Scleractinian Corals of the Dampier Port and inner Mermaid Sound: species list, community composition and distributional data.

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Abstract

Surveys of coral reef habitats in the Dampier Port and inner Mermaid Sound recorded 120 species of scleractinian coral from 43 genera. This is a relatively high species count for an inshore reef system, and represents a significant contribution to the region's marine biodiversity.

Five coral assemblages were distinguished on the basis of proportional differences in generic composition. Four of the assemblages are dominated by a single genus each: *Acropora* (particularly plate *Acropora*), *Porites*, *Pavona*, and *Turbinaria* respectively. The fifth assemblage is mixed, consisting predominantly of faviids, *Turbinaria*, and a variety of other scleractinian corals.

The distribution of the 5 assemblages appears to be correlated with prevailing water quality, wave energy and tidal current strength. Reefs adjacent to the Dampier townsite and along the western coast of the Burrup Peninsula, where the 2004 dredging programs were undertaken, consist predominantly of the mixed coral assemblage. These reefs are exposed to substantial natural turbidity and sedimentation for much of the year, and appear reasonably resistant to it. The *Pavona*, *Porites* and plate *Acropora* assemblages are likely to be more susceptible to dredging-related turbidity and sedimentation.

Information on the composition and distribution of coral assemblages within Mermaid Sound may provide a useful background for future monitoring and environmental management of the marine areas of inshore Dampier Harbour. In particular, it might be used to select spoil dumping sites for minimal impact, to ensure reference sites can be located in similar assemblages to impact sites, and to define ecological management areas for estimates of cumulative habitat loss.

Keywords: coral, diversity, communities

Introduction

Scleractinian coral communities of the Dampier Archipelago have been studied relatively intensively as a consequence of the industrial developments in Dampier's marine and coastal environment. Prior to the present study, a cumulative total of 229 scleractinian coral species from 57 genera had been recorded in the Dampier Archipelago—more than any other Western Australian location except Ashmore Reef (Marsh 1978; Veron and Marsh 1988; Veron 1993; Griffith 2004). Studies in coral community ecology have been carried out by Simpson (1988) and monitoring of coral health has been undertaken by several private sector companies (eg. LDM 2000; Blakeway this volume). Taxonomic surveys and ecological research have concentrated mainly on the outer Archipelago, whereas the monitoring studies have concentrated on the western coast of the Burrup Peninsula, where much of the industrial development has taken place.

The lack of detailed taxonomic information on the corals of the Inner Harbour has resulted in environmental protection and management efforts relying on the assumption that the species present, and their ecology, are similar to offshore habitats. This has hampered the Western Australian Environmental Protection Authority's (EPA's) ability to provide a robust scientific basis to the assessment of likely conservation significance of impacts associated with two major dredging programs carried out in the Harbour in 2004 (Stoddart & Anstee this volume). A better understanding of species distribution within potentially impacted areas could greatly enhance assessments regarding likely changes in coral distribution within ecological management units under the (WAEPA) Benthic Primary Producer Habitat policy (EPA 2004 ; MScience 2004; URS 2004).

Methods

Site Locations

Coral community composition and distribution were assessed quantitatively using data collected in the 2004 coral health monitoring programme undertaken by Mscience Pty Ltd for Hamersley Iron and the Dampier Port Authority (Stoddart et al. this volume). Selection of sites for the monitoring programme attempted to cover all substantial coral populations adjacent to dredging and spoil disposal operations, plus a range of reference sites not at risk. In total, 19 sites were selected for monitoring in that program, spanning an onshore to offshore gradient along the east and west coasts of Mermaid Sound (Table 1; Fig. 1). Several other sites within the Harbour were surveyed as single time samples to provide additional data on relative abundance of corals and for taxonomic lists. Substrates at all sampling locations were rock or boulder slopes partially to completely covered by corals, and bordered on the seaward side by mixed carbonate/terrigenous sediments. Maximum water depths at all sites were within the range of 6 to 10 m below mean lower low water (MLLW).

Sampling Methods

Coral communities of the Dampier Harbour exist most commonly as linear features fringing shorelines of islands or the Burrup Peninsula. In general they occur in a narrow depth range of 2 to 6m below MLLW. Within the coral health monitoring sites, quantitative assessment of the cover of living coral was undertaken every fortnight between November 2003 and December 2004. Digital photographs, each covering approximately 50 cm x 70 cm of the substrate taken at 1 m intervals along transects were used to provide a precise assessment of percent cover (see Stoddart et al. this volume). Cover of hard corals was subdivided into categories of *Acropora*, *Porites*, *Pavona*, Faviid, *Turbinaria*, "other" (including all hard corals not included in the former groups and hydrozoans such as *Millepora*). Non-coral categories included "other fauna" (including soft corals), "flora" and "abiotic" (including sand and rubble). Three additional sites (see Fig. 1 for locations) that were not part of the monitoring program—Outer Tidepole Island (OTPW), East Intercourse Island (EIIE) and an unnamed reef inside Tidepole Island (TCIR) - were surveyed in late 2004 on a single occasion using the same assessment method.

A species list for the area was compiled by surveying sites on SCUBA and either identifying species in-situ or, if they could not be positively identified, collecting fragments for later identification. Two initial surveys of approximately one hour duration were made at the Service Wharf Reef (SWR, Fig. 1) in addition to opportunistic surveys of up to 20 minutes at many of the coral health sites. Coral samples were bleached in chlorine then washed in fresh water and dried. A comprehensive collection of photographs was made of in-situ corals at all survey sites and also of the bleached skeletal samples. Identification was undertaken by comparison to specimens in the WA Museum collection and by reference to taxonomic literature including Griffith (2004), Veron (2000), Veron and Marsh (1988), Veron and Wallace (1984), Veron and Pichon (1976, 1980, 1982) and Veron et al. (1977).

To determine how well our coral species list represented the known coral community of the Dampier Archipelago, it was compared to species lists and distributional data from three previous quantitative surveys (Marsh 1978; Fisk 1991; Griffith 2004) and to a regional species list for the North West Shelf (Veron & Marsh 1988).

Statistical analyses

Coral composition - cluster analysis and non-metric multidimensional scaling

Relationships between the proportional composition of coral groups at each site were investigated using cluster analysis on the coral component of the transect data. Using the relative abundance of each group, a Euclidean distance matrix was generated for cluster analysis using Ward's minimum variance method (as reviewed in Legendre and Legendre 1998). A matrix dendrogram was used to aggregate coral sites into groups based on similarity in coral composition.

Following the recommendations of Legendre and Legendre (1998), the validity of the site groupings delimited by cluster analysis were checked using a second independent method—non-metric multidimensional scaling (NMDS). Kruskal's NMDS (Cox and Cox 2001) was performed using 10 random starts. Convergence on a 2-dimensional solution occurred after 8 iterations. Convergence was determined by performing Procrustes analysis with each iteration to the previous until it became non-significant, as outlined by Minchin (1987). NMDS dimension 1 and 2 scores for both sites and coral genus were plotted and overlaid with the site groupings produced by cluster analysis.

Co-occurrence of coral genera - cluster analysis of Pearson's correlation coefficient.

The distribution of coral genera between sites was compared using Ward's minium variance cluster analysis. The analysis was essentially the same as that used to group sites based on their proportions of coral genera, but instead grouped coral genera in terms of similarities in their distribution among sites. Pearson's correlation coefficients were calculated for each genus pair as a validation test.

Spatial analysis – Mantels test with permutation.

Following the method of Legendre and Legendre (1998), a comparison of linear geographic distance between sites and the similarity of genus composition was conducted using a Mantels test with permutation. Two Euclidian dissimilarity matrices were generated; one comparing coral composition of site pairs and one comparing linear distances between site pairs. The Mantel statistic was calculated as the correlation between two dissimilarity matrices. Its significance was calculated by permuting rows and columns of the dissimilarity matrix 5000 times and calculating "r" and "p" statistics (this is analogous to the procedure used for significance calculations in ANOSIM, see Clarke and Warwick 1994).

Results

Species list

We recorded a total of 120 scleractinian coral species from 43 genera (App.1) from the Dampier Harbour coral communities. Only one of these species, *Acropora kosurini*, has not been recorded previously in the Dampier Archipelago, despite having a large distribution range encompassing the entire North West Shelf (Veron 2000). An additional six coral species were not included in this species total as they could not be identified reliably. They are listed in Table 1 as *Acropora* sp. A, B, C, *Platygyra* sp. A, *Echinopora* sp. A and *Porites* sp. A.

Our species list appears to be a broadly representative subset of all species known to occur in the Dampier Archipelago. In terms of species richness within genera, our list (Fig. 2A) shows similar patterns to those of previous studies (Fig. 2B, compiled from data in Griffith 2004; Fisk 1991; LSC 1991; Veron and Marsh 1988). *Acropora* is the most speciose genus in our data set, contributing 21 species (17.5% of the species total). *Favia* is the second most speciose, contributing 9 species (7.5%). The genera *Favites*, *Goniastrea*, *Platygyra* and *Turbinaria* are each represented by 7 species (5.8% each), and the genera *Montipora*, *Goniopora*, *Porites* and *Psammocora* are each represented by 4 species (3.3% each). An additional three genera are represented by three species each, eight genera by two species each and 21 genera by one species each.

Figure 1. Location of monitoring sites in Mermaid Sound.

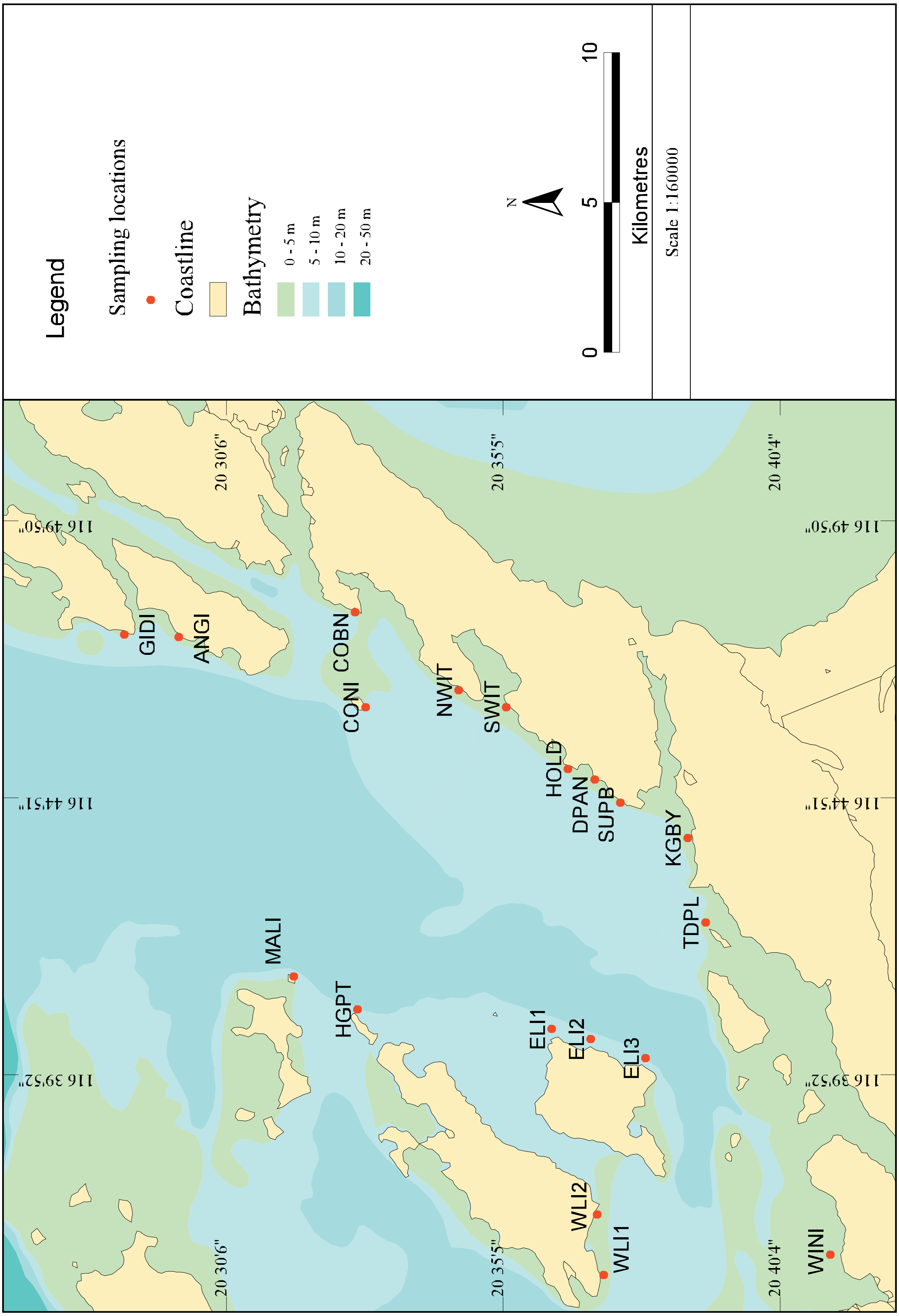


Figure 2: (a) Number of species in each coral genus recorded during this quantitative survey (b) Number of species in each coral genus recorded during pervious qantitative surveys (Marsh 1978; Fisk 1991;Griffith 2004)of the Dampier ArchipelagoHistograms # of species by genus.

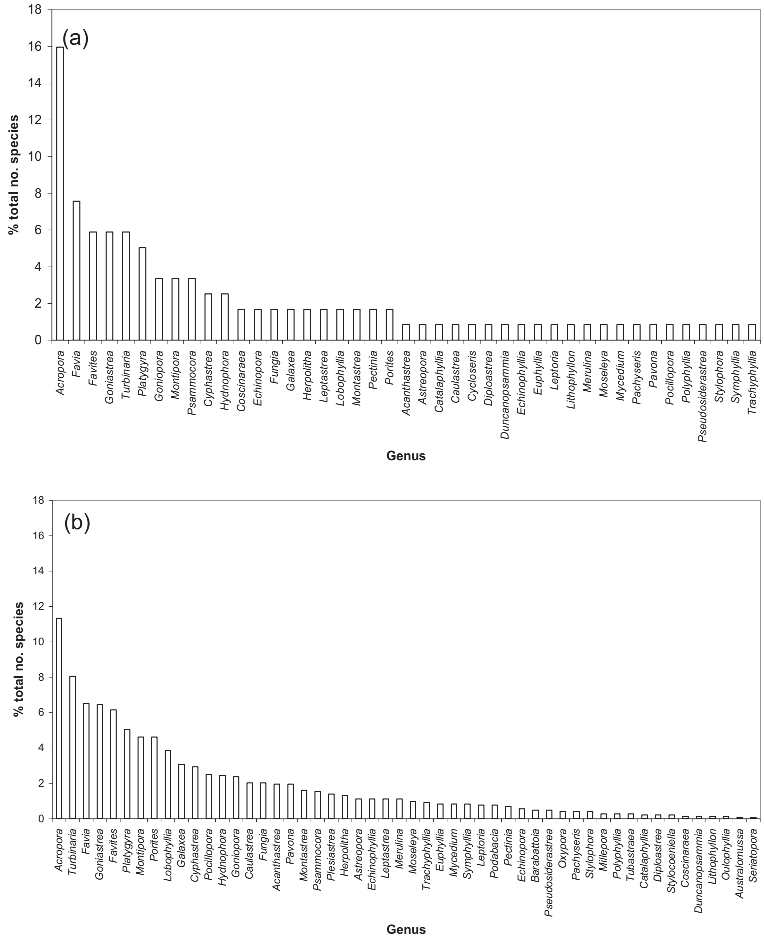


Figure 3: Dendrogram depicting sites grouped according to their similarity in coral genera composition

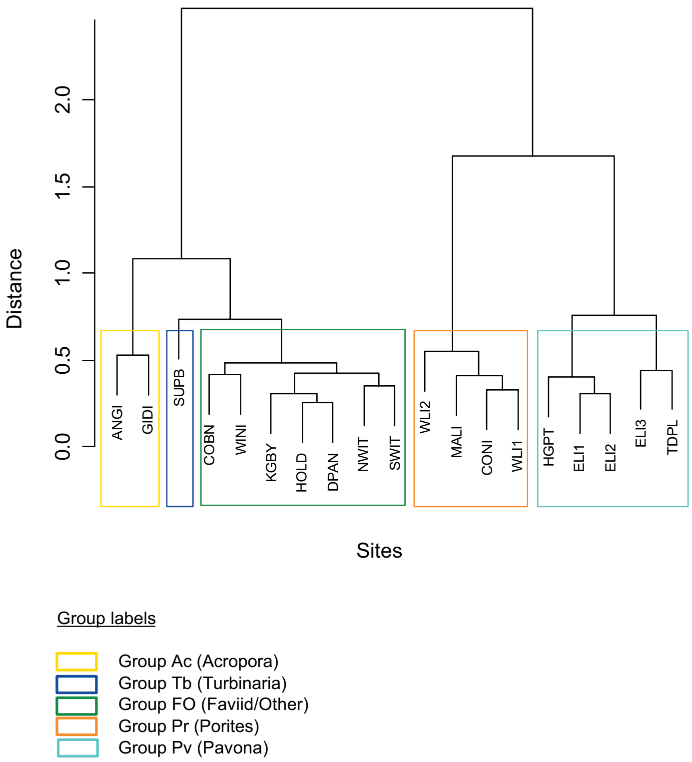


Figure 4: Non-metric multidimensional scaling plot depicting the six groups distinguished by cluster analysis.

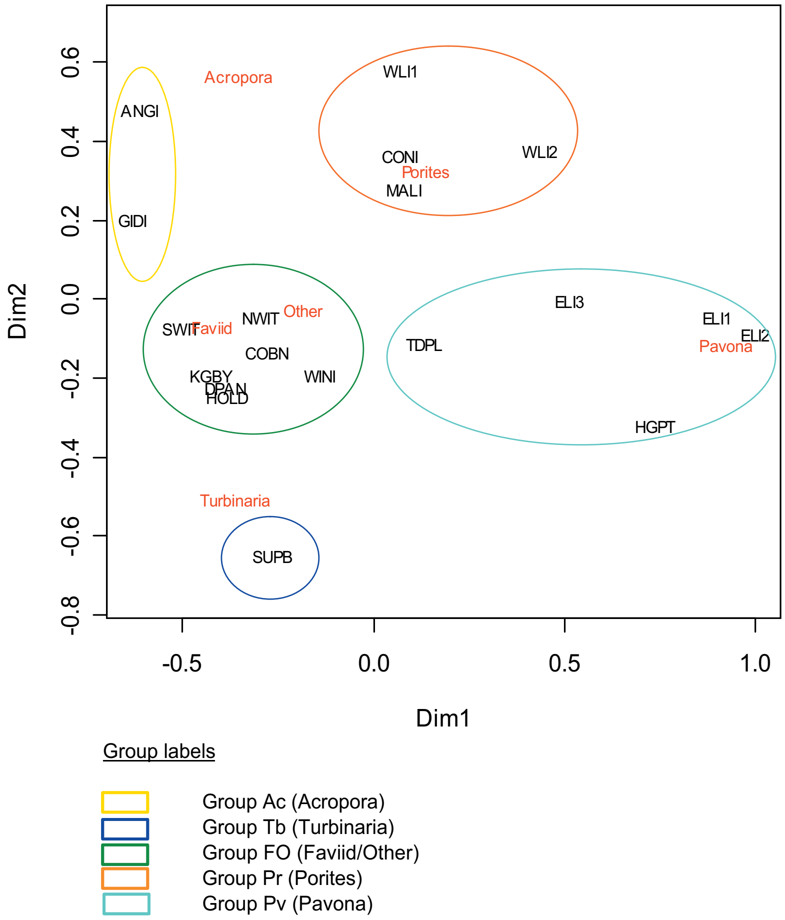
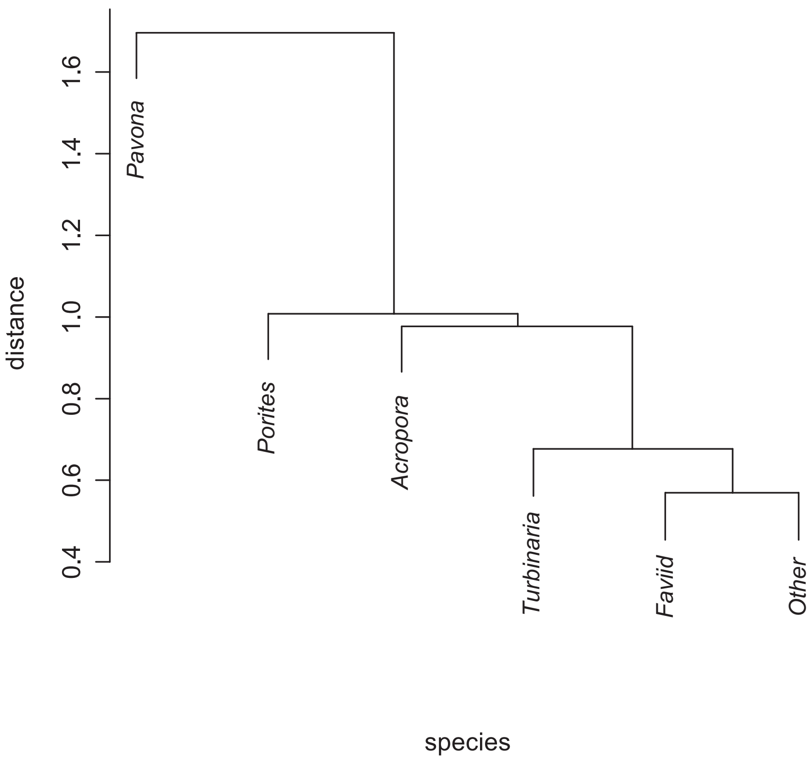


Figure 5: Dendrogram depicting coral taxa grouped according to similarity in distribution.



Although we did not record the abundance of individual species in our study, our qualitative impression was that the majority of species occurred at a relatively low frequency. This is supported by a comparison of our species list against the species abundance records from earlier quantitative studies—almost half of the species on our list occurred at only 10% or less of the cumulative 63 sites surveyed by Marsh (1978), Fisk (1991) and Griffith (2004). Although uncommon in Dampier, most of these species are common elsewhere in the Indo-Pacific (based on species data in Veron 2000). The few species that are uncommon both in Dampier and the wider Indo-Pacific include *Acropora kosurini*, *Acropora dendrum*, *Favia veroni*, *Duncanopsammia axifuga*, *Turbinaria conspicua* and *Favia maxima*. Not surprisingly, corals that are common at Dampier are also common in the wider Indo-Pacific (based on species data in Veron 2000). Thus it seems that Dampier has a fairly cosmopolitan coral community, with relatively few rare species. This statement should be qualified, in that some of the species we were unable to identify could be rare species, and there could also be misidentifications in our species list.

Community composition

Cluster analysis divided the 19 sites into five groups (Fig. 3). Although the process of selecting groups from a dendrogram is always somewhat arbitrary, this particular grouping is supported by the NMDS results (Fig. 4). The NMDS plot indicates that four of the five groups are characterised by the predominance of a single genus. Dominant genera include *Acropora* (particularly plate *Acropora*) for the group consisting of sites ANGI and GIDI, *Porites* for the group including sites WLI1, WLI2, MALI and CONI, *Pavona* for the HGPT, ELI1, ELI2, ELI3 and TDPL group, and *Turbinaria* for SUPB (Fig. 5). The fifth group of sites, comprising COBN, WINI, KGBY, HOLD, DPAN, NWIT and SWIT, is characterised by an abundance of faviids, *Turbinaria* and 'other corals'. The most abundant taxa in the latter category include *Lobophyllia*, *Echinophyllia*, *Goniopora* and *Caulastrea* inshore, and *Millepora* further offshore.

Co-occurrence of coral genera

The distributions of the six major taxonomic groups appear to be relatively independent; although all six groups occur at most sites, none co-occur in consistent proportions (Fig. 6). The closest relationship is between Faviids and 'other corals' (Fig. 5), which are distributed relatively evenly across most sites. The distributions of all other taxa are skewed toward one or more sites. The most extreme example is the genus *Pavona*, which constitutes 50% to 70% of the coral cover along the eastern shores of East and West Lewis Islands, but less than 10% at most other sites.

Spatial analysis

Spatial analysis indicates that physical distance between sites is not a good predictor of their similarity in generic composition (correlation coefficient $r = 0.05722$, significance $p = 0.254$). Despite the lack of a linear relationship, some of the variation in coral assemblages is clearly spatially associated. However, this is more likely to reflect the spatial pattern of habitat occurrence than limited dispersal patterns. For example, the *Pavona*-dominated assemblage consistently occurs on east-facing shores and the mixed coral assemblage on northwest-facing shores (Fig. 6).

Discussion

Coral species and assemblages

Many scleractinian coral species in the Dampier Archipelago are found over the entire inshore-to-offshore range of habitats, but a few species are restricted to turbid inshore reefs and others are restricted to outer reefs (Semeniuk et al. 1982; Marsh 1978, Paling 1986, Simpson 1988). Not surprisingly, our species list shows a bias toward the inshore species and includes species from all five of the predominantly inshore genera defined by Marsh (1978)—*Duncanopsammia*, *Caulastrea*, *Trachyphyllia*, *Moselya* and *Euphyllia*, but neither of the two offshore species—*Pocillopora eydouxi* and *Pavona minuta*. The relatively low proportion of *Montipora* species in our data set may be a further indication of a predominantly inshore fauna.

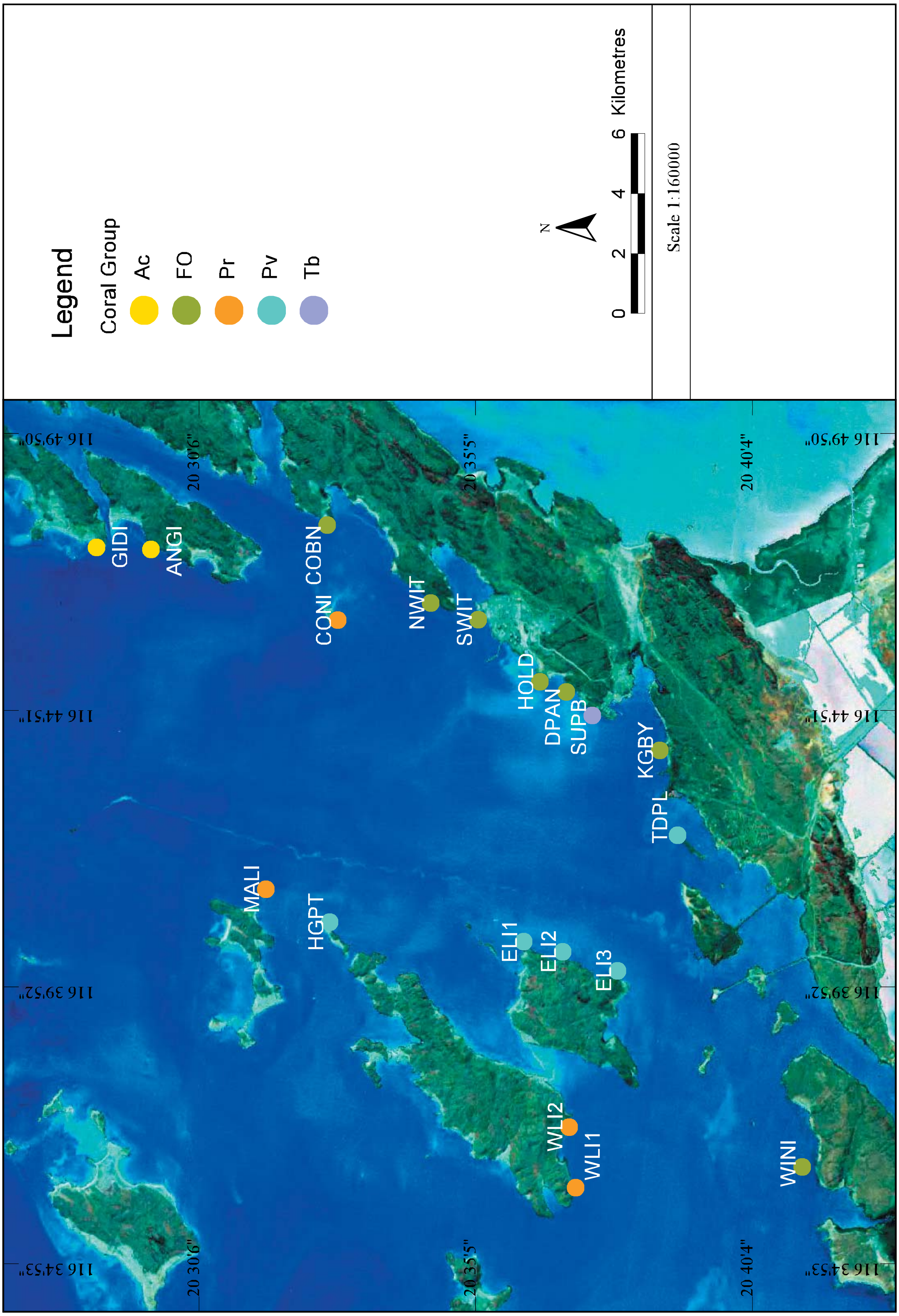
Previous authors on coral diversity within the Dampier area have suggested that inshore diversity will be much lower than that reported offshore (Veron & Marsh 1988, Simpson 1988). Given that context, the species diversity recorded in our surveys is surprisingly high, comprising just over half the total species pool recorded from the entire Dampier Archipelago. It is likely that additional species will be encountered at inshore sites with more exhaustive sampling. Clearly the inshore reefs of the Dampier Harbour and inner Mermaid Sound are species-rich, and are likely to be an important component of the inner shelf ecosystem.

Several authors have examined the relationship between corals and habitats within Mermaid Sound. Simpson and Grey (1989) found that corals were most abundant on upper seaward reef slopes of the islands and less abundant along the mainland coastline. Semeniuk et al. (1982) described differences between the coral communities of sloping rocky shores, where coral colonies reach a large size and are closely packed, or on flat limestone pavements, where coral colonies are small and interspersed with other sessile invertebrates. They also depicted coral depth zonation at several Burrup Peninsula sites and their diagram of Angel Island in particular (Fig. 8A of Semeniuk et al. [1982]) shows a consistent feature of several outer Mermaid Sound sites; the occurrence on the lower reef slopes of *Turbinaria* and other sediment-tolerant species which are generally more characteristic of shallow inshore sites.

Despite these indications of habitat-specific patterns in coral distribution, quantitative analyses have in the past failed to detect distinct associations between species assemblages and habitats within the Dampier Archipelago (Paling 1986; Griffith 2004). Those analyses relied solely on species presence or absence in comparing sites. When sites are compared using proportional composition of coral taxa, as suggested by Griffith (2004), clear associations between coral assemblages and habitats become apparent (eg. Fig. 3, 4 and 6).

Factors controlling these relationships can be inferred but cannot be ascertained with any certainty. Habitat-

Figure 6: Map showing proportion of each coral genus recorded at monitoring sites and total coral cover



specific variations in recruitment, growth or mortality could all potentially be responsible for the observed coral distribution. Perhaps the simplest explanation is that virtually all species in the regional pool can recruit to and survive in any of the available habitats (thus accounting for the lack of detectable pattern in the presence/absence data) but only a relatively small subset of species will thrive and become abundant in any particular habitat.

Based on our underwater observations through the year, and the water quality data (see Stoddart & Anstee this volume) coral assemblage distribution appears to be correlated with three environmental factors: wave exposure, turbidity (i.e. natural 'background' turbidity) and tidal currents. The *Acropora*-dominated assemblage (Fig. 7a) occurs in relatively exposed sites with low to moderate turbidity, the *Porites*-dominated assemblage (Fig. 7d) occurs at sites with good current flow and low to moderate turbidity, the *Pavona*-dominated assemblage (Fig. 7e) is found in relatively sheltered sites with moderate turbidity, and the *Turbinaria*-dominated assemblage (Fig. 7b) occurs in highly turbid environments.

The mixed faviid/*Turbinaria*/"other" coral assemblage (Fig. 7c) can perhaps be considered the default coral community of the inner Mermaid Sound. This assemblage is widespread in nearshore environments with intermediate levels of exposure, turbidity and current flow. There are several other influences on coral distribution in the Dampier Archipelago that are not well understood, including cyclones and floods. However, the apparent relationships outlined above suggest that coral distribution is determined more by prevailing conditions than by brief high-impact events.

The most striking feature of the inner Mermaid Sound coral community is the abundance of *Pavona decussata* along the eastern shores of East and West Lewis Islands. *P. decussata* colonies occur at these sites as dome-shaped clumps up to approximately 3m in diameter and can cover up to 75% of some reef areas. Veron (2000) notes that *P. decussata* is divisible into semi-distinct taxonomic units. This subspecies-level variation is evident at the East and West Lewis Island sites as noticeable differences in the scale of the characteristic cellular skeletal structure (Fig. 7f).

In addition to scleractinian corals, several other groups of sessile benthic organisms were recorded on the transects. The most common were soft corals of the genera *Sarcophyton*, *Lobophytum*, *Sinularia*, and *Nephthea*, hydrozoans of the genus *Millepora*, a variety of sponges, and at least two species of zoanthid. We did not undertake analyses of these individual taxa, but qualitatively it was apparent that soft corals tend to occur in the *Porites* and *Pavona* assemblages, *Millepora* tends to occur in the *Porites* assemblage (but was also abundant in the mixed assemblage at COBN), sponges tend to be more abundant in deeper environments and zoanthids occur on boulders in shallow environments on both sides of Mermaid Sound.

Management implications

The descriptions presented above of the differentiation and distribution of coral assemblages within Mermaid Sound may provide a useful background for future monitoring and environmental management of the marine areas of inshore Dampier Harbour. In particular, where impact monitoring is proposed, appropriate reference sites can now be located within similar community types and better ecological information is available to define meaningful ecological management areas for estimates of cumulative habitat loss (e.g. EPA 2004).

In terms of predicting the effects of impacts from dredging and infrastructure development, we estimate the 5 assemblages to rank, from lowest to highest susceptibility as *Turbinaria*, mixed (faviid/*Turbinaria*/other), *Pavona*, *Porites*, and *Acropora*. Most of the industrial development around Dampier has occurred near the townsite and on the west coast of the Burrup Peninsula, where coral reefs consist predominantly of the mixed coral assemblage (Fig. 5). These reefs receive substantial levels of natural turbidity and suspended sediment for much of the year, and appear reasonably resistant to it. The natural resilience of this assemblage has probably buffered it to a significant extent against the additional turbidity and sedimentation associated with dredging, construction and ship movements.

While some reefs located close to shiploading facilities, dredge sites and spoil grounds have suffered reductions in coral abundance and diversity (MScience 2004, Blakeway this volume), most of the mixed assemblage reefs in the Dampier Port and Mermaid Sound appear to be in reasonably good condition. The *Pavona*, *Porites* and *Acropora*-dominated assemblages also appear to be in good condition at present, but are likely to be more sensitive to turbidity and sedimentation than the *Turbinaria* and mixed coral assemblages. Consequently it should not be assumed that they will respond in the same way to dredging impacts as more resistant assemblages, and extra caution should be taken if dredging activities are planned near these assemblages.

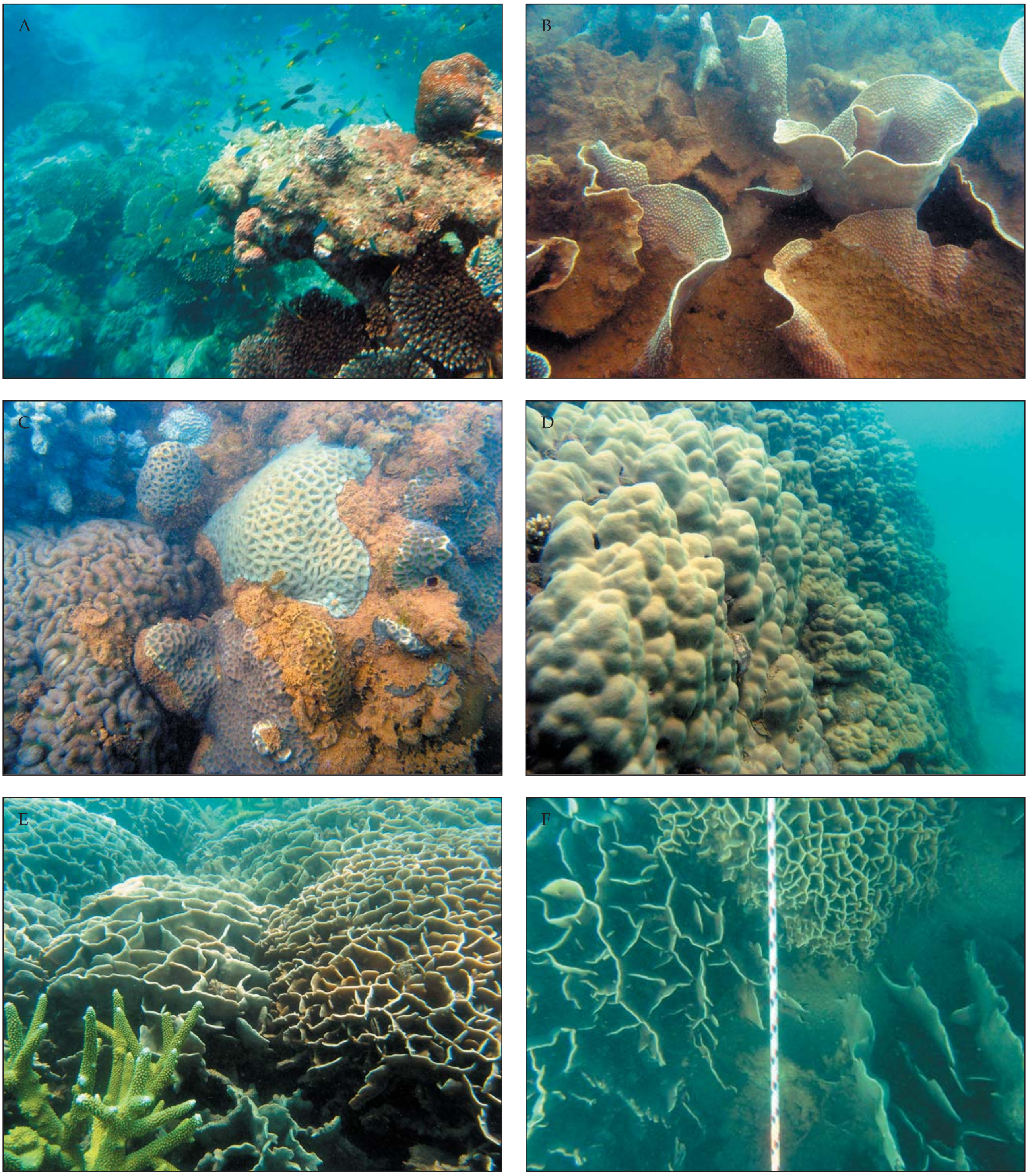


Figure 7:

A) Acropora-dominated assemblage, Angel Island. This image shows the steep drop-off at the edge of the reef flat.

B) Turbinaria-dominated assemblage, Supply Base.

C) Faviid/other coral assemblage, King Bay.

D) Porites-dominated assemblage, Conzinc Island. Porites colonies at this site are up to 3m in diameter.

E) Pavona-dominated assemblage, East Lewis Island 1. Branching Acropora lower left.

F) Morphological differences between adjacent Pavona decussata colonies (site ELI2)

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Appendix 1. Scleractinian coral species identified from Dampier Harbour.

Family Acroporidae

Acropora austera
Acropora clathrata
Acropora cytherea
Acropora dendrum
Acropora florida
Acropora formosa
Acropora gemmifera
Acropora glauca
Acropora humilis
Acropora hyacinthus
Acropora kosurini
Acropora latistella
Acropora microphthalma
Acropora millepora
Acropora nobilis
Acropora robusta
Acropora samoensis
Acropora solitaryensis
Acropora tenuis
Acropora verweyi
Acropora yongei
Acropora sp. A
Acropora sp. B
Acropora sp. C
Astreopora myriophthalma
Montipora danae
Montipora hispida
Montipora informis
Montipora turgescens

Family Agariciidae

Pachyseris rugosa
Pavona decussata

Family Caryophylliidae

Catalaphyllia jardinei
Euphyllia ancora

Family Dendrophylliidae

Duncanopsammia axifuga
Tubastraea diaphana
Turbinaria biffrons
Turbinaria conspicua
Turbinaria frondens
Turbinaria mesenterina
Turbinaria peltata
Turbinaria reniformis

Family Faviidae

Caulastrea tumida
Cyphastrea chalcidium
Cyphastrea microphthalma
Cyphastrea serailia
Diploastrea heliopora
Echinopora gemmacae
Echinopora lamellosa
Echinopora sp. A
Favia favus
Favia marshae
Favia matthaii
Favia maxima
Favia pallida
Favia rotumana
Favia speciosa
Favia stelligera
Favia veroni
Favites abdita
Favites chinensis
Favites complanata
Favites flexuosa
Favites halicora
Favites pentagona
Favites russelli
Goniastrea aspera
Goniastrea australensis
Goniastrea edwardsi
Goniastrea favulus
Goniastrea palauensis
Goniastrea pectinata
Goniastrea retiformis
Leptastrea pruinosa
Leptastrea transversa
Leptoria phrygia
Montastrea curta
Montastrea valenciennesi
Moseleya latistellata
Platygyra daedalea
Platygyra lamellina
Platygyra pini
Platygyra ryukyuensis
Platygyra sinensis
Platygyra verweyi
Platygyra acuta
Platygyra sp. A

Family Fungidae

Fungia cyclolites
Fungia fungites
Fungia repanda
Herpolitha limax
Lithophyllon undulatum
Podabacia crustacea
Polyphyllia talpina

Family Meruliniidae

Hydnophora exesa
Hydnophora microconos
Hydnophora pilosa
Merulina ampliata

Family Mussidae

Acanthastrea echinata
Lobophyllia corymbosa
Lobophyllia hemprichii
Symphyllia agaricia

Family Oculinidae

Galaxea astreata
Galaxea fascicularis

Family Pectiniidae

Echinophyllia aspera
Mycedium elephantotus
Pectinia lactuca
Pectinia paeonia

Family Pocilloporidae

Pocillopora damicornis
Stylophora pistillata

Family Poritidae

Goniopora djiboutiensis
Goniopora pendulus
Goniopora stutchburyi
Goniopora tenuidens
Porites cylindrica
Porites lutea
Porites lobata
Porites solida
Porites sp. A

Family Siderastreidae

Pseudosiderastrea tayami
Coscinarea columna
Coscinarea exesa
Psammocora contigua
Psammocora digitata
Psammocora profundacella
Psammocora superficialis

Family Trachyphylliidae

Trachyphyllia geoffroyi