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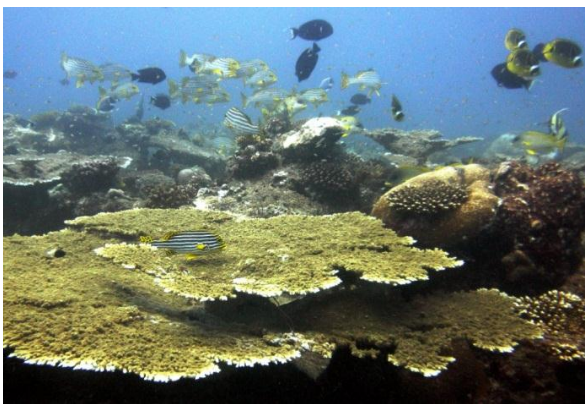


August 2011

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August 2011

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Acknowledgments

Our sincere thanks to our partners in Mozambique for hosting this research: Dr Adriano Macia of the University of Eduardo Mondlane and Dr Hermes Pacule, Director of CEPAM, Centro de Pesquisa do Ambiente Marinho e Costeiro of the Ministry of Environment (MICOA – Coordenacao Ambiental).

We gratefully acknowledge the generous support of Metundo Eco-Lodge who contributed full board accomodation and full use of their boat for the duration of the survey with no charges. All the staff at the Metundo Eco-Lodge gave us a warm welcome notably Renato Rizzi skipper and manager, Stefane Cade, dive master, and the owner Matteo Vaghi. We are extremely grateful to Matteo for this support.

Executive Summary

This rapid assessment of coral reefs in Cabo Delgado Province, northern Mozambique, was part of a regional project on the biodiversity and health of coral reefs in the Western Indian Ocean (WIO) led by CORDIO East Africa. This rapid assessment, in June 2010, situated around Metundo Island (11^{o}.08’ S, 40 ^{o}.40’ E) was the first survey to be conducted in Mozambique as part of a broader survey of the complex of reefs and islands of the Quirimbas Archipelago in the province of Cabo Delgado.

Several reef systems of the WIO were particularly badly affected by the 1998 El Nïno bleaching event, however, it appears that the northern reefs of Mozambique were more resilient to bleaching compared with southern Mozambique and other areas of the WIO. These reefs are hypothesised to be some of the most diverse, productive and healthy in the WIO being situated where the South Equatorial Current (SEC) hits the African mainland coast (around 10^{o}S) and then diverges north and south.

The objectives of this rapid assessment through SCUBA based surveys were to provide preliminary data on fish diversity and abundance, benthic cover, coral population structure and coral health to assess the resilience or health of the reefs around Metundo Island. Benthic cover focused on broad benthic categories and the algal community because they are important in assessing phase shifts from coral dominated reef communities to algal dominated communities. We quantified the diversity of coral reef fishes based on a complete species inventory of 19 families. Fish abundance and size data by species were also collected to assess the relative proportions of different trophic groups considered important in confering resilience to reefs to climate change.

The reefs around Metundo Island are structurally diverse with extensive areas of reef flat and submerged plateaus with rich coral growth. Outer reef slopes were characterised by moderate rugosity, diverse corals and relatively high coral cover. The area also borders deep channels with reef walls dropping spectacularly to several hundred metres. Hard live coral cover was high at several sites (> 50%) suggesting both large mature corals and also mono-specific stands. *Galaxea* and *Montipora* dominated corals in the largest size class (>320cm). Calcareous algal cover was also high at certain sites (32-37%). This is usually associated with healthy reefs as it provides stable substrate for coral recruits and is therefore important in reef recovery. The dominance by both number and area cover of the coral genus *Acropora* provides strong evidence that this coral has suffered little bleaching or has robust recovery, or both. Since *Acropora* is so susceptible to bleaching this result also supports suggestions that the reefs around Metundo have not been subjected to significantly and persistently elevated sea surface temperatures during recent El Niño events, or that these reefs are resistant to bleaching for other reasons, or a mixture of the two. This may be due to local topographic and oceanographic features of the area. Corals were also particularly healthy with less than 1% bleaching, mortality or disease recorded across all sites. These results corroborate previous suggestions that the northern Quirimbas reefs of Mozambique are both resistant to coral bleaching and/or have high capacity to recover.

The extensive and diverse reef structures no doubt account for the relatively high diversity of reef fishes. The total count of 212 species recorded serves as a preliminary inventory of species and patterns in diversity around Metundo. It was clear that the total

number of species was not reached, but the highest diversity per location, 106 species compares well with the highest species diversity recorded per site of 126 in NE Madagascar. Despite the relatively healthy and diverse reefs with minimal evidence of bleaching and reasonably high diversity of fish species, the densities of reef fishes were low. The highest density per trophic group was 21-24 fish/1000m^2 (omnivores). This is low compared with recent surveys in Madagascar where density per trophic group was often over 40 fish/1000m^2, and occasionally over 100 fish/1000m^2. Mean densities per trophic group ranged from 0.33 fish/1000m^2 (browsers – a mix of taxa including parrotfish and surgeonfish), to 2.67 fish/1000m^2 (piscivores –groupers and trevally), 6.7 fish/1000m^2 (planktivores), 8.0 fish/1000m^2 (grazers – surgeonfish and rabbitfish) and 12.0 fish/1000m^2 (omnivores – emperros, snapper and sweetlips). These results no doubt in part reflect the short and limited nature of the survey with only 4 sites, and those all limited to the northern leeward side of the Island. But they also suggest fishing pressure may be quite high. Local information suggested this is from itinerant fishermen coming mainly from Tanzania and Nacala. Other anthropogenic impacts in the northern Quirimbas are apparently low due to their remote location, poor access to markets, little infrastructure and lack of freshwater, though this is changing.

The low densities of reef fishes is of concern and indicates that fishing pressure may be relatively high. Further, with such a high proportion of *Acropora* on these reefs, their vulnerability to future bleaching from sea surface temperature increases is likely to be high. It is therefore crucial that other stresses such as overfishing are minimised to maximise the ability of these reefs to recover from a future bleaching event. It is highly recommended that a zoning system of fisheries management including a network of no-take zones (NTZs) is considered, and that planning starts immediately with local community members. Mozambique is in urgent need of marine scientists and managers with expertise in coral reef ecosystem management. Support for post-graduate level training in this field is much needed.

Given the relatively healthy condition of the reefs suggested by this rapid survey and the strategic location of the northern Quirimbas coral reef systems, we would suggest that the reefs around Metundo Island are of high conservation and research interest and can provide an important economic resource that can contribute to sustainable fisheries and development through tourism. The area is in urgent need of management and formal protection and a thorough biodiversity and reef status survey of the broader area is recommended.

1. Introduction

This rapid assessment of coral reefs in Cabo Delgado Province, northern Mozambique, was part of a regional project on the biodiversity and health of coral reefs in the Western Indian Ocean (WIO), funded through the Western Indian Ocean Marine Science Association's (WIOMSA) Marine Science for Management (MASMA) programme (Obura et al 2008). As part of this project the coral reef surveys in Cabo Delgado reported here, contribute to a collaboration between CORDIO East Africa, the University of Eduardo Mondlane (UEM) and Centro de Pesquisa do Ambiente Marinho e Costeiro (CEPAM) in Pemba.

Several reef systems of the WIO were particularly badly affected by the 1998 El Nïno bleaching event (Wilkinson 2000, Obura 2005). However, it appears that the northern reefs of Mozambique were more resilient to bleaching compared with southern Mozambique and other areas of the WIO (Obura, 2005, Davidson *et al.* 2006, Obura 2008, Hill et al 2009). In addition, these reefs are hypothesised to be some of the most diverse, productive and healthy in the Western Indian Ocean being situated where the South Equatorial Current (SEC) hits the African mainland coast (around 10^{o}S) and then diverges north and south (Obura et al 2008, Hill et al 2009). Consequently, the complex of reefs and islands of the Quirimbas Archipelago in the province of Cabo Delgado were selected for the diversity and reef health surveys of the MASMA funded project "Is there a Western Indian Ocean Coral Triangle?". This rapid assessment, in June 2010, was the first survey to be conducted situated around Metundo Island (11^{o}.08' S, 40 ^{o}.40' E). This builds on a number of surveys done through 2003-2006 around Vamizi Island just north of Metundo, through the Zoological Society of London (Hill et al 2009).

Anthropogenic impacts in the northern Quirimbas are low due to their remote location, poor access to markets, little infrastructure (Hill et al 2009) and lack of freshwater, though this is starting to change. The capital of Cabo Delgado, Pemba, is around 320km south of Mocimboa da Praia, the small town adjacent to Metundo Island which currently has no power. But the government is bringing power to Mocimboa da Praia, expected in 2010/11. This is likely to change levels of fishing pressure because of the ability to make ice and store fish. Other threats include high levels of immigration, improved access to markets and technology, and oil and gas exploitation (Hill et al 2009). Exploratory activities for oil extraction have now started: seismic surveys have been completed and the first experimental wells are being tested (IK pers. obs).

Due to the lack of freshwater on the Quirimbas islands few are settled since water has to be brought from the mainland. Therefore on Metundo and nearby Kifuki many villagers are mainly itinerant fishermen from Tanzania and Nacala, with a small group from the region (IS pers. obs.). Recent threats appear to be illegal fishing gears and the unregulated numbers of fishermen coming from outside the Province.

The capacity to conserve and manage coral reefs and associated coastal and marine resources is still limited in Mozambique. The intense civil war (1977-1992) was devastating for the country. While the political situation is now stable, Mozambique still has one of the lowest Human Development Indices of all countries in the world and the lowest in Africa (UNDP 2009). The long 2,600km coastline has coral reefs along its length, but conservation efforts only began in the last decade (through the Ministry for the Coordination of Environmental Affairs, MICOA). Much of this work has been targeted at the southern Quirimbas, mainly with the development of the Quirimbas National Park (Pereira *et al*., 2003). Coral reef scientists are still few in Mozambique yet the country has one of the longest coastlines in the WIO. The CORDIO Coral Triangle MASMA project also aims to build capacity in marine science in Mozambique, through direct experience working on surveys such as this rapid assessment.

The objectives of the rapid assessment were to provide preliminary data on fish diversity abundance and coral health and benthic cover. Benthic cover focused on broad benthic categories and the algal community because they are important in assessing phase shifts from coral dominated reef communities to algal dominated communities.

To measure the diversity of coral reef fishes we used the method designed for a biogeographic analysis of species distributions in the WIO developed for CORDIO's MASMA project recently applied to assess the reef fish populations of NE Madagascar (Samoilys and Randriamanantsoa 2011). It is based on compiling a complete species inventory of 19 families at each location. This group of 19 families includes potentially around 460 species in total from the WIO (Samoilys 1988, Obura 2004, Allen 2005, Davidson et al 2006), and represents 51% of the total number of coral reef species from 92 families reported from Madagascar (Allen 2005). This was considered to be broad enough and diverse enough to capture patterns in diversity of fishes across the WIO region.

Certain trophic groups of reef fish, particularly the herbivores, have been shown to play a critical role in coral reef resilience by controlling macroalgal communities and preventing coral-algal phase shifts (Bellwood et al 2004, Hughes et al 2005). Methods for assessing and monitoring coral reef resilience have recently been developed by the Working Group on Climate Change and Coral Reefs (CCCR - http://www.iucn.org/cccr/, Obura and Grimsditch 2009, Green and Bellwood 2009). Our surveys were designed to obtain fish abundance and size data by taxa that can be assigned to different trophic groups with a strong focus on herbivory after Green and Bellwood (2009), but also including other functional groups of fish (after Obura and Grimsditch 2009) to provide a broad and representative cross section of the reef fish community. The data can be adapted to ask general questions about reef fish population health as well as specific questions about the densities and biomass of key trophic groups considered important in reef resilience. Taxa were categorised into the following seven functional trophic groups: Piscivores, Omnivores, Corallivores, Invertivores, Planktivores, Detritivores, Herbivores (Lieske and Myers 1996, Samoilys and Carlos 2000, Obura and Grimsditch 2009), with the herbivores further broken down into six functional groups. These were based on Green and Bellwood (2009): large excavators, small excavators, scrapers, grazers, browsers and grazers/detritivores, each playing an ecological role in coral reef resilience to climate change.

Benthic cover, coral population structure and coral health were measured to assess the resilience or reef health of the Metundo reefs following procedures outlines in the CCCR manual (Obura and Grimsditch 2009). Benthic cover provides the main overall indicators of reef state, particularly the balance between corals and algae; as such surveys focussed on quantifying broad benthic categories. Coral population structure was assessed by measuring the size class distribution of selected corals which provides information on their demography (including recruitment, growth and mortality). The coral size class density and distribution data provided a rapid assessment of coral bleaching resistance and resilience at each survey site. Coral health was further assessed through quantification of bleaching, disease and mortality.

This study provides the first assessment of the coral reefs of Metundo Island and serves as a preliminary report on the status and health of these reefs in the far north of Mozambique and a useful guide for subsequent more detailed assessments.

2. Methods

The field team was based at Metundo Island just south of Vamizi Island from 18th to 26th June 2010. Metundo is an island formed from raised fossil coral, stretching around 7km long, with a perimeter of around 17km, supporting some low coastal forest, coconut plantations, white sandy beaches which green turtles nest on, and a few mangroves (*Avicenia* sp). Currently the island is privately leased by Metundo Lodge, a new eco-tourist lodge planning to open later in 2010. Strong south-east trade winds (> 20-25 knots) prevented covering a wide range of survey sites, and for three days it was not possible to survey at all.

Study sites
Nine sites were surveyed, eight on SCUBA, all to the north of Metundo Island moderately protected from the south-east winds (Figure 1, Table 1). It was not possible to survey any south facing reefs or eastern facing reefs due to the persistently strong winds. The nine sites represent six locations, as described in Table 1. Sites covered different reef zones ranging from extensive reef flats at 2m depth to fringing reef slopes and walls to a maximum of 17m (coral community surveys) to 27m (fish surveys).

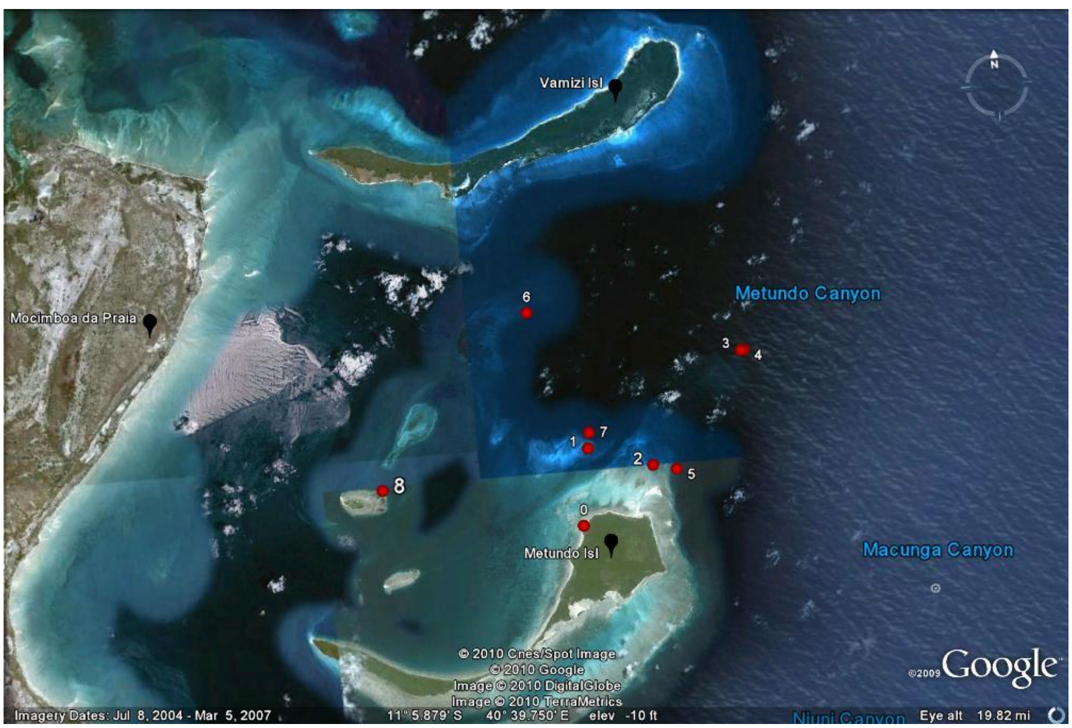

Figure 1. Survey sites around Metundo Island, Cabo Delgado, northern Mozambique. Site numbers are given in Table 1.

Table 1. Locations where fish species richness, fish abundance, coral health, benthic cover and coral colony size and density were recorded. Site numbers are indicated. Count time refers to fish diversity count; Abund=yes or no, indicates whether fish abundance surveys were done. Latitude and longitude for each site are given in the appendix. NB: only fish species diversity was recorded at Metundo W (on snorkel), therefore this site is not presented in the results, except for providing fish species to the total inventory of species.

Location	***Description***	***Site Number***	***Count time (min)/abund***
Metundo W	Beach reef flat, 0.5-2.0m	0 (snorkel only)	30 / no
Metundo flat NW	Extensive reef flat, 2-5m depth	1,2 combined	85 / yes
Makunga N	Exposed northern channel with vertical wall dropping to 100s of metres from reef plateau at ~11-16m	3, 4 combined	70 / yes
Metundo NE	Shallow extensive reef plateau at 8-10m fringing Metundo Island to the north	5	20 / yes
Baixo Pinguim NE	Extensive submerged reef top at 6-10m with S facing wall to 17m shelf	6	40 / yes
Metundo NW	Fringing reef, northern slope, 6-15m	7	30 / no
Vumba	Narrow fringe of corals on shallow sandy slope off Vumba Island, 2-10m	8	30 / no

Surveys

Four different types of surveys were conducted:

1. Fish diversity and abundance (MS &DM)
2. Benthic cover (IS)
3. Coral size classes (JN)
4. Coral health (SM & DM)

1. Fish diversity and abundance

1.1 Diversity

The diversity of coral reef fishes was measured from presence/absence of species obtained from SCUBA and snorkel underwater visual census (UVC) surveys at the selected sites. The 19 families selected for surveys are shown in Table 2. The method collated species richness over a range of coral reef habitats and depth zones. Reef slope, back reef and bay habitats were prioritised for the survey sites to maximise diversity, but outer slopes were restricted due to the strong winds.

At each location two replicate sites were selected for surveys. At each site two 30-40 minute surveys were done recording presence/absence of all species within the 19 families After each dive species observed were further verified using photographs and taxonomic references.

The Coral Reef Fish Diversity Index (CFDI), developed by Allen and Werner (2002) for estimating reef fish diversity based on the six most abundant, speciose and characteristic families of coral reefs, marked * in Table 2, was calculated to assess the overall diversity of coral reef fishes.

Table 2. Reef fish families surveyed for diversity assessment.

Group	Families
Largest and most diverse families	Labridae (wrasse)* Serranidae (groupers) Pomacentridae (damsel fishes)*
Known "Indicator" families	Chaetodontidae (butterfly fishes)* Scaridae (parrot fishes)* Acanthuridae (surgeon fishes)* Lutjanidae (snappers) Pomacanthidae (angel fishes)*
Fishery importance	Lethrinidae (emperors) Haemulidae (grunts) Mullidae (goat fishes) Siganidae (rabbit fish) Nemipteridae (bream) Carangidae (trevally)
Others	Caesionidae (fusiliers) Balistidae (trigger fish) Monacanthidae (file fish) Ostraciidae (box fish) Tetraodontidae (puffer fish)

* = families in the CFDI (Allen and Werner 2002)

1.2 Reef fish abundance

At each location a combination of two "long swims" 200mx20m transects (LS n=2, approx. 4000m^2) and five 50 x 5 m transects (TS n=5, 250m^2) were censused, where possible. This was generally achieved from two sites on the reef within around 500 – 1000m of each other. Occasionally only one dive was possible giving LS=1, TS=3. The long swim involved a timed swim of 10 min covering approximately 200m along the reef parallel to the reef crest ranging over the depths of the reef slope but, counting fish within a 20m swathe, depending on visibility. This method was used to maximise sampling of the larger mobile and diver –shy fish (e.g. bumphead parrots, large groupers, maori wrasse and sharks). Any departures from the standard transect length and width were documented for area estimation.

On this basis the abundance of all species from sixteen families of reef associated fish and one wrasse (Labridae: *Cheilinus undulatus*) were censused. Most of these were recorded to species level so that they could be assigned to the correct trophic group. Where this was not necessary, such as with the balistids and pomacanthids, fish were recorded by family and behavior (benthic vs. planktonic). Species or taxonomic groups surveyed were assigned to a trophic functional group (Appendix 2) based on the Climate Change Coral Reef Working Groups (CCCR)'s resilience assessment method and literature on feeding preferences (Lieske and Myers 1996, Samoilys and Carlos 2000, Green and Bellwood 2009, Obura and Grimsditch 2009).

2. Benthic cover

A line intercept transect (English et al., 1994) of 25m was done at each site to measure the percentage of benthic cover, using the same transect of the coral size class samples and population structure (see below). Benthic categories recorded were those recommended by Obura and Grimsditch (2009). The minimum line intercept sample recorded was 10cm.

3. Coral population structure

Coral size classes per genera were quantified at each site using the rapid assessment protocol (Obura and Grimsditch, 2009). Six coral size classes were surveyed: 11-20, 21-40, 41-80, 81-160, 160-320, and >320cm. Data were recorded in 25 x1 m belt transects at each site for colonies of 23 pre-selected coral genera. 1-2 transects were done per site. Number of colonies per genus and % area covered were measured and are presented per $100m^2$. A 1m PVC pipe was used to help guide estimation of transect width, held out in front as the observer swam along the transect. The PVC was marked at 10, 20, 40 and 80 cm to help with coral colony size estimation. Only colonies whose centre lay within the transect were counted while large colonies with their centre outside the transect were ignored.

4. Coral health condition

Measures of coral health were done on the same transects as the coral population structure sampling and were done for the same six coral size class categories. Five categories were used for visual estimation of coral condition in affected colonies: normal, pale, bleached (white colour), recently dead and diseased. For each colony, the proportion of each coral condition were approximated as a fraction (%), with the total sum being 100%. For consistency in estimation the same observer (SM) was used throughout the survey. Note that only colonies with the presence of one of the above conditions were sampled. Thus the proportion for 'normal' coral area presented in the results represents the proportion of normal coral area in affected colonies.

3. Results

3.1 Fish diversity and abundance

Fish Diversity

A total of 212 species from the set of 19 families were counted in only six days of SCUBA surveys (total time 305 min) across six locations around Metundo Island (Appendix 1). The highest diversity per location, 106 species, was recorded at Makunga, the submerged reef plateau with a northern facing vertical wall dropping to hundreds of meters. Diversity was also notably high on the extensive reef flat fringing the north of Metundo Island (Metundo flat NW) in only 2-5m water depth. At Vumba, a shallow fringe of corals off the sandy slope of the island, 12 additional species were seen that had not been sighted at the other sites; an indication of its different habitat characteristics.

Diversity was high in the families typically associated with healthy and diverse coral reefs: labrids (wrasses), pomacentrids (damselfishes) and chaetodons (butterflyfishes) (Table 3.1). A CFDI of 137 was calculated based on the total number species in the Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae and Acanthuridae, highlighted in Table 3.1.

Table 3.1. Total number of reef fish species by family and location. Locations are described in Table 1 and Appendix 1. Highlighted families used to calculate CFDI diversity index.

Family	Makung a N	Metundo flat NW	Baixo Pinguim	Metund o NE	Vumb a	Metundo NW	Tota l
Pomacentridae	7	21	15	10	16	10	30
Pomacanthidae	5	1	3	4	2	2	7
Labridae	17	24	23	15	13	8	42
Chaetodontidae	17	9	9	10	4	8	18
Scaridae	9	13	8	7	3	7	17
Acanthuridae	15	9	8	9	4	4	23
Serranidae	9	1	3	2	4	4	13
Lethrinidae	1	2	3	4	3	2	7
Lutjanidae	3	4	4	7	0	1	7
Caesionidae	2	0	3	4	4	3	7
Haemulidae	6	1	0	0	1	0	6
Nemipteridae	0	1	0	0	1	0	1
Mullidae	4	3	3	3	1	1	6
Siganidae	1	1	0	0	0	2	2
Balistidae	6	2	3	2	1	2	8
Monacanthidae	0	1	1	0	1	1	3
Ostraciidae	0	0	1	0	0	1	2
Tetraodontidae	0	3	3	1	1	0	7
Carangidae	4	0	0	0	0	0	4
TOTAL	**106**	**96**	**90**	**78**	**59**	**56**	**212**

Monacanthids (Filefishes) and ostracids (Trunkfishes) were almost absent (Table 3.1). Similarly, siganids (rabbitfishes) and nemipterids (bream) were also rare – probably a reflection of the generally outer exposed reefs that were surveyed. Although some inner reef flat and more sheltered reefs were surveyed they were all offshore near Metundo Island and therefore far from the continental shore line and influence of mangroves, rivers and seagrass beds.

Fish Abundance

Few of the larger species recorded by the long swims (200 x 20m transects) were present. No sharks, scombrids, humphead parrotfish (*Bolbometapon muricatum*) or *Cheilinus undulatus* (Napolean wrasse) were counted at any of the sites and carangids and piscivores were few, the former only seen on the reef plateau and wall at Makunga (Figure 3.1.1). Of these taxa, sharks and *Bolbometapon muricatum* were not seen throughout the survey. *Cheilinus undulatus*, the Napolean wrasse, was seen once at Makunga during species presence counts and two tuna (probably dogtooth and probable big eye), also at Makunga.

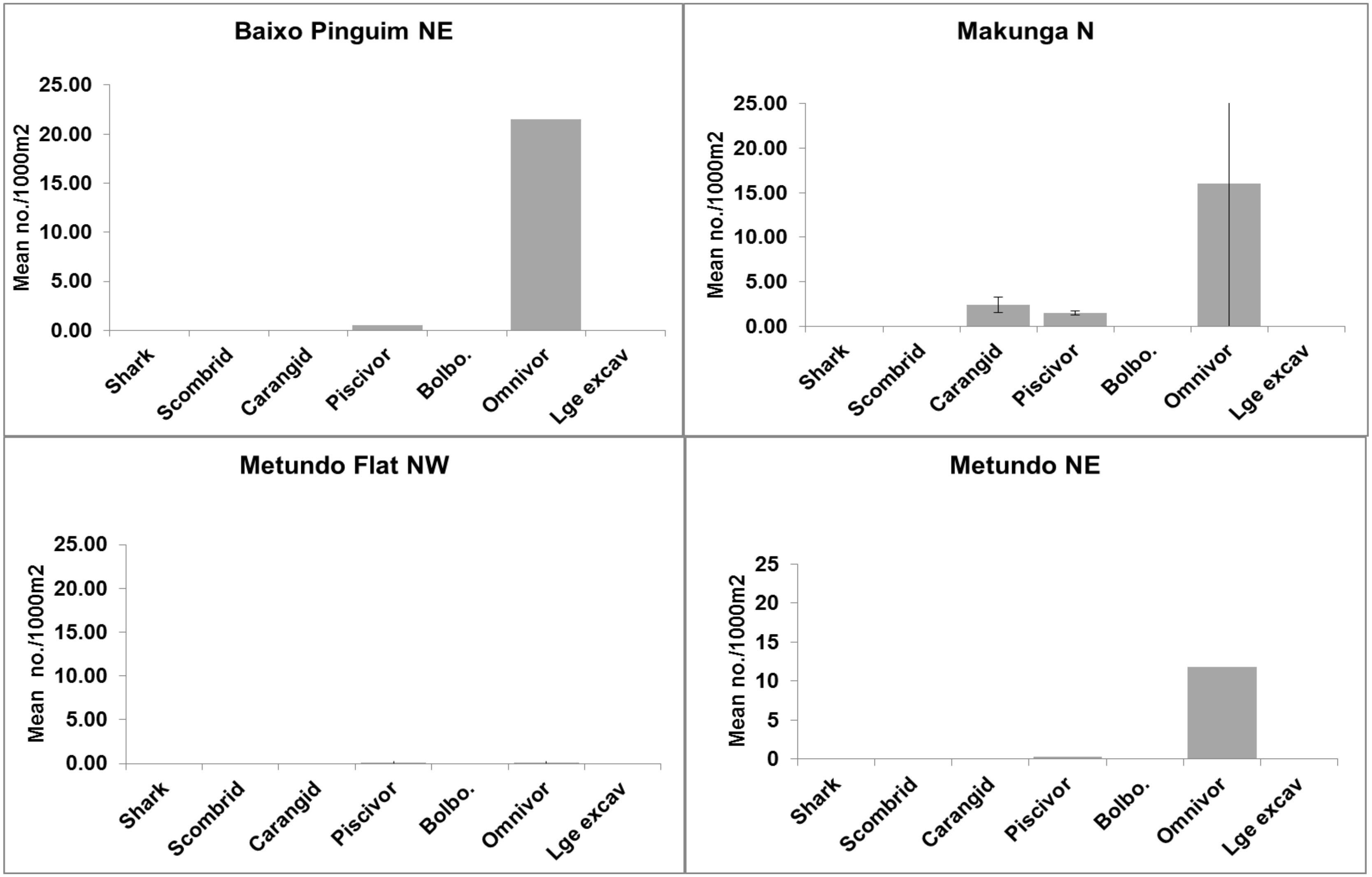

Figure 3.1.1. Mean abundance of large fish species from "Long swims" (approx. 200x20m transects). n=2 per site except Baixo Pinguim and Metundo NE where only 1 was done. Site descriptions are given in Table 1 and trophic groups in Appendix 2. Bolbo.=*Bolbometapon muricatum.*

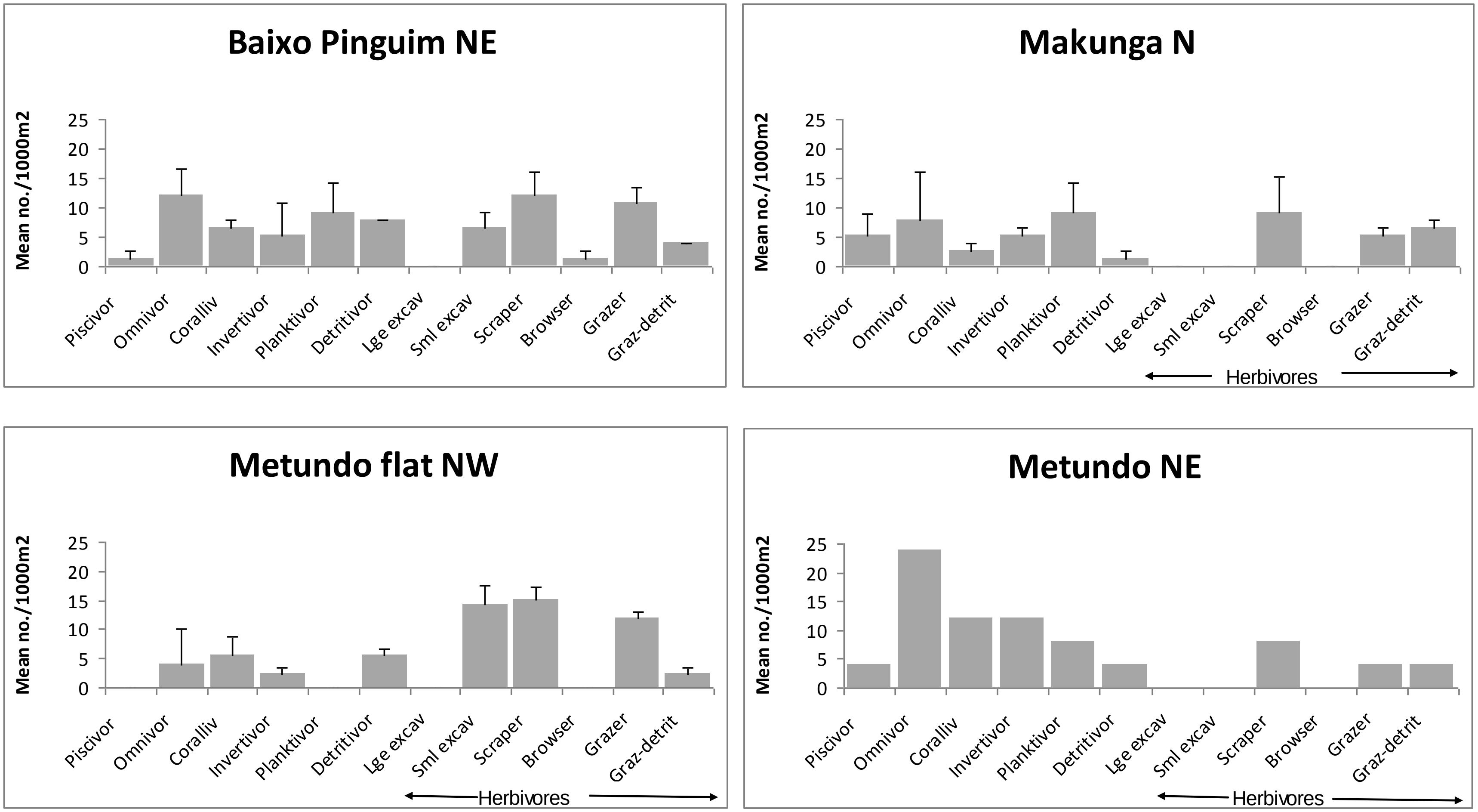

Figure 3.1.2. Mean abundance of reef fishes summarised by trophic group from 50x5m transects. n = 3-5, except at Metundo NE where only 1 transect was completed.

The 50m transects (Figure 3.1.2) provide more accurate estimates of density of medium to smaller sized species and recroded a range of trophic groups at each site, but sites differed considerably. For example at Baixo Pinguim all trophic groups were present except for the large excavators (large *Chlororus* spp. *Cetoscarus)* and most groups were seen in moderate to high densities (Figure 3.1.2). In contrast, at the deep outer wall of Makunga N and at the extensive reef plateau of Metundo NE three of the herbivore groups, the large and small excavators and the browsers, were all absent. Not surprisingly, piscivore densities were highest at Makunga (5.33 fish/1000m^2) and were absent on the reef flat of Metundo. The highest densities (24.00 fish/1000m^2) of omnivores (snapper, emperors and sweetlip) were counted at Metundo NE which was 2-5 times greater than at other sites (though there was no replication at this site). The Long swim recorded a similar density at Baixo Pinguim (Fig.2.1.1). Planktivore densities were generally low, ranging from 8.00-9.33 fish/1000m^2 at all sites except Metundo reef flat where they were absent, no doubt a reflection of the lack of schooling planktivores such as *Naso* spp. (unicornfishes). In terms of the herbivores, the following results are notable: large excavators were absent at all sites (Fig. 3.1.1, 3.1.2); the shallow reef flat supported the highest densities of scarids – the small excavators (14.4 fish/1000m^2) and scrapers (15.2 fish/1000m^2); and generally moderate densities of grazers and grazer-detrivores were counted at most sites (Figure 3.1.2). Overall, fish densities were low – no trophic group exceeded 25fish/1000m^2.

3.2 Benthic cover

Hard live coral cover was relatively high at several sites, notably at Vumba where over 70% cover was recorded, and at Metundo NW where over 50% cover was recorded (Figure 3.2.1). Vumba was characterised by very large colonies of *Galaxea* and *Montipora*, but liitle else (Figure 3.2.1). Calcareous algae was also high at certain sites, notably the submerged plataeux at Metundo NE (37.2%) and the deep wall at Makunga N (31.5%). This cover is usually associated with healthy reefs providing stable substrate for coral recruits. Rubble was either absent or represented less than 15% except at the shallow site of Vumba.

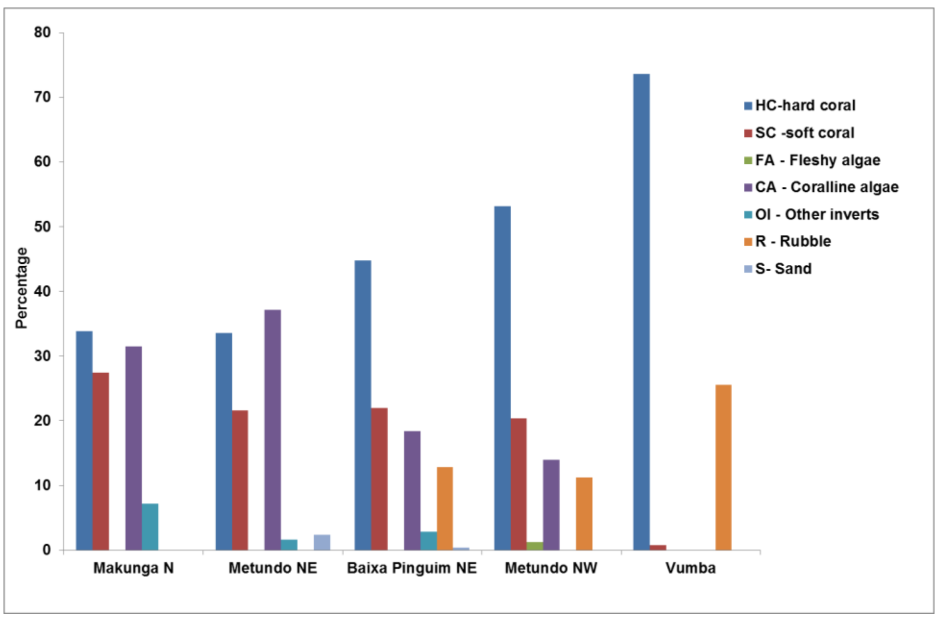

Figure 3.2.1. Benthic cover at Metundo island survey sites.

3.3 Coral population structure

Coral genera and area cover

Acropora was the most dominant genus in both number of colonies and area covered accounting for 37% of coral area that was measured, and 36% of all colonies counted (Figure 3.3.1). Other important genera by area include *Galaxea* (20%) and *Montipora* (12%), followed by *Echinopora* and massive *Porites* (8%). All other genera had low cover ranging between 1% - 2% (Figure 3.3.1)

After the *Acropora, Fungia* and *Porites* ranked highly in terms of number of colonies. *Galaxea* and *Montipora* covered large areas but had small numbers of colonies (7% and 4% respectively). This reflects the presence of few but large colonies (>320cm) of *Galaxea astreata* and foliose *Montipora* at some sites. The highest number of coral colonies per transect was recorded at Metundo NE, a shallow extensive reef plateau (Table 1).

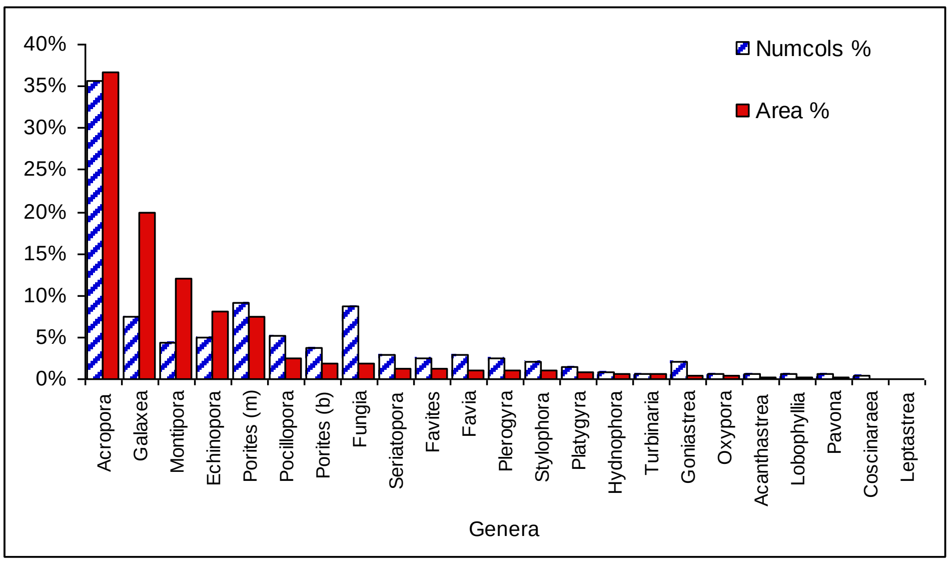

Figure 3.3.1. Overall comparison of coral genera distribution (% number of colonies and area) across all sites.

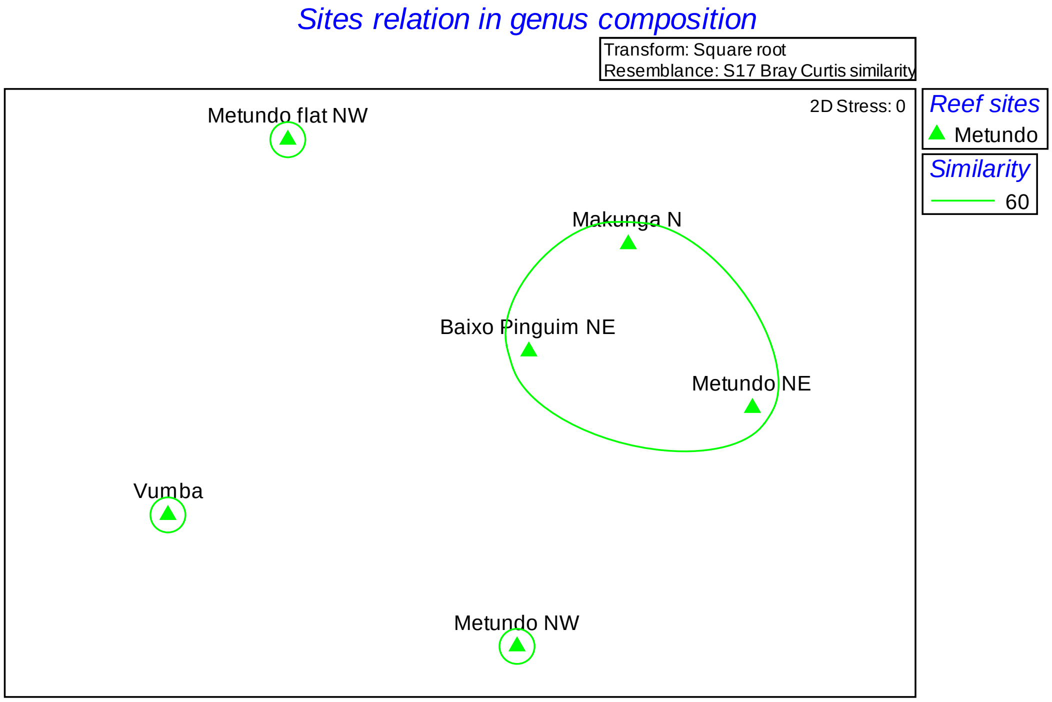

Figure 3.3.2. Two-dimension MDS of all 6 sites based on density of coral genera with Bray- Curtis similarity at 60% resemblance (square root transformed data).

The differences in coral population structure between sites were further explored through non-metric MDS ordination of samples (all 6 sites). Data separated into one cluster of three sites, Makunga N, Baixo Pinguim NE and Metundo NE (60% similarity) and three outliers (Figure 3.3.2). High densities of massive *Porites* are likely to be driving the cluster of the three reefs, as illustrated by MDS plots of relative abundance of different coral genera (Figure 3.3.3). This figure further explains why Vumba, a patchy shallow fringing reef on sand, was the main outlier. Vumba was characterised with exclusively high densities of *Seriatopora*, high cover of *Galaxea astreata* (Figure 3.3.4) and high abundance of *Fungia* (Figure 3.3.1). Metundo NW separates as an outlier probably due to the absence of *Montipora* and the abundance of *Fungia*, while Metundo flat NW seprates as an outlier due to high abundance of *Stylophora*.

Coral size class distribution

The distribution of coral sizes showed a decreasing number of colonies with increasing colony size, a typical curve reflecting natural mortality of corals with time (Fig 3.3.4). However, this was not directly reflected in the area cover curve, where colony sizes did not increase uniformly with age. Instead, from a peak in area cover for size class 21-40cm, a decline in area was seen to the lowest cover in size class 81-160 cm. Area cover then increased again in the largest size classes of 161-320cm and >320cm. This suggests disturbance in the past and coral mortality, probably due to partial bleaching, and/or COTS predation which did not cause severe mortality of medium to large colonies which therefore subsequently recovered.

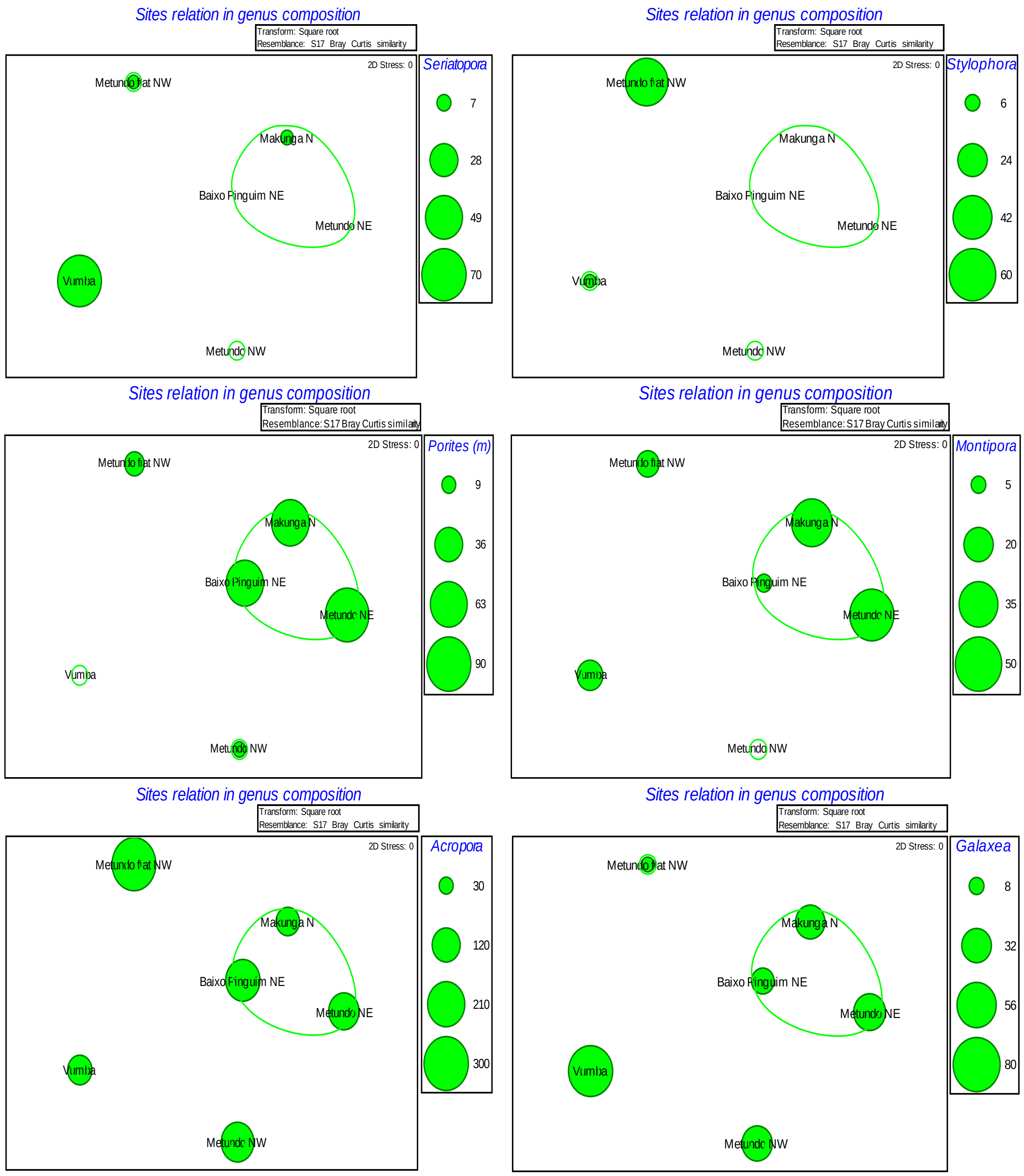

Figure 3.3.3. Bubble plots showing variation in the distribution and relative abundance of some important coral genera between sites.

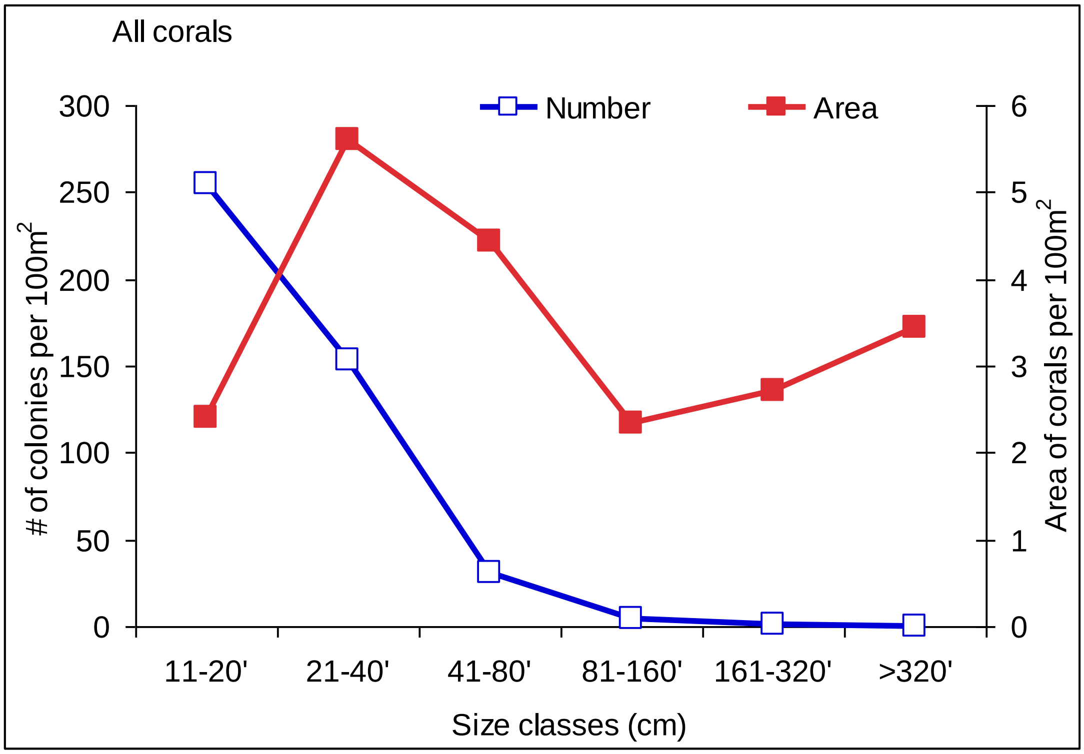

Figure 3.3.4. Corqal colony size class distribution, all sites pooled, showing the distribution of different coral sizes by number and area cover.

Not surprisingly the highest average coral density of 254.7 per 100 m^2 is shown in the smallest size class measured, 11-20 cm while the lowest density 0.4 per 100 m^2 occurs at the largest size > 320cm (Fig 3.3.4). On average there were 445 (+/- 32 SE) colonies in an area of 100 m^2, corresponding to an average of 20.9 m^2 of coral colony surface area. The largest number of colonies (548) was counted on the reef plateau at Metundo NE with the lowest (342) on the wall at Makunga N (Fig 3.3.5).

In general, *Acropora* was the dominant genus across all size classes in both number of colonies and area (Fig 3.3.6). The larger colonies (>80cm) have likely survived any bleaching in the past, while the peak in the distribution suggests high recruitment and re-growth suggesting a resilient *Acropora* community. *Galaxea* and *Montipora* dominated corals in the largest size class, >320cm, each covering 1.72 m^2 of coral area (Fig. 3.3.6). Though both these genera showed a sharp decline in colony density after the initial recruitment. Possibly this was due to little substrate available for colonisation and growth of small corals. Other corals such as the massive *Porites* and the free living mushroom coral *Fungia*, were relatively more abundant in terms of number of colonies, but represented by the smaller size class, 11-20cm. *Echinopora* was relatively dominant by area represented by the medium size class colonies, 41-80cm (Fig 3.3.6).

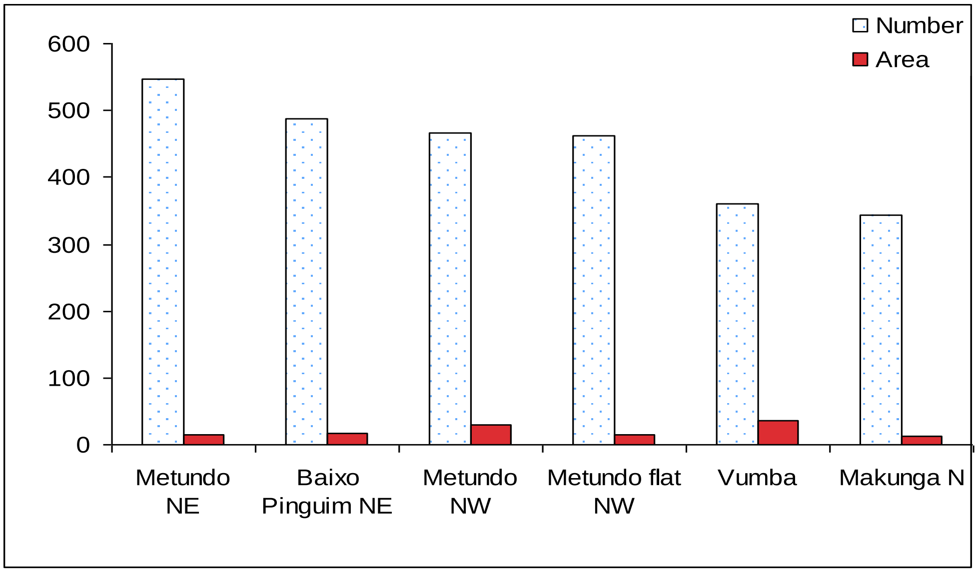

Figure 3.3.5. Comparison of coral genera distribution (number of colonies and area standardised to 100 m^2) by site.

Not surprisingly the smallest size class, 11-20cm, were the most abundant at all six sites surveyed (Figure 3.3.7). The largest number of colonies was observed at Baixo Pinguim NE. In terms of area coverage three sites Metundo flat NW, Baixo Pinguim NE and Metundo NE, were dominated by corals in size class 21-40cm. Vumba was dominated by large colonies, >320cm, while the cover of corals at Metundo NW was more or less uniform across all size classes except the largest (Fig 3.3.7).

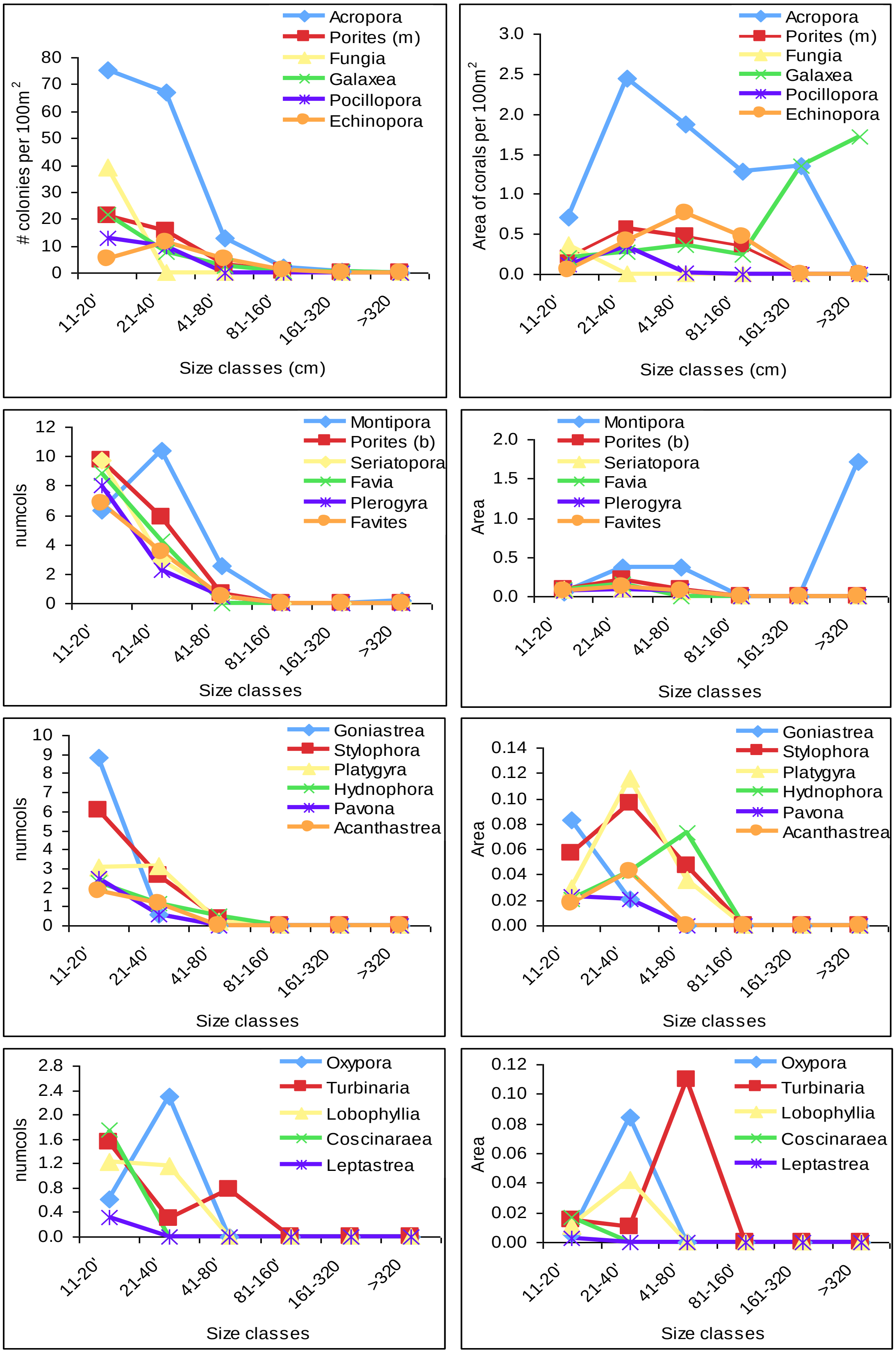

Figure 3.3.6. Distribution of coral colony size and area by genus, all sites pooled.

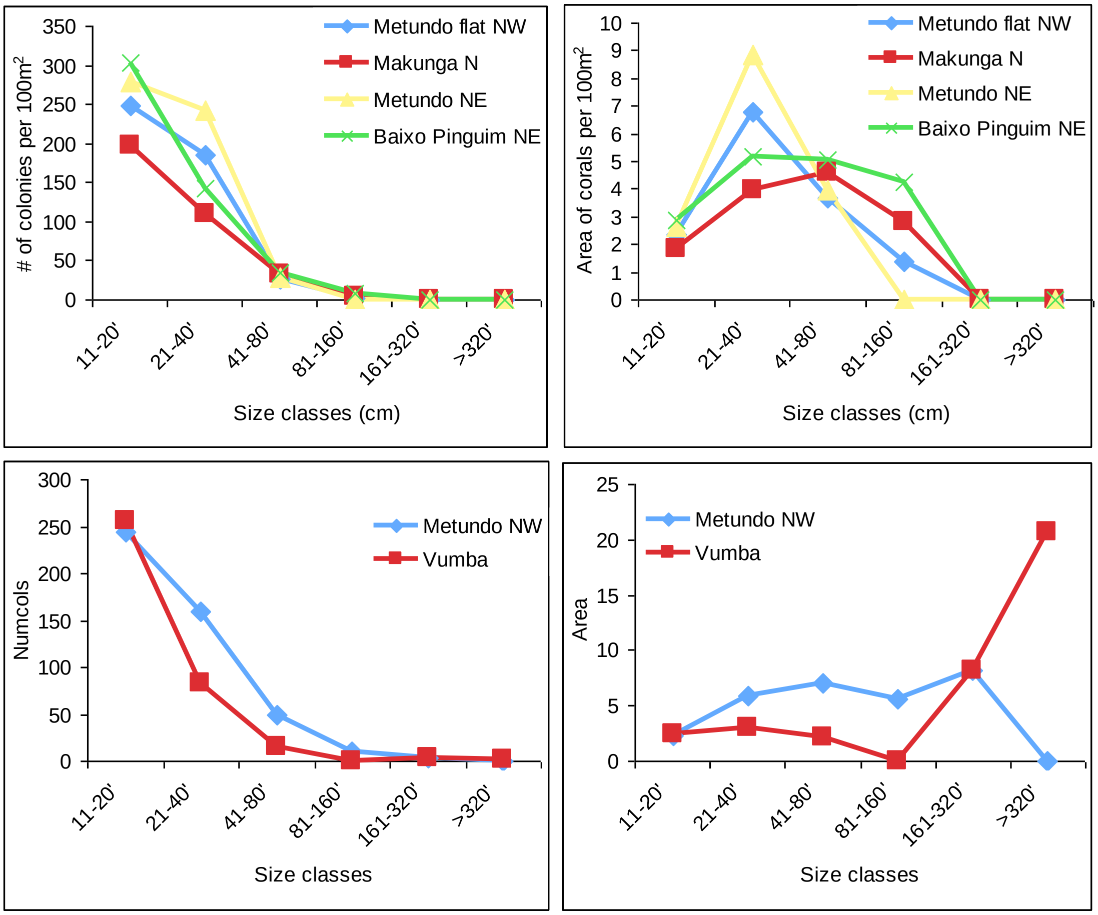

Figure 3.3.7. Distribution of coral colony sizes and area coverage by sites.

The MDS plot for coral size distribution between sites shows that sites clustered into one group with two outliers (Fig 3.3.8). The two outliers can be explained by: Vumba had the largest coral colonies (>320cm), especially of *Galaxea astreata* and *Montipora sp,* and Metundo NW had relatively higher numbers of medium to large colonies.

In the bubble plots (Fig 11) both the distribution and density of 11-20cm corals are relatively uniform across all sites. This is post juvenile size which suggests a highly uniform recruitment going in the past across all sites and the variation that followed is probably due to ecological disturbances by fishing, and COTS.

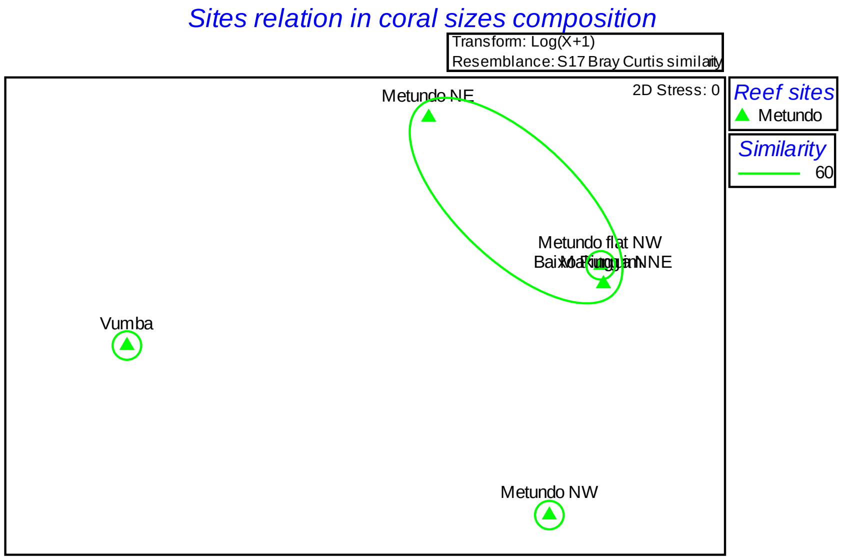

Fig 3.3.8. 2-d MDS of samples (all 6 sites) based on coral sizes and Bray-Curtis similarity with log (X + 1) transformed data showing similarity of samples at 60% resemblance.

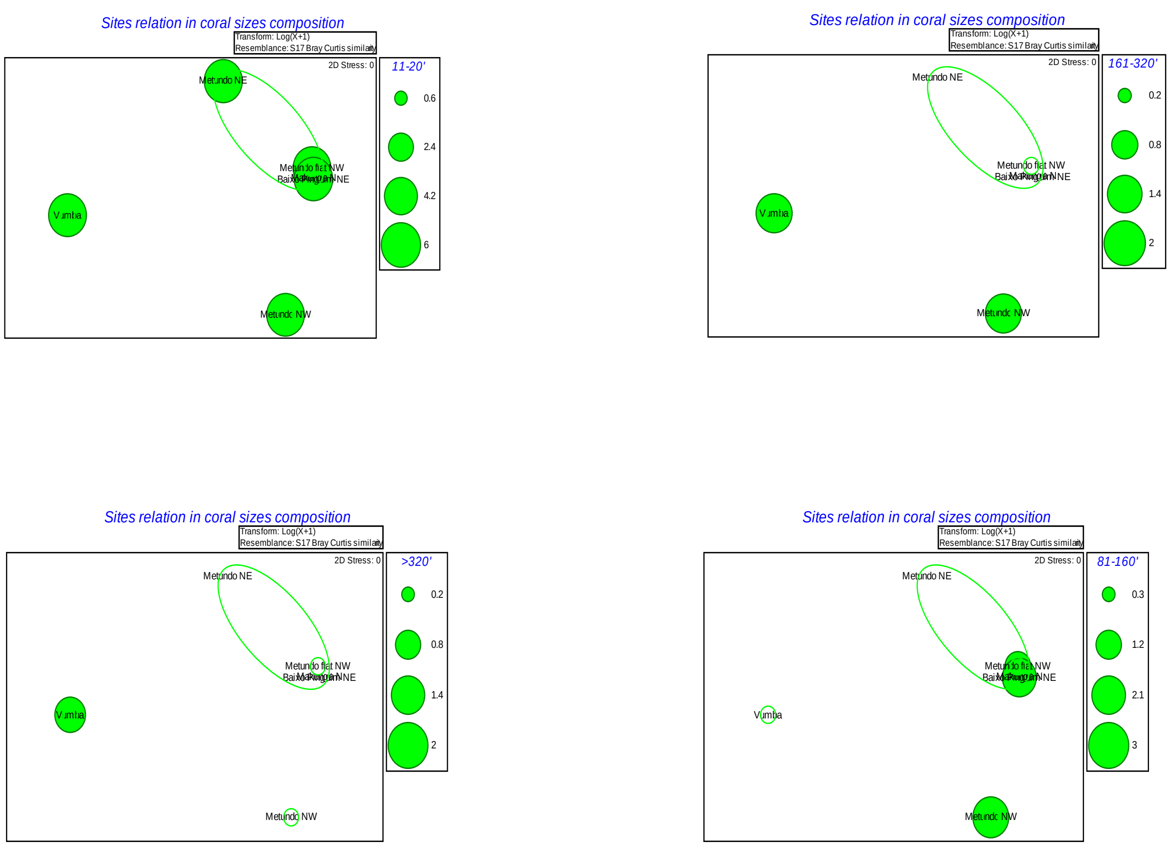

Fig 3.3.9. Variation between sites in the distribution and abundance of various coral sizes.

3.4 Coral health

We sampled 383 coral colonies across six size class categories (11-20, 21-40, 41-80, 81-160, 161-320 and >320cm) which represented 301m² of coral colony area in six sites. 21 coral colonies (5%) representing 17m² of total area, were observed to be pale, bleached (white), dead or diseased.

Sites

Less than 1% bleaching, mortality or disease was recorded across all sites (Fig. 3.4.1). Most of the corals observed were normal (96.4%), with 1.1% paled, 1.5% bleached, 0.05% dead and 0.9% diseased (Figure 3.4.1) Baixo Pinguim had the highest bleaching and paling at 6% and 4.6% of total coral area, respectively, followed by Metundo NW with 1.6% bleached and 0.9% pale. Vumba had the most diseased colony area, 3.1%, followed by Baixo Pinguim (2%).

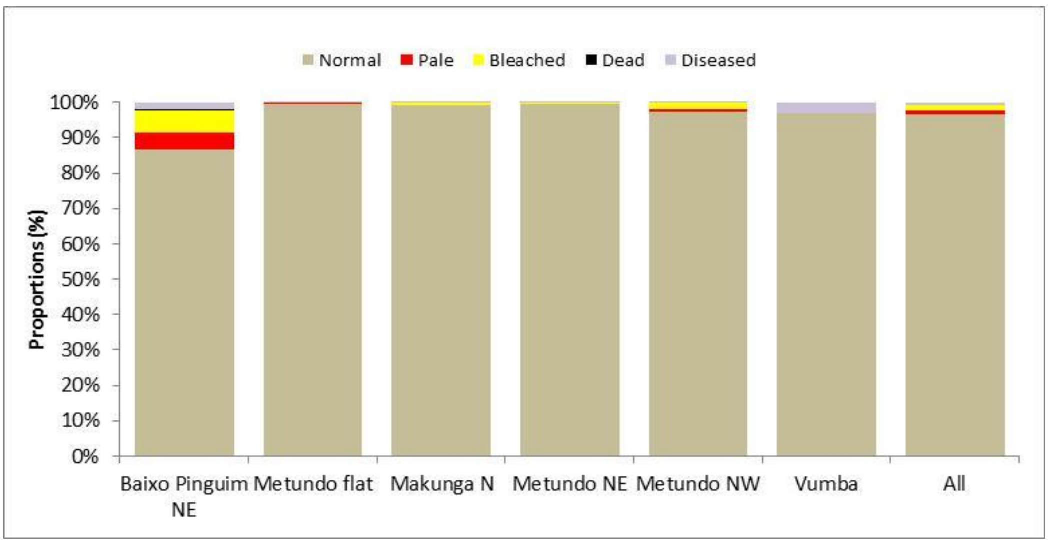

Figure 3.4.1 Proportion of 5 coral health categories by coral colony by site

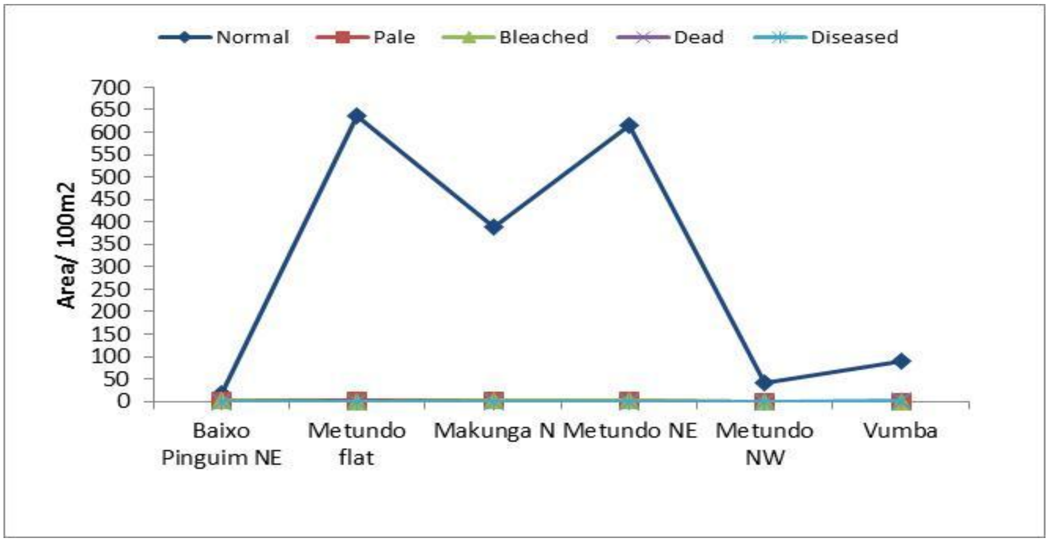

Figure 3.4.2 Average area of 5 coral health categories by site.

Size classes

Most of the corals which were observed to be bleached, paled, dead or diseased were medium-large sized colonies (11-20, 21-40 and 41-80 cm). Corals in size class 11-20cm had the highest mortality, bleaching and the highest diseased area (0.1% dead, 1.2% bleached and 0.4% diseased, Figure 3.4.3). Paling was largely observed in 41-80 cm size class corals. Corals in size class 21-40cm were the least affected (Fig 3.4.3).

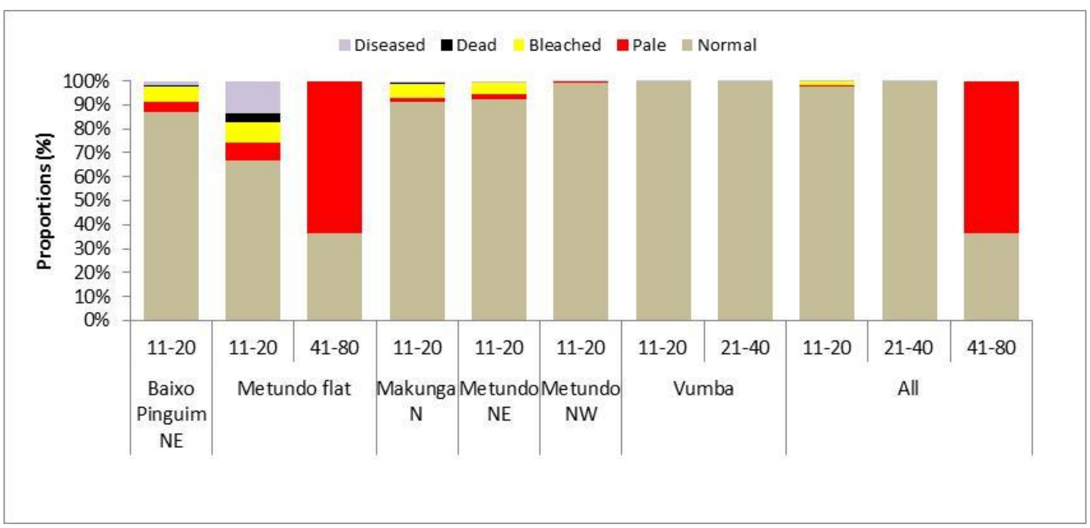

Figure 3.4.3 Proportion of coral health condition across affected size classes only, per site, and summarised across sites

Genera

The proportion of the four unhealthy coral conditions varied considerably between coral genera and between sites (Fig. 3.4.4, Fig. 3.4.5). Mortality was only observed in two genera, *Astreopora* and *Acropora,* while several genera were observed to have diseased tissue. For example, when bleached *Fungia* colonies were found they were 100% bleached, and the highest diseased area (39%) was observed in *Seriatopora* (Figure 3.4.4).

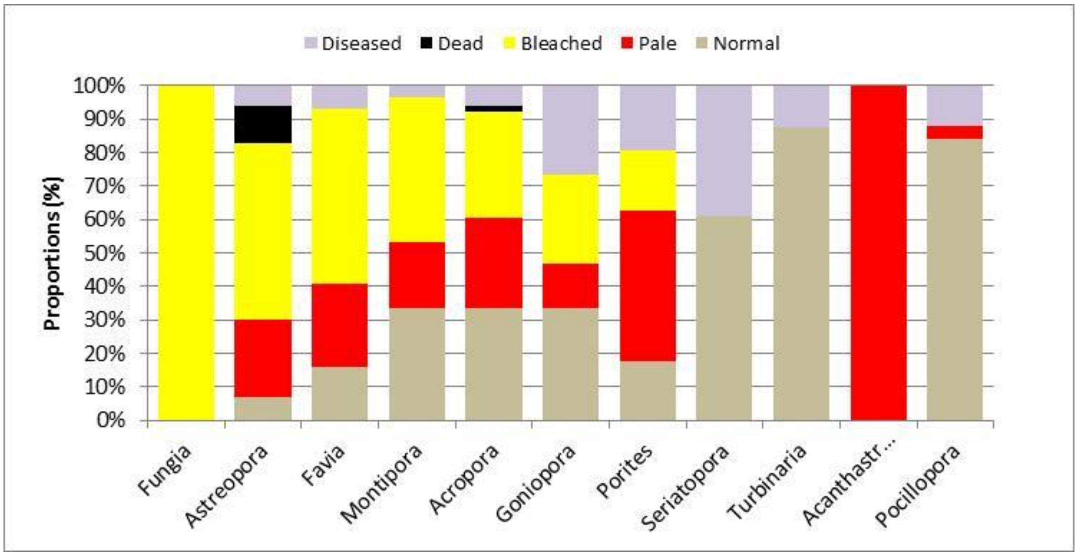

Figure 3.4.4 Proportions of coral health condition by genera for affected colonies.

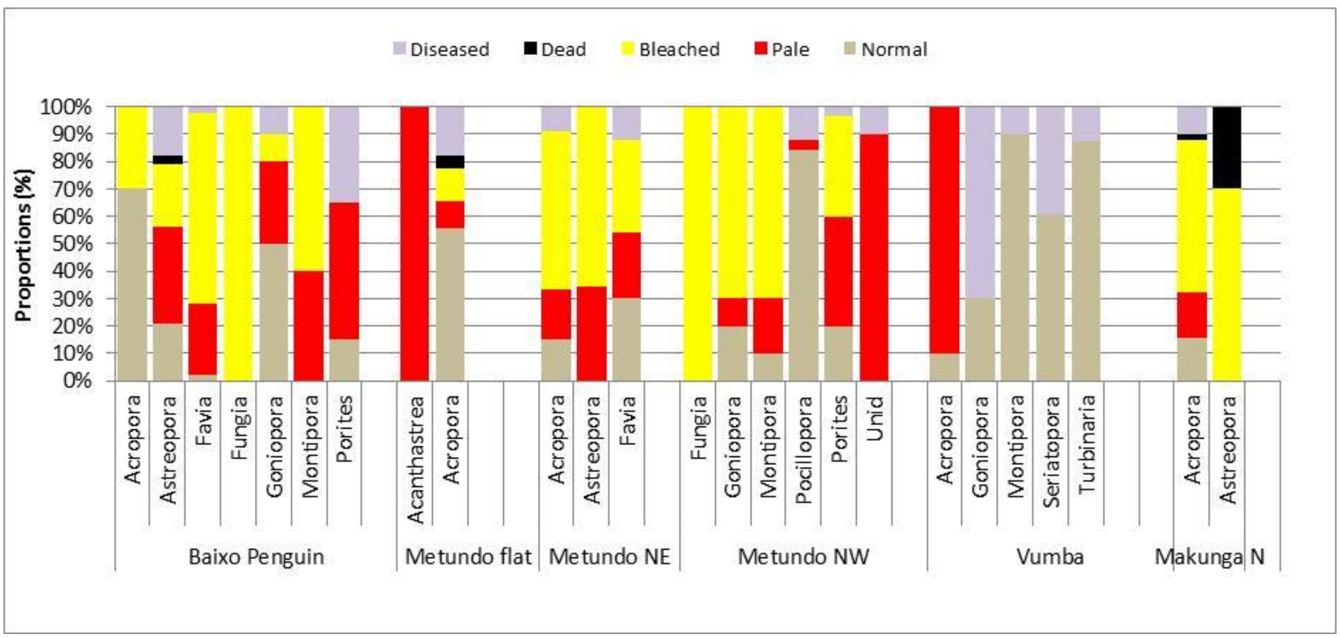

Figure 3.4.5 Proportions of coral health condition across genera and sites. Unid = unidentified genera.

Differences between sites were apparent (Figure 3.4.5), but more likely to reflect geomorphological differences between sites in terms of prevalence of very large colonies (Vumba) and diversity of genera.

4. Discussion

The reefs around Metundo Island are structurally diverse with extensive areas of reef flat and submerged plateaus with rich coral growth. Outer reef slopes were characterised by moderate rugosity, diverse corals and relatively high coral cover. The area also borders deep channels with reef walls dropping spectacularly to several hundred metres.

Benthic cover and coral health
Hard live coral cover was high at several sites, notably at Vumba (> 70% cover) and at Metundo NW (> 50% cover). These values are very high for the WIO where average values are in the order of 20-40% (Muthiga et al 2008), but are reflective of coral communities dominated by mono-generic stands for example of *Galaxea* spp. or *Acropora* spp. Calcareous algae were also high at certain sites, notably the submerged plataeux at Metundo NE (37.2%) and the deep wall at Makunga N (31.5%). Calcareous algae is usually associated with healthy reefs providing stable substrate for coral recruits and are therefore a healthy indicator and considered vital for resilience to climate change (Birrell et al 2008).

The dominance by both number and area cover of the coral genus *Acropora* provides strong evidence that this coral has suffered little bleaching or has robust recovery, or both. Since *Acropora* is so susceptible to bleaching (Loya 2001, Obura 2001) this result also supports suggestions that the reefs around Metundo have not been subjected to significantly and persistently elevated sea surface temperatures during recent El Niño events, or that these reefs are resistant to bleaching for other reasons, or a mixture of the two. This may be due to local topographic and oceanographic features. There were however few very large colonies of *Acropora* spp. counted in the transects possibly due to physical damage through strong winds and swell. Though few, some very large *Acropora* plate corals were seen, much larger than those encountered further north in Tanzania (JN, MS, pers. obs.).

Galaxea and *Montipora* dominated corals in the largest size class (>320cm). The presence of large coral colonies is a reflection of a healthy reef, and that the sites have high reproduction potential to rejuvenate the reef and ecosystem. Other important coral genera contributing to coral cover of the reefs were *Galaxea, Montipora*, *Echinopora* and massive *Porites.* Sites differed with the largest number of coral colonies (548) counted at Metundo NE while the lowest count (342) was observed on the wall at Makunga N. The pattern in abundance of different coral colony sizes, from many small colonies to few mid sized colonies and then more abundant large colonies does suggest some disturbance in the past and coral mortality. This may have been due to partial bleaching, and/or COTS predation which did not cause severe mortality of medium to large colonies which therefore did not die. Corals were also particularly healthy with less than 1% bleaching, mortality or disease recorded across all sites.

These results corroborate previous propositions that the northern Quirimbas reefs of Mozambique are both resistant to coral bleaching and/or have high capacity to recover (Garnier 2008, Obura 2008, Hill et al 2009).

Fish diversity and abundance
The extensive and diverse reef structures no doubt account for the relatively high diversity of reef fishes. The total count of 212 species surveyed serves as a preliminary inventory of species and patterns in diversity. It was clear that the total number of species was not reached. This is well illustrated when our data are compared with the comprehensive reef surveys conducted in 2006 around Vamizi Island just to the north of Metundo (Davidson et al 2006, Hill et al 2009), and with species counts reported by Perreira (2000) for the whole of Mozambique (Table 4.1). The differences suggest the present study recorded around 80% of the expected total number of species that occur in the area.

The highest diversity per location, 106 species, recorded at Makunga N, compares well with the highest species diversity recorded per site of 126 in NE Madagascar from 16 locations surveyed over 20 days using the same method (Samoilys & Randriamanantsoa 2011).

Table 4.1 Total species counts for the six most speciose reef fish families; also used to estimate Allen's CFDI diversity. Previous data reported in Hill et al 2009.

Family	This study 2010	Davidson et al 2006	Perreira 2000
Pomacentridae	30	35	45
Pomacanthidae	7	11	12
Labridae	42	52	67
Chaetodontidae	18	21	23
Scaridae	17	20	24
Acanthuridae	23	31	31
CFDI	**137**	**170**	**202**

Considering the rapid nature of this survey (8 SCUBA dives, 305 min. for fish diversity counts), coral reef fish diversity was high. In only five days of surveys, covering a relatively small region, and with no opportunity to survey the outer SE facing reef slopes, 64% of the total number of fish species counted to date in the WIO (Samoilys unpubl.) were recorded in the Metundo Island area (Table 4.2). Thorough surveys of Metundo and to the north around Vamizi Island and the northern Quirimbas Marine Park planned for 2011 are likely to bring the total number closer to 300.

Despite the relatively healthy and diverse reefs with minimal evidence of bleaching and reasonably high diversity of fish species, the densities of reef fishes were not high. The highest density per trophic group was 24.0 fish/1000m^2, for omnivores. This is low compared with recent surveys in Madagascar (Samoilys & Randriamanantsoa 2011) where density per trophic group was often over 40 fish/1000m^2, and occasionally over 100 fish/1000m^2, with maximum values of 168.8 fish/1000m^2 (planktivores), 114.4 fish/1000m^2 (scrapers) and 106.4 fish/1000m^2 (invertivores) recorded at certain sites. Taxa that were noticeably in low numbers or absent around Metundo Island were the schooling planktivores, e.g.such as the *Naso* spp. unicornfishes, and certain butterflyfishes (*Heniochus* spp. and *Hemitaurichthys* spp.).

Table 4.2. Regional comparison on reef fish species diversity. Total species in data set to date: 332 (data from Samoilys in prep.). CFDI= coral fish diversity index (Allen and Werner 2002).

	Grande Comore and Moheli - Comoros	**NE Madagascar (Samoilys & Randriamanantsoa 2011)**	**Metundo – Mozambique (this study)**	**Mozambique (Perreira 2000)**	**Madagascar (Allen 2005)**
Tot. no. species	226	276	212	344	367
CFDI Index	147	172	137	202	176
Length of survey	10 days	17 days	5 days	Cumulative reports and surveys	Cumulative reports and surveys since 1891

Comparisons with surveys conducted in 2006 just to the north around Vamizi Island (Davidson et al 2006) help put our results into context:

- similar piscivore densities (5.6 fish/1000m^2) at their steep wall site, as recorded at our steep wall site of Makunga N (5.3 fish/1000m^2)
- substantially different scarid densities (scraper and small excavator) of up to 30 fish/1000m^2 at our sites compared with around 100 fish/1000m^2 at Vamizi leeward reef slope sites;
- similar omnivores densities (mean of 12 fish/1000m^2) compared with 5-17 fish/1000m^2 at Vamizi leeward (northern) sites, except the eastern wall where they recorded 121 fish/1000m^2 in 2006;

Our results possibly reflect the short and limited nature of the survey with only 4 sites, and those all limited to the northern leeward side of the Island. They may also reflect population depletion due to fishing in some species groups.

One area that we were unable to survey due to unworkable weather was the dive site called "Neptunes" along the same wall as our Makunga N site, in the deep channel between Metundo and Vamizi islands, well known to one of us (IS) where sharks, carangids and other large piscivores aggregate in large numbers. Hill et al (2009) also refer to this site. They describe observing "100+ grey reef sharks and many species of groupers, emperor and snapper, the latter in schools too abundant to estimate numbers. Large indivduals (>1m) of *E. lanceolatus* and *E. tukula*, were observed, as well as Napolean wrasse. Trevallies were seen in abundance as well as other top predators such as dogtooth tuna." Such densities of top predators and in particular sightings of sharks like this have not been sighted throughout the WIO sites we have surveyed over the last 12 months, from Tanzania to Comoros and Madagascar (Samoilys unpubl. data.). The lack of humphead parrot fish, Napolean wrasse, carangids and large groupers at our survey sites suggests that more surveys are needed to properly estimate populations of these taxa. The data from Neptunes site (Hill et al 2009) suggests there are key sites where these top trophic level species aggregate and these would be important for conservation, sustainable population management and tourism.

Although this section of Mozambique's coastline has seen very little development, largely due to lack of infrastructure notably power, roads and limited freshwater at least on the islands, the situation is about to change. Power has now been brough to Mocimboa da Praia, roads are improving and commercial fishing ventures from the south are said to be moving north to establish businesses (IS pers. obs.). It is therefore crucial that management systems are put in place before this happens. There are examples that can be borrowed from elsewhere in the region, and the recent emergence of co-management and locally managed marine areas (LMMAs) for both biodiversity conservation, as well as sustainable fisheries, are models that should be adapted for this northern Quirimbas marine ecosystem.

Management

With such a high proportion of *Acropora* on these reefs, their vulnerability to future climate change induced sea surface temperature elevation is likely to be high. it is therefore crucial that other stresses such as overfishing are minimised to maximise the ability of these reefs to recover from a future bleaching event.

The low densities of reef fishes is of concern and indicates that fishing pressure may be relatively high. it is highly recommended that a zoning system of fisheries management including a network of no-take zones (NTZs) is considered, and that planning starts immediately with local community members acting as one of the key management partners. The ideal institution to lead this process would be the community fishing councils (CCPs). The previous data from Neptunes site (Hill et al 2009) suggests there are key sites where large and top trophic level species such as sharks, carangids, large groupers, humphead parrot fish and Napolean wrasse, occur or aggregate. These sites are therefore very important for sustainable population management and tourism and should be considered early in conservation planning.

Mozambique is in urgent need of marine scientists and managers with expertise in coral reef ecosystem management and support for post-graduate level training in this field is much needed.

Given the relatively good health condition suggested by this rapid survey and the strategic location of the northern Quirimbas coral reef systems we support the key recommendations from earlier work around Vamizi (Garnier et al 2008, Hill et al 2009): the area is of high conservation and research interest, is an important economic resource that if managed wisely can contribute to sustainable fisheries and development through tourism. The area is urgently in need of management and formal protection.

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Appendix 1. GPS coordinates for each study site.

Waypoint	Location	SiteCode	Deg S	Minutes S	Deg E	Minutes E	Survey Date
268	Metundo flat NW	Metund1	11	07.479	40	40.559	21/06/2010
269	Metundo flat NW	Metund2	11	07.900	40	41.761	21/06/2010
270	Makunga N	Metund3	11	05.924	40	43.625	22/06/2010
271	Makunga N	Metund4	11	05.919	40	43.679	23/06/2010
272	Metundo NE	Metund5	11	08.016	40	42.201	23/06/2010
273	Metundo W	Metund0	11	08.909	40	40.342	18/06/2010
274	Baixo Pinguim NE	Metund6	11	04.850	40	39.645	24/06/2010
275	Metundo NW	Metund7	11	07.189	40	40.606	24/06/2010
276	Vumba	Metund8	11	07.903	40	36.602	26/06/2010

Appendix 2. Trophic functional groups used to assign fish species for abundance surveys.

Functional Group	Group/family	English name or species	Notes on feeding habits and selection of species
Piscivores	Carangidae	Trevally	top level predators, they exert top-down control on lower trophic levels of fish, are very vulnerable to overfishing, and good indicators of the level of anthropogenic disturbance (fishing) on a reef.
	Serranidae	Groupers	
	Lutjanidae	*Aprion viriscens*	
	Elasmobranchii	Sharks and rays	
	Scombridae	Tunas	
Omnivores	Haemulidae	Sweetlips	Second-level predators with highly mixed diets including small fish, invertebrates and dead animals, their presence/absence is also a good indicator of anthoropogenic disturbance (fishing).
	Lethrinidae	Emperors	
	Lutjanidae	Snappers except *Aprion viriscens*	
Corallivores	Chaetodontidae	Butterflyfish	Obligate and facultative corallivores are a secondary indicator of coral community health. 8 species: *C. bennetti, C. lineolatus, C. melannotus, C. meyeri, C. ornatissimus, C. trifascialis, C. trifasciatus, C. zanzibarensis*
Invertivores	Pomacanthidae	Angelfish	Feed on coral competitors such as soft corals and sponges, their relative abundance may be a secondary indicator of abundance/stability of these groups and of a phase shift. Except *Centropyge* spp. which are grazer-detrivores
	Balistidae	Triggerfish	Benthic triggerfish (e.g. *Sufflamen* spp.)
	Chaetodontidae	Butterflyfish	Non-corallivore species - all others except the 8 above and *H. zoster* and *H. diphreutes* which are planktivorous
	Labridae	*Cheilinus undulatus*	Only this labrid surveyed
Planktivores	Balistidae	Triggerfish	Resident on reef surfaces, but feed in the water column. Their presence/absence may be related to habitat for shelter and water column conditions

Functional Group	**Group/family**	**English name or species**	**Notes on feeding habits and selection of species**
			Trigger fish in the water column (eg. *Melichthys* spp., *Odonus niger*)
	Chaetodontidae	*Hemitaurichthys zoster*	
		Heniochus diphreutes	
	Acanthuridae	*Naso* spp. >20cm	Large *Naso* in water column, except *unicornis* and *tuberosus* (below) which are always Browsers
		A. mata	
		A. nubilus	
		A. thompsoni	
		Paracanthurus	
	Caesionidae	Fusiliers	
Detritivores	Acanthuridae	*Ctenochaetus*	Feed on organic matter in sediment and on reef surfaces, their relative abundance may be an indicator of eutrophication and conditions unsuitable for corals.
Herbivores			Exert the primary control on coral-algal dynamics and are implicated in determining phase shifts from coral to algal dominance especially in response to other pressures such as eutrophication, mass coral mortality
Large excavators	Scaridae	*Bolbometopon*	Take few, large, deep bites, remove much substratum and play a key role in bioerosion
		Chlorurus spp. >35cm	
		Cetoscarus bicolor	
Small excavators		*Chlorurus spp. <35cm*	Remove substrate - play a smaller role in bioerosion

Functional Group	**Group/family**	**English name or species**	**Notes on feeding habits and selection of species**
Scrapers		*Scarus spp.*	Remove algae, sediment and other material by closely cropping or scraping the substrate
		Hipposcarus spp.	
Browsers	Scaridae	*Calotomus* spp.	Feed on large macro-algae
		Leptoscarus spp.	
	Acanthuridae	*Naso unicornis*	
		Naso tuberosus	
		Naso spp. <21cm	
	Ephippidae	Bat fish – *Platax* spp.	
	Siganidae	*S. canaliculatus*	
	Kyphosidae	Rudder fish	
Grazers	Acanthuridae	*Zebrasoma* spp.	graze epilithic algal turfs, which can also limit growth of macroalgae
		A. nigrofuscus	
		Acanthurus spp.	Small surgeon species, incl. *lineatus*
	Siganidae	*Siganus* spp.	Except *Siganus canaliculatus*
Grazer-detritivores	Acanthuridae	*A. blochii*	Ring tails. Feed on algal turf, sediment and some animal material. Similar role to grazers - remove macroalgae
		A. dussumieri	
		A. leucocheilus	
		A. nigricauda	
		A. xanthopterus	
		A. tennenti	
	Pomacanthidae	*Centropyge spp*	

Appendix 3 - Fish species list (18-26th June 2010)

Family	*Species*	English family name
Acanthuridae	*A. blochii*	Surgeonfishes
Acanthuridae	*A. dussumieri*	
Acanthuridae	*A. leucocheilus*	
Acanthuridae	*A. leucosternon*	
Acanthuridae	*A. lineatus*	
Acanthuridae	*A. nigricaudus*	
Acanthuridae	*A. nigrofuscus*	
Acanthuridae	*A. tennenti*	
Acanthuridae	*A. thompsoni*	
Acanthuridae	*A. triostegus*	
Acanthuridae	*A. xanthopterus*	
Acanthuridae	*C. striatus*	
Acanthuridae	*C. strigosus*	
Acanthuridae	*Ctenochaetus binot*	
Acanthuridae	*N. brevirostris*	
Acanthuridae	*N. hexacanthus*	
Acanthuridae	*N. lituratus*	
Acanthuridae	*N. thynnoides*	
Acanthuridae	*N. vlamingii*	
Acanthuridae	*Naso annulatus*	
Acanthuridae	*Paracanth. hepatus*	
Acanthuridae	*Z. scopas*	
Acanthuridae	*Z. velliferum*	
Balistidae	*B. viridescens*	Triggerfishes
Balistidae	*Balistapus undulatus*	
Balistidae	*Balistoid. conspicillum*	
Balistidae	*Melichthys niger*	
Balistidae	*Odonus niger*	
Balistidae	*Rhinecanth. aculeatus*	
Balistidae	*S. chrysoptera*	
Balistidae	*Sufflamen bursa*	
Caesionidae	*C. lunaris*	Fusiliers
Caesionidae	*C. xanthonota*	
Caesionidae	*Caesio caerulaurea*	
Caesionidae	*Caesio teres*	
Caesionidae	*Pterocaesio marri*	
Caesionidae	*Pterocaesio pisang*	
Caesionidae	*Pterocaesio tile*	
Carangidae	*C. ferdau*	
Carangidae	*C. melampygus*	
Carangidae	*S. lysan*	
Carangidae	*Selar crumenophthalmus*	
Chaetodontidae	*C. bennetti*	Butterflyfishes

Family	*Species*	English family name
Chaetodontidae	*C. falcula*	
Chaetodontidae	*C. guttatissimus*	
Chaetodontidae	*C. kleinii*	
Chaetodontidae	*C. lunula*	
Chaetodontidae	*C. madagaskariensis*	
Chaetodontidae	*C. melannotus*	
Chaetodontidae	*C. meyeri*	
Chaetodontidae	*C. trifascialis*	
Chaetodontidae	*C. trifasciatus*	
Chaetodontidae	*C. unimaculatus*	
Chaetodontidae	*C. xanthocephalus*	
Chaetodontidae	*Chaetodon auriga*	
Chaetodontidae	*F. longirostris*	
Chaetodontidae	*Hemitaurichthys zoster*	
Chaetodontidae	*Heniochus acuminatus*	
Chaetodontidae	*Heniochus diphreutes*	
Chaetodontidae	*Heniochus monoceros*	
Haemulidae	*P. gaterinus*	Sweetlips
Haemulidae	*P. plagiodesmus*	
Haemulidae	*P. playfairi*	
Haemulidae	*Plectorhinchus albovittatus*	
Haemulidae	*Plectorhinchus flavomac.*	
Haemulidae	*Plectorhinchus orientalis*	
Labridae	*A. meleagrides*	Wrasses
Labridae	*A. twistii*	
Labridae	*Anampses caeruleopunt*	
Labridae	*B. axillaris*	
Labridae	*B. diana*	
Labridae	*Bodianus anthioides*	
Labridae	*C. caudimacula*	
Labridae	*C. diagrammus*	
Labridae	*C. fasciatus*	
Labridae	*C. oxycephalus*	
Labridae	*C. trilobatus*	
Labridae	*C. undulatus*	
Labridae	*Cheilinus chlorourus*	
Labridae	*Cheilio inermis*	
Labridae	*Coris aygula*	
Labridae	*Epibulus insidiator*	
Labridae	*Gomphosus caeruleus*	
Labridae	*H. dussumieri*	
Labridae	*H. hortulanus*	
Labridae	*H. iridis*	
Labridae	*H. marginatus*	
Labridae	*H. melapterus*	
Labridae	*H. scapularis*	
Labridae	*Coris cuvieri*	

Family	*Species*	English family name
Labridae	*Hemigymnus fasciatus*	
Labridae	*Hologymnosus annulatus*	
Labridae	*L. dimidiatus*	
Labridae	*Labrichthys sp.1*	
Labridae	*Labrichthys unilineatus*	
Labridae	*Labroides bicolor*	
Labridae	*Macropharyngodon bipartitus*	
Labridae	*Novaculichthys taeniorus*	
Labridae	*Pseudocheilinus evanidus*	
Labridae	*Pseudocheilinus hexataenia*	
Labridae	*Pteragogus cryptus*	
Labridae	*S. bandanensis*	
Labridae	*Stethojulis albovittatus*	
Labridae	*T. hardwicki*	
Labridae	*T. herbracium*	
Labridae	*T. lunare*	
Labridae	*Thalassoma amblycephal*	
Labridae	*Thalassoma sp.1*	
Lethrinidae	*Gnathoden. aurolinea*	Emperors
Lethrinidae	*Gymnoc. griseus*	
Lethrinidae	*L. erythracanthus*	
Lethrinidae	*L. harak*	
Lethrinidae	*L. mahsena*	
Lethrinidae	*L. obsoletus*	
Lethrinidae	*Monotaxis grandoc*	
Lutjanidae	*Aphareus furca*	Snappers
Lutjanidae	*L. fulviflamma*	
Lutjanidae	*L. gibbus*	
Lutjanidae	*L. kasmira*	
Lutjanidae	*L. monostigma*	
Lutjanidae	*L.bohar*	
Lutjanidae	*Macolor niger*	
Monacanthidae	*Amanses scopas*	Filefishes
Monacanthidae	*C. fronticinctus*	
Monacanthidae	*Pervagor janthinosoma*	
Mullidae	*M. vanicolensis*	Goatfishes
Mullidae	*P. bifasciatus*	
Mullidae	*P. cyclostomus*	
Mullidae	*P. macronema*	
Mullidae	*P. pleurostigma*	
Mullidae	*Parupeneus barberinus*	
Nemipteridae	*S. ghanam*	Bream
Ostraciidae	*O. meleagris*	Trunkfishes
Ostraciidae	*Ostracion cubicus*	
Pomacanthidae	*Apolemichthys trimacul*	Angelfishes
Pomacanthidae	*C. bispinosa*	

Family	*Species*	English family name
Pomacanthidae	*C. multispinis*	
Pomacanthidae	*P. imperator*	
Pomacanthidae	*P. semicirculatus*	
Pomacanthidae	*Pomacanthus chrysurus*	
Pomacanthidae	*Pygoplites diacanthus*	
Pomacentridae	*A. allardi*	Damselfishes
Pomacentridae	*A. leucogaster*	
Pomacentridae	*A. sexfasciatus*	
Pomacentridae	*A. sparoides*	
Pomacentridae	*A. vaigiensis*	
Pomacentridae	*Amphiprion akallopisos*	
Pomacentridae	*C. atripectoralis*	
Pomacentridae	*C. cauruleus*	
Pomacentridae	*C. dimidiata*	
Pomacentridae	*C. lepidolepis*	
Pomacentridae	*C. nigrura*	
Pomacentridae	*C. ternatensis*	
Pomacentridae	*C. weberi*	
Pomacentridae	*Chromis agilis*	
Pomacentridae	*Chromis cf.leucura*	
Pomacentridae	*Chry. biocellata*	
Pomacentridae	*D. trimaculatus*	
Pomacentridae	*D.carneus*	
Pomacentridae	*Dascylus aruanus*	
Pomacentridae	*N. cyanomos*	
Pomacentridae	*Neoglyphid. melas*	
Pomacentridae	*P. baenschi*	
Pomacentridae	*P. caeruleus*	
Pomacentridae	*P. sulfureus*	
Pomacentridae	*P. trilineatus*	
Pomacentridae	*Pl. johnstonianus*	
Pomacentridae	*Pl. lacrymatus*	
Pomacentridae	*Plectroglyphid. dickii*	
Pomacentridae	*S. nigricans*	
Pomacentridae	*Stegast fasciolatus*	
Scaridae	*Calotomus carolinus*	Parrotfishes
Scaridae	*Calotomus spinidens*	
Scaridae	*Cetoscarus bicolor*	
Scaridae	*Chl. sordidus*	
Scaridae	*Chl. strongylocephalus*	
Scaridae	*Chlororus atrilunula*	
Scaridae	*Hipposcarus harid*	
Scaridae	*S. frenatus*	
Scaridae	*S. ghobban*	
Scaridae	*S. niger*	
Scaridae	*S. psittacus*	
Scaridae	*S. rubroviolaceus*	

Family	*Species*	English family name
Scaridae	*S. russelli*	
Scaridae	*S. scaber*	
Scaridae	*S. tricolor*	
Scaridae	*S. viridifucatus*	
Scaridae	*Scarus caudofasciatus*	
Scombridae	*Gymnosarda unicolor*	Tunas
Scombridae	*Thunus obesus*	
Serranidae	*Aethaloperca rogaa*	Groupers
Serranidae	*Anyper. leucogramm.*	
Serranidae	*C. leopardus*	
Serranidae	*C. miniatus*	
Serranidae	*C.urodeta sb nigripinnis*	
Serranidae	*Cephalopholis argus*	
Serranidae	*E. fuscoguttatus*	
Serranidae	*E. merra*	
Serranidae	*E. spilotoceps*	
Serranidae	*Gramm. sexlineatus*	
Serranidae	*P. punctatus*	
Serranidae	*Plectropomus laevis*	
Serranidae	*V. louti*	
Siganidae	*S. stellatus*	Rabbitfishes
Siganidae	*S. sutor*	
Tetraodontidae	*A. mappa*	Pufferfishes
Tetraodontidae	*A. nigropunctatus*	
Tetraodontidae	*C. janthinoptera*	
Tetraodontidae	*C. solandri*	
Tetraodontidae	*C. valentini*	
Tetraodontidae	*Canthigaster amboinensis*	
Tetraodontidae	*Canthigaster bennetti*	