FRONTIER TANZANIA MARINE RESEARCH PROGRAM

Utende Beach, Mafia Island, Tanzania

TZM Phase 174 & 181 Science Report
1st October 2017 – 31st March 2018
Joanna Read
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Acknowledgements

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Staff Members

Project Coordinator outgoing  Maite Shahali  
Research Officer  Joanna Read  
Assistant Dive Officer  outgoing  Jonathan Cooper  
Boat Captain  Mussa
General Summary
All field work carried out by Frontier Tanzania Research Assistants (RAs) in phases 174 and 181 was within Mafia Island Marine Park (MIMP) boundaries. Snorkeling surveys for seagrass and mangroves were continued over the last two phases. Having received training from whale shark experts, basic data was also collected on whale sharks around Mafia, and tourist-whale shark interaction research conducted. The data collected on coral genus instead of the previous benthic substrate and morphology method is reported here for the first time.

Marine Protect Areas (MPA) are sanctuaries for coral reefs that can work towards mitigating the effects of anthropogenic exploitation and climate change, if effectively managed (Mora, et al. 2006). The Mafia Island Marine Park is a multi-user MPA consisting of three different zonation tiers: Core, specified and general use; with the overall aim to conserve and protect the biodiversity of Mafia Island reefs (MIMP 2011). There are approximately 23,000 people living within the Marine Park boundaries, many of whom depend on the marine ecosystems either directly eg through fishing or indirectly e.g. through tourism.

Project Aims
The overall aim of these two phases was to monitor the health of the different marine habitats found within the Marine Park and set up a study on whale shark behaviours in response to tourist interactions.

Project Objectives
1. monitor the health of the coral reefs within Chole Bay through baseline survey protocols, specifically focusing on the diversity of coral genera
2. compare the diversity and abundance of fish and invertebrates found within different species of seagrass
3. monitor the fish and invertebrates found at high tide along the edge of the mangroves bordering Utende beach, as part of an interconnecting habitat with the marine life in seagrass and coral reefs
4. record the interactions of tourists and tour operators viewing whale sharks and gather basic biological data on whale sharks

Training
All Research Assistants (RA’s) were given a series of lectures and tests to ensure quality of data collected was accurate and efficient, listed below in Table 1.

To ensure accuracy of data collection RAs had a pass mark of 95% in all four areas of data collection (coral, fish, invertebrate and seagrass identification) before beginning surveys.
Table 1. Briefing Sessions and Science lectures given in Phase 174 and 181

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Description</th>
<th>Lecturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome to Mafia</td>
<td>General introduction to Mafia Island, Utende Village and Frontier’s role in MIMP</td>
<td>MS</td>
</tr>
<tr>
<td>Hazards of the reef</td>
<td>Health and safety lecture on the potential dangers and hazards of marine life</td>
<td>MS</td>
</tr>
<tr>
<td>Benthic Identification</td>
<td>Methodology 30 coral genera</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Fish Identification</td>
<td>Methodology 42 fish families</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Invertebrate Identification</td>
<td>Methodology 20 invertebrates</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Introduction to Coral Biology</td>
<td>Brief introduction to coral reefs and their importance</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Seagrass</td>
<td>Introduction to types of seagrass, distribution and economic and ecological importance 9 species</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Mangroves</td>
<td>Introduction to types of mangroves, distribution, ecological and economical importance</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Coral reef ecology</td>
<td>Formation of corals, distribution patterns</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Coral Reef Management</td>
<td>MPA and their uses</td>
<td>Self-taught</td>
</tr>
<tr>
<td>Whale Shark Biology and Conservation</td>
<td>General biology of whale sharks, their threats and conservation efforts to date</td>
<td>Self-taught</td>
</tr>
</tbody>
</table>

Research Assistants continued the efforts in assisting MIMP staff with their monthly beach cleans and surveys on Utende beach. RAs were also able to go into a local men’s class three times a week to teach and help local men working in the tourism industry to practice English. RAs on teaching placements taught English and generally helped out at Utende Primary School. Bird-watching with Mafia Ornithological and Research Centre was also available.
Study Areas

The marine park covers 822 km², see Figure 1, located between S 07° 45’ 07”, E 39° 54’ 01” and S 08° 09’ 40”, E 39° 30’ 00” (Figure 1.)

Within the park, a zoning policy was developed with three zones; Core Zone (CZ), Specified Use Zone (SUZ) and General Use Zone (GUZ) (Figure 21). Within CZs there is no resource extraction but diving and research is permitted. Within SUZs only locals are allowed to extract fish using gear considered sustainable by MIMP. Within GUZs national fishing regulations apply and tourists can obtain permits to undertake activities within the park.

Mafia Island is globally recognized area for marine biodiversity and conservation with some of the richest marine biodiversity in the Indian Ocean (Benjaminsen and Bryceson 2012). Our coral, fish, invertebrate and seagrass research take place in the Chole Bay area (Figure 2). The bay has a maximum depth of 15m and is sheltered from wave action by a stretch of coral reef at the edge of the bay and the Indian Ocean. Large seagrass beds comprised of Thalassia hemprichii, Cymodocea spp, Enhalus acoroides and Thalassodendron ciliatum are interspersed with complex coral reef structures within a bay fringed by mangroves. Mafia Island is also one of the few places in the world where whale sharks (Rhincodon typus), a usually solitary and migratory species, reside all year round.

Chole Bay is at the intersection of strong competing forces in terms of ecological conservation. Firstly, Chole Bay contains the most fish landing sites in the country and Mafia Island is home to the
country’s largest seafood processing factory. The local community is highly dependent on marine resources for subsistence, while increased pressures from globalization have made artisanal fishing less capable of supporting basic needs for local fisherman. Secondly, Mafia Island is the site of the first marine conservation zone in Tanzania and the MIMP General Management Plan is primarily focused on biodiversity conservation and sustainable fishing practices. Finally, Chole Bay is home to the most popular dive and tourism sites for Mafia Island.

The local communities work in collaboration with MIMP to exchange knowledge and set rules for the park. MIMP has also provided gear exchange programs, education in sustainable fishing and training on alternative incomes such as seaweed farming and beekeeping. Interviews of fishing communities in MIMP in 2012 showed that in general, local fishermen supported MIMP and recognised the benefits of the more sustainable fishing practices (such as the end of dynamite fishing) implemented since 2000 (Kincaid, Rose and Mahudi 2014). Closer analysis reveals differences in the application of MIMP regulations and the distribution of resources with specific fishing communities. For example, small-scale fisherman from Chole who have historically used net gear are restricted to the shallow GUZ, and increased competition in the zone is causing the area to become overexploited and is also causing destruction to local seaweed farms. Meanwhile, fisherman from Utende who have traditionally fished with fixed gear such as lines and traps are allowed by MIMP in the SUZ, providing them more locations and deeper waters in which to fish (Kincaid, Rose and Mahudi 2014). The fishing community in Jibondo, in contrast, has completely rejected MIMP regulations citing undue hardship and continues to use illegal pull nets to obtain higher catch yields despite risk of confiscation or other harsh punishment (Moshy and Bryceson 2016). While the protections provided by MIMP have improved Chole Bay from an ecological standpoint, they have come at a high cost to the livelihoods of many members of the local community. Many fisherman are trapped in a cycle of poverty, hunger and debt and elders report lower standards of living compared to 20 years ago (Moshy, Brycesona and Mwaipopo 2015).

Figure 2. Satellite image of Chole Bay showing survey sites and management zones.
Research Projects

Project 1. Monitoring whale shark behaviour in response to boat and snorkel tourism

Introduction

There is a significant industry around whale shark tourism on Mafia Island, with several ‘whale shark safari’ companies taking tourists out in boats, usually from the main port Kilindoni. Whale sharks have recently been registered as endangered on the IUCN red list. They are also one of the largest ocean animals that are possible for humans to swim alongside in perfect safety and the whales are starting to attract more attention from tourists as a result.

Whale sharks tend to remain in an area for less time if there are tourists present, and if they have been previously injured by boats (recognisable by visible scars), they tend to avoid boats again in the future (Norman 1999). Therefore, it is important to monitor the effects tourists are having on the whale shark population at Mafia Island and to evaluate the effectiveness of the ‘Code of Conduct’ at keeping tourist behaviour within acceptable limits for the whale sharks.

Whale shares are only visible to tourists (and researchers) at the surface from November to March, when the plankton is at the surface (Rohner, et al. 2015). Close to the shore, the whale sharks at Mafia Island are mostly juvenile males which are generally below 13m in size (pers. observation; adult whale sharks can grow up to 20m in length).

The Code of Conduct was created in collaboration with the Mafia District Council, stakeholders from the fisheries sector and conservation NGOS. Experts on whale shark behaviour visit Mafia Island every year to conduct research and to train whale shark safari tour guides on the Code of Conduct. Compliance to the Code of Conduct is voluntary, however, and adherence varies.

Key features of the Code of Conduct for tourists include: 1) snorkelers are to remain 2m away from the whale shark’s head and 3m away from its tail 2) snorkelers should not block the whale shark’s path 3) no flash photography is allowed.

The Code of Conduct for boats includes: 1) boats must maintain a 20m distance from the whale sharks with only 1 boat in this proximity to each whale shark 2) other boats in the vicinity must remain 100m away 3) boats should not block the whale shark’s path and 4) boats must only allow 10 snorkelers in the water at a time.

Method

Whale shark data was collected to the West of Kilindoni, the main port on Mafia Island, outside of the Marine Park. Frontier collaborated with one whale shark safari company, ‘Whale Safari’, over the last season and accompanied them on 11 trips in Phase 174 and 9 trips in Phase 181 when they had bookings to take tourists to see the whale sharks. Frontier’s volunteer and staff on the whale shark project attended, gave a briefing to the tourists on whale shark biology, explained the Code of Conduct and then gathered data on whale shark and tourist interactions.

Observations from the boat were made on the numbers of boats and swimmers in the water in the vicinity of a whale shark and any breaches in the Code of Conduct. Behaviours were categorised in according to Table 3.
Table 2. Behaviour codes for tourism interactions with whale sharks

<table>
<thead>
<tr>
<th>Behaviour Code</th>
<th>Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO</td>
<td>Swimmer touching of shark</td>
</tr>
<tr>
<td>PR</td>
<td>Swimmer under 3m proximity to shark</td>
</tr>
<tr>
<td>FL</td>
<td>Flash photography</td>
</tr>
<tr>
<td>BL</td>
<td>Swimmer blocking shark path</td>
</tr>
<tr>
<td>REV</td>
<td>Boat revving engine</td>
</tr>
<tr>
<td>OV</td>
<td>Boat driving</td>
</tr>
<tr>
<td>RA</td>
<td>Boat under 20m proximity to shark</td>
</tr>
<tr>
<td>D</td>
<td>Whale shark diving behaviour (avoidance)</td>
</tr>
<tr>
<td>S</td>
<td>Whale shark sped up</td>
</tr>
<tr>
<td>B</td>
<td>Whale shark banking (avoidance)</td>
</tr>
<tr>
<td>AB</td>
<td>Whale shark abnormal behaviour</td>
</tr>
<tr>
<td>F</td>
<td>Whale shark feeding behaviour</td>
</tr>
</tbody>
</table>

The Marine Megafauna Foundation, Mozambique provided advice and training for developing our methods for observing tourism operations with whale sharks in Chole Bay. Using snorkelling gear, surveyors entered the water at the same time as the tourists and proceeded to observe interactions with whale sharks.

Results

Five trips were made where conditions were suitable to accurately record data. In total, 36 whale sharks were observed and 29 were able to be estimated for size. Sizes ranged from 3m to 12m, and the mean size was 7.17m long. There was a maximum of 5 boats and 15 swimmers in the water in the vicinity of a whale shark at any one time (see Table 3 for more details).

Of the 30 breaches in the Code of Conduct recorded 13 were of a boat in too close proximity to a whale shark, and 10 were of swimmers in too close proximity.
Table 3. Basic data collected on whale sharks, their size, behaviour and numbers of tourists in their vicinity. See methods section for key to breaches in Code of Conduct.

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of boats</th>
<th>Number of swimmers</th>
<th>Numbers of whale sharks</th>
<th>Breaches in Code of Conduct</th>
<th>Size of Whale Sharks (m)</th>
<th>Whale Shark Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>14/12/2017</td>
<td>1-4</td>
<td>4-15</td>
<td>8</td>
<td>3 RA/ 1 OV / 4 REV</td>
<td>6-10</td>
<td>Diving/sped up</td>
</tr>
<tr>
<td>18/12/2017</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>None</td>
<td>6-10</td>
<td>Diving/feeding</td>
</tr>
<tr>
<td>21/12/2017</td>
<td>1-2</td>
<td>9-13</td>
<td>7</td>
<td>10 PR/ 2 BL / 3 RA</td>
<td>5-10</td>
<td>Diving/feeding</td>
</tr>
<tr>
<td>27/12/2017</td>
<td>2-5</td>
<td>1-6</td>
<td>12</td>
<td>None</td>
<td>4-12</td>
<td>Feeding/swimming</td>
</tr>
<tr>
<td>7/3/2018</td>
<td>3</td>
<td>5-10</td>
<td>4</td>
<td>7 RA</td>
<td>3-6</td>
<td>Diving/feeding</td>
</tr>
</tbody>
</table>

Discussion

When disturbed by human interference, whale sharks will often change direction. A previous study found that directional change in whale sharks is caused mainly by path obstruction and proximity of a swimmer to a whale shark (Quiros 2007). The most common breaches of the Code of Conduct noted during this study were related to proximity of swimmers and boats to whale sharks, and whale shark avoidance behaviours were observed during our study.

Enforcement of the Code of Conduct is not straightforward. Locals on Mafia Island are dependent on the tourism revenue from whale shark safaris. When only one or two whale sharks surface in the area on one day, there is inevitably pressure on the whale sharks from tourist operators edging closer and allowing infringements of the Code of Conduct.

Local knowledge suggests that when more whale sharks are spotted in the vicinity, breaches in Code of Conduct by tour operators and tourists are less frequent. Our observations to date do not necessarily support this assertion, however. In one survey, we observed 10 instances of tourists swimming too close to the sharks when there were a total of 7 whale sharks spotted that day. We did also observe that whale sharks banked and changed their behaviour less frequently when the Code of Conduct was followed.

The two most common breaches noted, both boats and snorkelers in overly close proximity to the whale sharks, illustrate that more work is required to encourage adherence to the Code of Conduct. Operators do risk revocation of their “eco-friendly” status, however this enforcement has never been administered to date and breaches are still common. Our future data collection efforts aim to contribute to and evidence base on the frequency of breaches and potentially increase enforcement of the Code of Conduct.
Project 2. Monitoring fish and invertebrate community composition within seagrass meadows.

Introduction

Seagrass meadows are important habitats and sources of food for multiple species of fish and invertebrates. There are also reports of nearly extinguished populations of dugongs in East Africa that frequent seagrass beds around Mafia Island (Muir et al., 2003, Marsh, 2008).

Adult reef fish often migrate to the seagrass daily to forage while many species’ juveniles rely on seagrass meadows for refuge during development. Most studies of ontogenetic migration report that juveniles utilize mangrove and seagrass habitats for development more often than coral reefs (Berkström, Jörgensen and Hellström, 2013; Nagelkerken, et al. 2000). For example, a 2013 study in Chole Bay found evidence of ontogenetic and diurnal migration corridors between shoreward seagrass meadows and offshore coral reefs for 2 snapper species (Berkström, Jörgensen and Hellström 2013). As many of these seagrass meadows are located in the GUZ, they are some of the only regions available for legal net fishing in Chole Bay. Berkström Jörgensen and Hellström (2013) also observed juvenile Lutjanus fulviflamma (dory snapper) in higher congregations in mangrove roots, despite the fact that this species is known to prefer seagrass and hypothesises that this may be due to high predation pressure of seagrass beds. This could also be in relation to increased fishing pressure or seabed disturbance. Most of the GUZ in Chole Bay is restricted to the shallows and nets must be dragged on the seabed to catch blackspot snappers (can refer to both Lutjanus fulviflamma or Lutjanus ehrenbergii) (Moshy and Bryceson 2016). Seagrass height was also shown to be a strong determinant for density and species richness in juvenile fish species in Gullström (2008).

Currently, there is little consideration for seagrass conservation in the MIMP management plan. This project aims to demonstrate the ecological and economic value of seagrass meadows in Chole Bay to influence future conservation efforts.

Methods

In this phase, data was collected at 3 sites off the shore of Utende beach in the GUZ to identify seagrass species and their corresponding fish and invertebrate communities.

Surveys were conducted on slack low tide via snorkeling. The first surveyor would reel out a 20m transect tape parallel to the shore, on the shoreward edge of a thick seagrass bed (Figure 3). The surveyor identified fish to family level and tallied how many of each were seen within approximately 5m of the transect line.

At 5m intervals a 1m x 1m quadrat was estimated by a second surveyor, following the first, at 50cm either side of the transect (Figure 4.) The surveyor estimated the overall percentage of seagrass cover and then identified the seagrass species present within the quadrat, estimating the percentage cover of each species. Three stems of each species was measured and averaged for height. Invertebrates were identified and tallied along the transect in a U-pattern of 2.5m.

A total of 39 transects where laid during phases 174 and 181.
Data analysis

The dominant seagrass species per transect was calculated by adding together the percentage cover of each species, and the one with the highest percentage was determined to be the dominant. There were no cases of equal total percentage.

Statistical analysis was conducted in the statistical computing and graphics software R (R Core Team, 2018) and Excel (Windows Office, 2010).
Results and Discussion

Fish community composition

There were 5 different species of seagrass identified in our surveys; *Cymodocea serrulata* (CS), *Enhalus acoroides* (EA), *Syringodium isoetofolium* (SI), *Thassalia hempricii* (TH), and *Halodule uninervis* (HI). Either *C. serrulata* or *E. acoroides* were the primarily dominant species in 28 out of the 39 transects. Unique fish species per transect ranged from 1 to 18, with at least 1 species of fish observed in each survey. Seagrass coverage and the related fish abundance and fish species diversity are plotted in Figure 5. The highest values for both fish abundance (205 individuals) and fish diversity (18 species) were found in Transect 14, which was dominated by *S. isoetofolium*.

![Figure 5. Plot of seagrass coverage, fish abundance and fish species diversity from snorkel survey. The size of the point represents diversity of fish species; color represents which seagrass species was most dominant at the site.](image)

Of the 10 transects where *Scaridae* were identified, three seagrasses were dominant, with *E. acoroides* showing the highest total numbers of *Scaridae* and numbers of transects along which they were spotted, followed by *S. isoetofolium* and *C. serrulata*, see .
Table 4. Scaridae abundance per transect with dominant seagrass species

<table>
<thead>
<tr>
<th>Dominant seagrass species</th>
<th>Total numbers of Scaridae</th>
<th>Numbers of transects where Scaridae were spotted</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Enhalus acoroides</em></td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td><em>Syringodium isoetifolium</em></td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td><em>Cymodecea serrulata</em></td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

Invertebrate community composition

Invertebrate diversity ranged from 0 to 9 species per transect with 2 sites having 0 invertebrates. Seagrass coverage and the related invertebrate abundance and invertebrate species diversity are plotted in Figure 6.

![Figure 6](image)

*Figure 6. Plot of seagrass coverage, invertebrate abundance and invertebrate species diversity from snorkel surveys. The size of the point represents diversity of invertebrate species; color represents which seagrass species was most dominant at the site.*

*E. acoroides* was the tallest dominant seagrass species, on average, at nearly 50cm tall (Figure 7). *C. serrulata, S. isoetifolium* and *T. hempricii* all ranged between 21 and 27cm on average. *H. uninervis* was the shortest dominant seagrass species observed at an average height of 12cm.
Our analysis of the data to date did not find any significant correlations between total percentage seagrass cover and measures of fish and invertebrate abundance and diversity.

Our data did find that in Chole Bay, *E. acoroides* more often supported a higher diversity and abundance of both fish and invertebrates than *T. hempricii*. The average height of seagrass was also much higher for all transects dominated by *E. acoroides*, which means this species may be offering better refuge from predation.

Future research will incorporate more sites, and in particular, include areas where more net fishing techniques are known to be used to compare ecosystem health between fishing techniques.
Project 3. Documenting coral, fish and invertebrate species abundance and diversity within popular dive sites in Chole Bay

Introduction

Frontier’s coral monitoring research aims to assist MIMP by collecting data on the status of the ecosystem to inform management initiatives. The coral reefs within MIMP have been improved since 2000, especially since the halt of dynamite fishing, but still face threats such as overexploitation of nearby unprotected areas that serve as juvenile recruitment or food sources, sea level rise, ocean acidification, increasing temperatures and destructive fishing practices.

Methods

Fish and invertebrate surveys were conducted with SCUBA gear using the transect methodology applied in Project 1. The sites surveyed are all common dive locations in Chole Bay.

Using the same 20m transect laid out for fish and inverts a third surveyor recorded the coral genus via a line intercept transect, including coral up to 50cm either side of the transect tape if there was no coral directly beneath the transect and a set of 30 of the most common coral genera were selected for identification.

Study Area

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Coordinates</th>
<th>Management</th>
<th>Date</th>
<th>Range</th>
<th>Surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milimani South</td>
<td>-7.56778 39.4706</td>
<td>SUZ</td>
<td>29/01</td>
<td>28/02</td>
<td>5</td>
</tr>
<tr>
<td>Fringing reef that runs perpendicular to Chole Wall, to the west of Kinasi Pass, and borders the channel running from the mouth of the bay inwards, within the Specified Use Zone. This site comprises mostly of foliose, columnar and submassive coral morphologies. Fish are diverse with lots of damsel fish, soldier fish and triggerfish.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milimani North</td>
<td>-7.5678 39.476</td>
<td>SUZ</td>
<td>10/02</td>
<td>16/02</td>
<td>2</td>
</tr>
<tr>
<td>An area of sheltered fringing reef, within the Specified Use Zone facing inward from the mouth of the bay. Located several hundred metres west of the Kinasi Pass, this site is surrounded by sand and sea grass beds. Milimani contains a coral shelf that gradually drops to around 20m and contains an abundance of foliose, massive and branching coral. Fish diversity is high, with fish species ranging from moustache triggerfish to juvenile groupers, with large schools of soldierfish frequently observed sheltering in the submassive coral.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Rock</td>
<td>-7.53822 39.39232</td>
<td></td>
<td>10/02</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Small limestone island surrounded by reef that creates a wall dive. Westerly side shallow, Easterly side deep.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Msumbji</td>
<td>-7.5 39</td>
<td>GUZ</td>
<td>24/10</td>
<td>02/03</td>
<td>3</td>
</tr>
<tr>
<td>This small reef contains a wide variety of corals along slopes and sheer walls, along with spires of coral that form overhangs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coral Gardens</td>
<td>-7.5 39</td>
<td>SUZ</td>
<td>05/01</td>
<td>28/02</td>
<td>4</td>
</tr>
<tr>
<td>Kinasi Pass</td>
<td>-7.95 39.8167</td>
<td>CZ</td>
<td>02/09</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Kinasi Pass is in the Core Zone reaching a maximum depth of around 26 m. Few coral formations are found shallower than 20m, hence experienced divers are needed to carry out a survey at this depth, as air consumption limits dive time. There is a pinnacle of rock with high fish abundance, the rest of the site is predominantly rubble with some black corals. This site is at the entrance of the bay so it is very susceptible to strong currents and dives need to be accurately scheduled to avoid a drift dive.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shore MID (Nudi City)</td>
<td>-7.5823 39.456</td>
<td>GUZ</td>
<td>05/02/</td>
<td>17/02/</td>
<td>4</td>
</tr>
</tbody>
</table>
Results and Discussion

Our observations did not yield any significant correlations between coral community assemblage and fish or invertebrate assemblage between the sites surveyed, although this is likely related to sampling methodology which will be revised in future research. Figures 21 and 22 display the relative abundance and species richness observed at each site. Following is a description of the community composition observed at each site.

![Abundance of fish and invertebrate at dive sites in different Zones of MIMP](image1)

**Figure 16. Abundance of fish and invertebrate at dive sites in different Zones of MIMP**

![Diversity of fish and invertebrates at dive sites in different Zones of MIMP](image2)

**Figure 17. Diversity of fish and invertebrates at dive sites in different Zones of MIMP**

Milimane South comprises mostly of foliose, columnar and submassive coral morphologies. Our observations found this site to be the most diverse in our study area for coral genera, with 24 unique species. The most common coral at Milimane South was Pachyseris (12.5%), often taking the foliose form, and Pavona clavus (11.1%), which was predominantly sub-massive.
The coral at Nudi City, which is close to shore and located within the GUZ, was dominated by soft corals, mostly *Xenia* (39.5% coverage) and *Nepthea* (12.1% coverage). Soft corals can rapidly colonise any space after a destructive event, with their carpeting growth and not many predators (Barnes and Hughes 2000). This coral community composition was expected is expected for a habitat comprised of sediment with lack of rock as a substrate for harder corals (Barnes and Hughes 2000) and may also reflect the overexploitation and destructive fishing practices in the GUZ.

Coral Gardens’ most common coral (16.6% coverage) was not a true scleractinia, but a hydrozoan called *Millepora*, commonly known as fire coral due to its stinging cells. This was closely followed by *Lobophyton*, a soft coral, at 11.3% coverage.

The coral at Msumbiji was dominated by *Pavona cactus* (52.1%), a foliose coral, with *Alveopora*, a massive coral, the next most common (16.1%). *Pavona cactus* has been shown to be susceptible to competition from soft coral, so the relatively low soft coral presence (8.8%) at this site may be providing an opportunity for this species to flourish.

The most dominant coral coverage at Small Rock was *Millepora* at 21%, with *Lobophyton* also common at 11.0%. *Millepora* is recognized as being quick to recover after bleaching events (Lewis 2006). The second most common coral by percentage cover was *Porites rus*, a sub-massive species of *Porites*, which is usually massive. It has been suggested that *Porites rus* has a high tolerance to short term decreases in pH, and so might be tolerant to future ocean acidification (Comeau, Carpenter and Edmunds 2013). This site might have been exposed to extreme environmental conditions, resulting in these dominant coral genera.

Nudi City in the General Use Zone is a close second for invertebrate abundance, although these are dominated by sponges, feather stars and anemones and the site has the lowest fish abundance.

**Proposed Work for Next Phase**

- Survey mangrove habitats for juvenile fish populations
- Create a survey methodology for evaluating the impact of
- Set up monitoring plan for turtle hatching season
- Alter coral surveys to conform to Reef Check methodology and MIMP objectives
- Coordinate fish survey methodology with MIMP 2018 objectives
- Coordinate with MIMP on community environmental awareness programs

**References**


MIMP. *Mafia Island Marine Park General Management Plan.*


Quiros, Angela L. "Tourist compliance to a Code of Conduct and the resulting effects on whale shark (Rhincodon typus) behavior in Donsol, Philippines." *Fisheries Research* (Fisheries Research), 2007: 102-108.
