to the identification of many families from the current study not progressing to species level, there is a low degree of overlap between studies from different depths and habitats in the Ningaloo region. This suggests that the mollusc fauna collected in this study is significantly different from that of the surrounding deeper and shallower areas.

At least three species found in this study are thought to be new to science: *Septifer* sp., *Chicoreus* sp. and *Scaeochlamys* sp. 1.

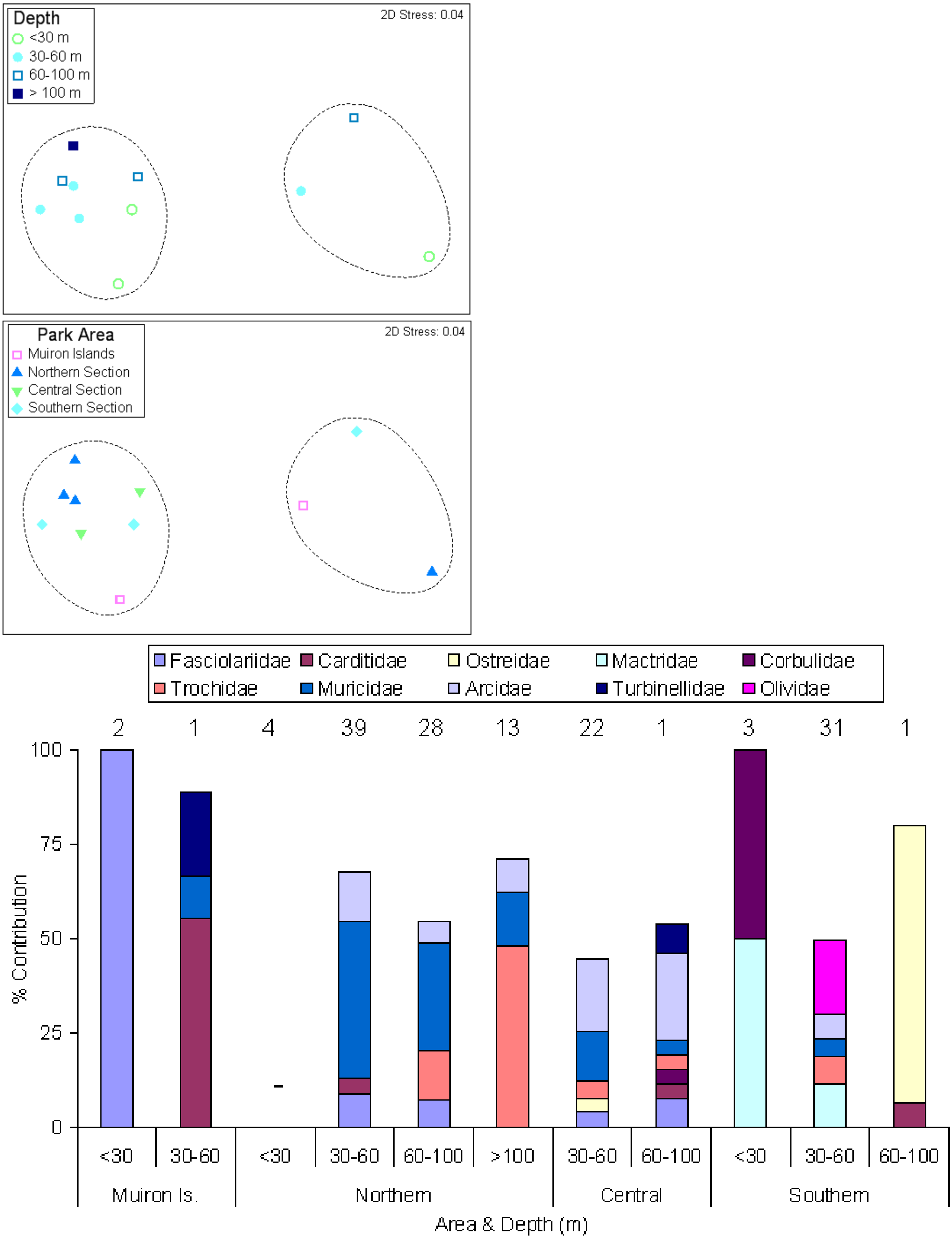

Figure 6. Multi-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of the average mollusc family abundance for each area and depth. Groups are significant, $p < 0.05$, with SIMPROF at 20% similarity. The top 10 families that contributed to the similarity within each area and depth are displayed (* similarities zero, - no species collected). Numbers at the top of each group are the number of stations included in that group.

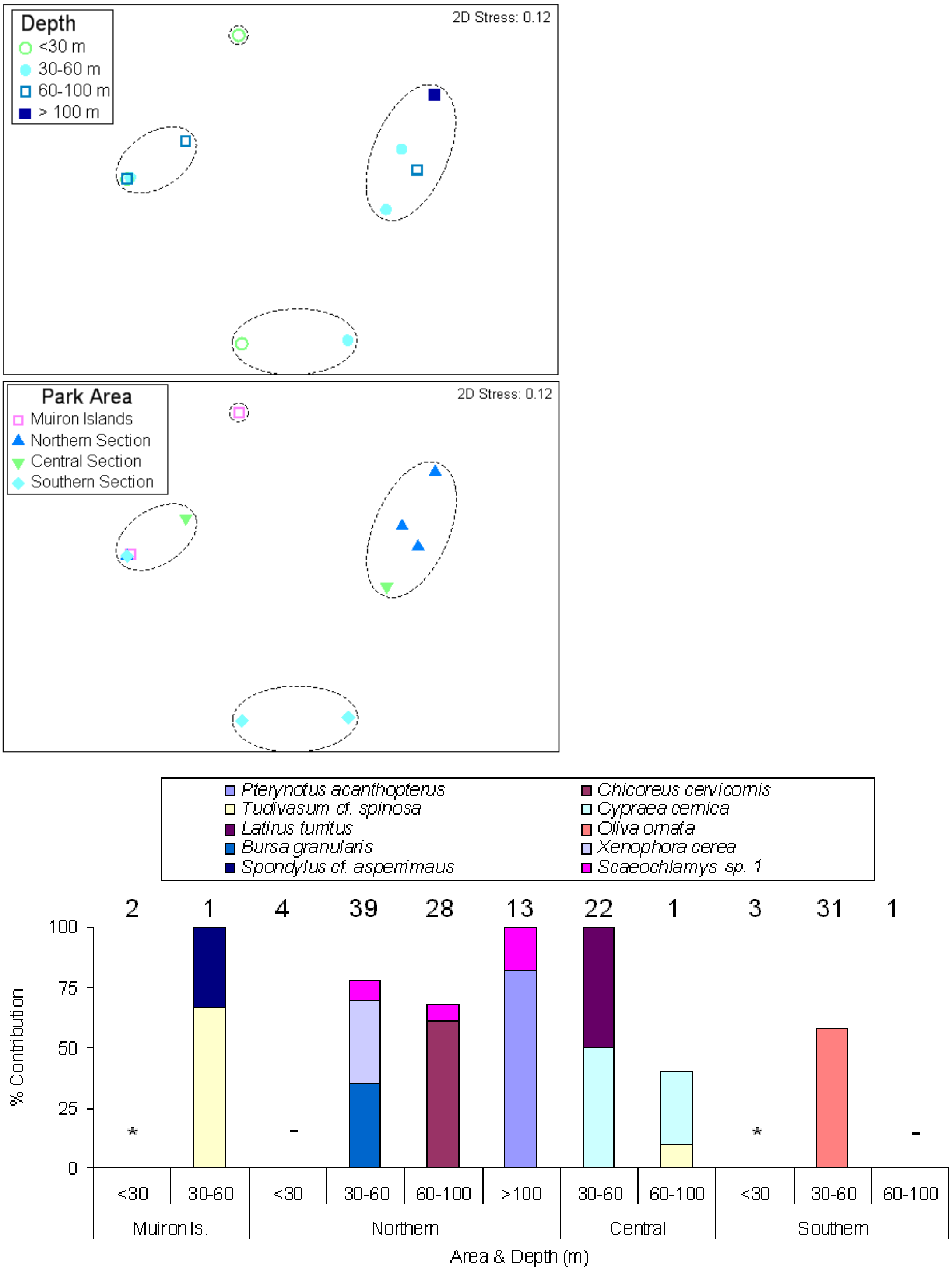

Figure 7. Multi-dimensional scaling plots based on a zero-adjusted Bray-Curtis matrix of the average mollusc species only abundance for each area and depth. Groups are significant, $p < 0.05$, with SIMPROF at 18% similarity. The top 10 species that contributed to the similarity within each area and depth are displayed (* similarities zero, - no species collected). Numbers at the top of each group are the number of stations included in that group.

Table 5. Top 10 most abundant mollusc families

Top 10 - Families	Count
Arcidae	531
Muricidae	147
Trochidae	130
Limidae	92
Fasciolariidae	53
Bursidae	47
Buccinidae	46
Pteriidae	46
Cypraeidae	36
Pectinidae	29

Table 6. Top 10 most abundant mollusc species (for those specimens identified to species level).

Top 10 - Species	Count
Chicoreus cervicornis (Lamarck, 1822)	24
Bursa granularis (Röding, 1798)	17
Cronia avellana (Reeve, 1846)	10
Cypraea cernica Sowerby, 1870	10
Oliva ornata Marrat, 1867	10
Barbatia (Acar) plicata (Dillwyn, 1817)	9
Tutufa bufo (Röding, 1798)	9
Coralliophila radula (Adams, 1855)	8
Glycymeris persimilis (Iredale, 1939)	8
Scaeochlamys sp. 1	8

When the top 10 taxa by abundance of individuals of each phylum were listed for each of the four area categories, it was apparent that some species were dominant in more than one area, but their abundance could be very different, e.g. *Ophiothrix (Keystonea) smaragdina* had high abundance (116 individuals) in the northern area compared to 9 and 11 individuals in the central and southern areas respectively (Table 7). This was also seen in the sponges e.g. *Petrosia (Petrosia)* sp. SS2 with 21 individuals in the northern section compared to four in each of the central and southern areas. Other species were only dominant in one area e.g. the sponges *Haliclona (Haliclona)* sp. Ng1 and *Sigmaxinella* sp. SS1 and the echinoderms *Clypeaster virescens* and *Acanthocidaris maculicollis* were in high numbers in the northern area, but were not found in high numbers in the other areas (Table 7).

Table 7. Top 10 taxa of each phylum for four area categories used in this study.

Porifera		Echinodermata		Mollusca	
Taxa	**Count**	**Taxa**	**Count**	**Taxa**	**Count**
Muiron Islands					
Axinella sp. Ng3	13	*Rhynobrissus hemiasteroides*	3	Arcidae spp.	13
Monanchora sp. Ng1	1	*Lovenia elongata*	2	*Coralliophila radula*	8
Oceanapia sp. Ng1	1	*Nacospatangus interruptus*	2	*Glycymeris persimilis*	8
		Prionocidaris baculosa	2	Carditidae spp.	5
		Dictenophiura stellata	1	*Cypraea helvola*	4
		Eucidaris metularia	1	*Pyrene turturina*	3
		Holothuria (Halodeima) edilus	1	*Coralliophila neritoidea*	2
		Linckia guildingi	1	*Cypraea cernica*	2
		Ophiocoma cf. *doederleini*	1	Lima spp.	2
		Ophionereis porrecta	1	*Tudivasum* cf. *spinosa*	2
Northern					
Petrosia (Petrosia) sp. SS2	21	*Ophiothrix (Keystonea) smaragdina*	116	Arcidae spp.	406
Haliclona (Haliclona) sp. Ng1	11	*Macrophiothrix* spp.	76	*Clanculus* spp.	69
Axinella sp. Ng3	10	*Ophiactis savignyi*	69	*Arca* spp.	66
Ecionemia sp. Ng1	7	*Ophiothrix (Ophiothrix) ciliaris*	61	Muricidae spp.	40
ORDER: Lithistida spp.	7	*Ophiothrix* spp.	34	Limidae spp.	28
Sigmaxinella sp. SS1	7	*Clypeaster virescens*	32	Trochidae spp.	25
Iotrochota acerata	6	*Acanthocidaris maculicollis*	29	*Chicoreus cervicornis*	24
Raspailia (Parasyringella) sp. Ng1	6	*Ophiothela danae*	25	Pteriidae spp.	21
Monanchora sp. Ng1	5	*Heteronardoa diamantinae*	20	*Morula* spp.	17
Caulospongia amplexa	4	*Prionocidaris baculosa*	17	*Pteria* spp.	16
Central					
Petrosia (Petrosia) sp. SS2	4	*Ophiothrix (Ophiothrix) ciliaris*	31	Arcidae spp.	14
Caulospongia amplexa	3	*Ophiactis savignyi*	13	*Arca* spp.	9
Thorecta sp. Ng1	3	*Ophionereis porrecta*	12	*Cypraea cernica*	5
Xestospongia sp. Ng1	3	*Macrophiothrix* spp.	9	Astele spp.	4
Xestospongia sp. Ng4	3	*Ophiothrix (Keystonea) smaragdina*	9	Limidae spp.	4
Acanthella sp. Ng3	1	*Ophiomastix elegans*	8	*Engina* spp.	3
Acanthodendrilla sp. Ng1	1	*Ophiothrix (Keystonea) martensi*	6	Gastrchaenidae spp.	3
Axinella sp. Ng3	1	*Ophiothrix (Keystonea)* spp.	6	Pectinidae spp.	3
Crella (Yvesia) sp. SS2	1	*Amphiura (Amphiura)* sp.	5	Pleurobranchidae spp.	3
Desmacidon sp. Ng1	1	*Amphiura* spp.	5	*Cypraea caurica*	2
Southern					
Spheciospongia cf. *papillosa*	8	*Ophiothrix (Ophiothrix) ciliaris*	26	Limidae spp.	46
Ecionemia sp. SS1	6	*Macrophiothrix* spp.	20	Mactridae spp.	21
Axinella sp. Ng3	5	*Ophiothrix (Keystonea) martensi*	19	Ostreidae spp.	15
Ecionemia sp. Ng1	4	*Temnopleurus michaelseni*	17	*Clanculus* spp.	13
Geodia sp. SS2	4	*Ophiactis* spp.	16	*Astele* spp.	12
Petrosia (Petrosia) sp. SS2	4	*Rhynobrissus tumulus*	13	*Oliva ornata*	10
Biemna sp. SS2	3	*Echinolampas ovata*	11	*Barbatia (Acar) plicata*	9
Crella (Yvesia) sp. SS2	3	*Ophiothrix (Keystonea) smaragdina*	11	Arcidae spp.	9
Ecionemia sp. SS3	3	*Ophiacantha clavigera*	9	*Cronia avellana*	8
Iotrochota cf. *baculifera*	3	*Ophiothela danae*	9	*Bursa granularis*	7

Discussion.

The total number of taxa identified in this study was 618 comprising 155 species of sponge, 227 echinoderms and 236 molluscs from 145 stations sampled.

Sponges. The collection was dominated by biomass of sponges. Of the 145 stations sampled in this project, the samples from 126 stations contained sponges. A total of 155 sponge species were recorded as dominant i.e. within a sled tow at a station the weight of a species was ≥1 kg. This finding supports the suggestion that the sponges are the dominant component of the filter feeding communities off the Ningaloo reef tract. In addition nMDS plots grouped the stations into five clusters based on the dominant sponge species present. Some of these clusters were from a single area in the park e.g. all northern stations at <60 m depth, and all southern stations <100 m depth formed two distinct groups. Other clusters included stations with a range of depths across different latitudinal areas. These results suggest that the distributions of some of these species may be constrained by depth or that some species require specific habitat characteristics found only in particular areas of the Ningaloo region. This result can be more fully explored when a synthesis analysis is undertaken that combines habitat and fish assemblage data.

The results also show that dominant species change latitudinally across areas of the marine park, for instance, *Spheciospongia* cf. *papillosa* was found in the southern area below Amherst Point and *Ecionemia* sp. SS1 was found to dominate in the northern area north of Point Cloates. Other species were more widespread e.g. *Petrosia (Petrosia)* sp. SS2 occurred along the reef tract but was particularly dominant in the northern and central areas. Some species contributed significantly to the overall faunal biomass in the area, e.g. almost 360 kgs of *Petrosia (Petrosia)* sp. SS2 was sampled from stations in this study. This massive species would be a major habitat contributor in the filter feeding communities of this region.

Comparison of the sponge species collected in this study with those collected from studies in adjacent depths and habitats demonstrate that the majority of the species (~80%) were not found in deeper waters off Ningaloo, or in Exmouth Gulf. However, 35 of these species (26%) were found in depths >100 m further south along the Western Australian coastline. No comparative studies are available north of Ningaloo, but deeper water sponges from the northwest are currently being identified and will be available for comparison in the future.

The majority of the sponge species found in this study have not been identified to known species. In large part this is because the sponges of WA are still poorly known and described. A series of revisions of some of the dominant genera are required along with descriptions of new species, and these are tasks beyond the timeframe and scope of this study. However it is highly likely that many of the species recorded here are new to science. This study has resulted in the first comprehensive collection of sponges from this region and has provided a basis for ongoing taxonomic and biogeographic studies of these dominant filter feeders.

Other sessile taxa. Very few cnidarians dominated the filter feeding biomass collected in this project with the weight of these taxa being low. Occasionally other sessile taxa comprised a significant component of the biomass collected e.g. an ascidian at station 53, a bryozoan at station 54 and a coral species at station 60.

Echinoderms. Echinoderms were reported from 120 of the 145 stations examined in this study. All echinoderms have been examined and a total of 227 taxa have been identified. The most speciose class of echinoderms was the brittle stars with 69 taxa. This number is considered to be an underestimate as there were several problematic species complexes in four genera which will yield additional species with further taxonomic study (T. O'Hara, pers. comm.). The sea stars, urchins and crinoids had similar numbers of species (61 sea stars, 40 urchins and 34 species of crinoids) and there were 23 taxa of holothurians recorded.

NMDS plots grouped the stations into four clusters based on species present, with stations in the northern area (from Point Cloates northwards) being composed of similar species. Based on the samples of the echinoderm fauna the remainder of the stations did not separate on area or depth suggesting that many echinoderm species may be widespread within the study area. This was the case for one of the most abundant species of brittle star, *Ophiothrix (Ophiothrix) ciliaris*, which was found in all surveyed areas of the park. This species and *O. (Keystonea) smaragdina* were the two most common brittle star species in this study with 119 and 136 individuals being recorded respectively, and both these species are associated with sponges (L. Marsh, pers. comm.), adding weight to the suggestion the sponges dominate the hard substrata off the reef edge at Ningaloo. Two other less common ophiotrichid species found in this study are also associated with sponges: *Ophiothrix (Ophiothrix) exigua* and *O. (Placophiothrix) lineocaerulea*. Two species are associated with cnidarians: *Ophiothela danae* is usually found entwined in gorgonians and *Ophiogymna* species are found in soft corals, while *Opriomaza cacaotica* and *Gymnolophus obscura* occur on comasterid crinoids.

Most of the ophiuroid species recorded in this study are typical of tropical shelf environments in the north-west of Australia, with a mixture of hard substrate cryptofauna and soft-sediment epifauna and infauna (T. O'Hara, pers. comm.). Several were coral reef species such as *Macrophiothrix callizona*, *M. robillardi* and *Ophiocoma brevipes*, which had previously been reported in very shallow depths (<2 m), but were found in 40-75 m depth in this study (L. Marsh, pers. comm.). Of these species only one (*M. callizona*) has previously been reported from Ningaloo reef. A few species were more typical of southern Australia, such as *Amphiura dolia*, *Ophiactis tricolor*, and *Ophiacantha clavigera* (T. O'Hara, pers. comm.). Three ophiuroid species in this study are considered endemic to north-western Australia: *Ophiothrix (Placophiothrix) lineocaerulea*, which was previously known from the

Montebello Islands to the Kimberley (L. Marsh, pers. comm.), *Ophiolepis unicolor* and *Ophiothrix smaragdina* (T. O'Hara, pers. comm.).

The Asteroidea (sea stars) consisted predominantly of shallow water coral reef species with 35 of the 61 asteroid species recorded in this study having also been reported from previous studies on Ningaloo reef. Many of the species were soft substrate asteroids which may suggest the sled occasionally went over soft bottom, or the sediment cover over pavements was sufficient to accommodate these species. Distribution data shows that 18 of the asteroid species found in this study are tropical Indo-West Pacific species, 16 are found in northern Australia and south-east Asia, three are endemic to northern Australia, and only two (possibly three) are southern temperate species (L. Marsh, pers. comm.).

The small collection of holothurians consisted almost entirely of tropical species. No southern temperate species were reported from this study unless the tentatively identified *Australocnus occiduus* proves to be correct. This species has not previously been found north of Jurien Bay. There are no endemic west coast species as far as is known, and only one species, *Loisettea amphictena,* is endemic to north-western Australia. Of the known holothurian species most are widespread Indo-west Pacific species with four species from northern Australia and the Indian Ocean and three from northern Australia and south-east Asia (L. Marsh, pers. comm.).

These findings indicate that the Ningaloo echinoderm fauna consists predominantly of tropical shelf or reef species that are largely Indo-West Pacific with a second strong northern component, and a minor southern component with few southern temperate species found in this study.

The large number of possible new species, at least 25, and distribution records found in this study reflect the minimal sampling of deeper communities off the reef edge on the NW coast of Australia (T. O'Hara, pers. comm.).

Molluscs. Almost 240 species of molluscs were collected from 97 of the 145 stations sampled by benthic sleds. Of these, 103 have been identified to species, 35 have tentatively been identified to that level, of which at least three are considered to belong to new and undescribed species. Of the remaining species, 53 have currently been identified to the generic level. The remaining species have not yet been identified beyond the family level.

Statistical analyses of the mollusc data highlighted the importance of resolving taxonomic identifications to the highest level possible. The analyses undertaken on molluscan families did not give the same level of discrimination as the species dataset. NMDS plots grouped the stations into four clusters based on species present, with stations in the northern area (from Point Cloates northwards) all in one cluster along with some stations from the central area (Point Cloates to Amherst Point). Most of the southern stations grouped together and one cluster contained stations that were more widespread with southern, central and Muiron Islands stations included. The last cluster comprised the Muiron Islands alone.

A number of the more abundant species were found to be dominant in particular areas or depths e.g. the scallop *Scaeochlamys* sp. 1 at depths >30 m in the northern area and *Cypraea cernica* in the central area at depths between 30-100 m. *Oliva ornata* was relatively common in the southern area and *Chicoreus cervicornis* and *Bursa granularis* were dominant in the northern area. Only the species *Tudivasum* sp. cf. *T. spinosa* was found in relatively high numbers in more than one area in this survey, occurring in both the Muiron Islands and the central area. These localised distributions could reflect the degree of dispersal ability of some of these species, or could indicate their dependancd on specific habitat requirements. However, the sled sampling technique may not have collected these species in a thorough and consistent manner.

When species collected in this study were compared to other studies in the same region very few taxa were found to occur at deeper depths, on the adjacent coral reefs, or in Exmouth Gulf. Only 17 of the species collected in this study had previously been reported from Ningaloo Reef and 14 had been reported from shallow depths in Exmouth Gulf (see Appendix 4). One species of scallop, *Annachlamys flabellata*, was found in this study, and previously on the reef and in Exmouth Gulf. Only 14 species have been collected from deeper stations off Ningaloo. This very low degree of species overlap with the results of studies from different depths and habitats in the same region suggests that the mollusc fauna is quite specialised and may have microhabitat requirements that may be detected when the synthesis of this data with habitat characteristics is undertaken. A contributing factor to the differences between these surveys might also be that the collecting methods used in this survey are less suitable for effectively sampling the molluscan fauna of the area, much of which is infaunal in soft and hard substrates or is of a cryptic habit.

In this study three species of molluscs appear to belong to undescribed species. Although this is a lower proportion than indicated for either the sponges or the echinoderms, the number will most certainly increase as all material from this study is identified past family level. There has been very little molluscan work at these mid-depths outside the Ningaloo lagoon or along the whole Western Australian coast. Most work has been at shallow diving depths or has been in much deeper depths, such as the Diamantina and Soela expeditions, the latter on the North West Shelf.

Of the molluscan species from this survey that are currently identified, all are typical of the known fauna of the northwest of Australia. Most inhabit both inshore and offshore waters of appropriate depths. Many herbivorous species belonging to gastropod families such as the Haliotidae, Fissurellidae, Trochidae and Turbinidae, which are abundant and diverse in shallower waters, were not found alive in the sled hauls. However, a few of the trochid species and many species of the family Cypraeidae that eat sponges were present. One interesting record is the presence of the cowrie *Cypraea friendii jeaniana*, a subspecies endemic to this region but often in deeper waters.

Dominant among the gastropods are carnivorous species of a variety of families including the Bursidae, Ranellidae, Muricidae, Turbinellidae, Buccinidae, Nassariidae and Conidae, which feed on a wide variety of prey including worms, barnacles and other molluscs. Living bivalves were poorly represented in this survey's results with most of the known species from this region being cemented to hard substrates, or infaunal in soft or hard substrates.

An interesting result is the diversity exhibited within the family Xenophoridae, the species of which are thought to feed upon detrital material, foraminiferans and filamentous algae from the surface of soft substrates.

Overview.

As stated in the introduction the primary aims of this component of the study were to contribute to the following management questions:

1. What is the distribution of the major benthic communities in the deeper non-lagoonal waters of the Ningaloo Marine Park?

We have found that this varies according to phyla: the echinoderms seem to be quite widespread, while the sponges and molluscs appear to be much more localised.

2. What are the major species/functional groups in the major benthic communities?

It is confirmed here that sponges dominate the filter feeding communities and echinoderms and molluscs dominate the motile benthic phyla.

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

The top 10 species by abundance of individuals for each phylum are provided for the four park areas examined in this study. They indicate that some species were in high numbers in all areas, while others were in high numbers in one or two areas but not in others suggesting that species distributions may be patchy in the region or perhaps have specific microhabitat requirements found in some park areas, but not others.

4. What are the causes of these distributions?

This question and question three above will be addressed when the results of this study are compared with the bathymetry and habitat classifications examined in other studies in this node. A synthesis analysis comparing habitat characteristics with some species distribution patterns could address this question. However, part of the answer will be related to life history characteristics, in part species' methods of dispersal e.g. pelagic vs restricted, but also microhabitat requirements, or the need to access specific food resources. For many species these biological constraints on species distributions are still poorly known.

5. What is the significance of the biodiversity of these deeper non-lagoonal waters globally?

The echinoderms had a large tropical shelf component and many coral reef species, but also numerous new species and extensions of biogeographic distributions. It has been more difficult to determine the significance of the sponges in a global context due to the lack of species names, but many species do appear to have localised distributions. Localised distributions were also common for the molluscs, although a lot of the molluscs are known species. In general there appears to be a relatively high level of endemicity of the fauna in these non-lagoonal depths.

6. Are the deeper non-lagoonal sections of the sanctuary zones appropriately situated with respect to conservation and representativeness?

For sponges it was clear that some groupings were not in sanctuary zones while others were. In general, species groups for the three phyla were aligned with areas across the region. Stations in the northern area, which contains the narrow shelf environment, often grouped separately from the other areas. The Muiron Islands stations sometimes grouped with the central and southern areas, perhaps because these areas all have a widening shelf environment.

7. What species/functional groups and sites should be used to measure temporal changes in these communities in the long-term?

Some of the larger biomass and more abundant species of sponges could be considered for video monitoring. If the sponges have distinctive growth forms that could be readily distinguished from other species it is possible that a remote monitoring system could work. Candidate sponge species could be *Petrosia (Petrosia)* sp. SS2, *Axinella* sp. Ng3 and *Spheciospongia* cf. *papillose*. Many of the echinoderms and molluscs that occurred in significant numbers were cryptic and therefore would need to be destructively sampled to be detected.

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