TANZANIA MARINE RESEARCH PROGRAMME

Utende, Mafia Island, Tanzania

TZM Phase 141 Science Report

6th January – 24th March 2013

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1. Introduction

Tropical marine ecosystems including coral reefs, mangrove forests and seagrass meadows are valuable environmental resources that provide significant economic goods and ecosystem services to people all around the globe (Kimirei, 2012; Nagelkerken et al., 2000; Hughes et al., 2003). They contribute to the livelihoods and food security of millions of people living in coastal countries; play a crucial role in stabilizing global ecosystems and in mitigation of coastal erosion (Hoegh-Guldberg, 1999). The health and stability of these resources is therefore critical to human wellbeing worldwide (Wilkinson et al., 1999).

Tanzania is currently rated as one of the poorest countries in the world, with a large proportion of its population directly or indirectly depending on coastal ecosystems for the provision of cheap protein through subsistence fishing, trade in marine resources and dive tourism (Francis et al., 1997). Amongst Tanzania’s administrative regions, the Mafia Archipelago is one of the least developed, with a disproportionately large percentage of the population depending on farming and subsistence fishing (Holberg, 2008).

Mafia Island is located approximately 120 km south of Dar-Es-Salaam, 20 km offshore of the Rufiji Delta and 850 km south of the equator. It is the central island of the Mafia Archipelago which consists of about 15 sandstone and coral rag islands, several of which are inhabited. Mafia is the largest island measuring approximately 50 km long and 15 km across at its widest point. There is an estimated population of 40,000 people living on the main island, with the majority being based in the south of the island.

The archipelago is significantly less developed than its neighbours Pemba and Zanzibar (Holberg, 2008; Boeser, 2005) and has far fewer tourists per year (Holberg, 2008). However, as foreign investment increases, it has been predicted that this will change over the coming years.

While increased tourism and development of infrastructure is expected to benefit the local population, it also puts pressure on a way of life that has been established over countless generations. Subsistence fishing and unregulated small scale trade are often the only means of obtaining protein on Mafia Island (Holberg, 2008). Given the fragility of coastal ecosystems, an increase in these practices may lead to biodiversity loss. The creation of a sustainable fishery system that guarantees the livelihood of people whilst also protecting the reefs, is therefore of primary concern (ISRS, 2004).

Frontier’s engagement in Tanzania began in 1989 with the first TZM project located in Utende, Mafia Island (1989 – 1995). The project’s initial objectives were to supply a detailed and comprehensive set of baseline data on the marine environment within Chole Bay, on the east coast of Mafia. With the aid of this
In 1995, Tanzania established its first multi-user marine park, the Mafia Island Marine Park (MIMP). A management plan was established and the park was gazetted in 1995. The MIMP is responsible for the management of the park and reports to the Marine Parks & Reserves Unit of Tanzania, based in Dar-es-Salaam. This park is one of the few in the world that includes both terrestrial and marine areas in its management plan.

Multi-user marine parks aim to conserve resources and biodiversity and also improve fisheries and the livelihoods of the local people. Successful MPAs have increased abundance and biomass of target species (Lester, 2009), increased fish recruitment (Evans et al., 2008) and migration of adults into neighbouring areas (Jupiter and Egli, 2010). Tanzania pledged to have 10% of its marine area under conservation by 2012 and 20% by 2025 (Ruitenbeek, 2005). Tanzania currently has 12.5% of its coastal waters under some form of protection (World Bank, 2008).

Frontier returned to Utende, Mafia Island in 2010. The marine park boasts great biodiversity with 273 species within 63 genera of coral (Obura, 2004). Fish biodiversity is also high, with 394 species recorded from 56 genera (Garpe and Ohman, 2003). The marine resources around Mafia are some of the richest in Eastern Africa and the marine park is a critical area for biodiversity (CBD, 2001).

The Marine Park still allows some fishing practices within the park but some do occur illegally. There is a commercial trade in sea cucumbers, gastropods, lobsters and fish (Pers Comms). Although a lot of products are consumed locally, some are exported to Dar-es-Salaam and from there to international markets (Pers comms). Locally, the majority of fish consumed are emperors and reef needle fish. However, the locals are happy to consume most fish that are caught; including boxfish, parrotfish, rabbitfish, rays and crocodilefish (Pers Comms). Dynamite fishing and seine netting are illegal practices but still occur at some places within the Marine Park. Live coral mining for lime and use in construction also still occurs on a small scale. Mangrove pole cutting still occurs and is difficult to monitor as there are many access points to the forests. There are five species of sea turtle that have been recorded in the Marine Park, but in some places they are captured for meat and their eggs collected. Tourist operations also cause some threats locally through anchor damage, diver damage, mangrove clearances for beaches, plastic pollution and sewage.

The Mafia Island Marine Park is different to most protected areas in that it encompasses both terrestrial and marine areas in its management plan and that it currently has around 20,000 – 22,000 people living within the boundaries of the park. Hence, the management needs to finely balance environmental conservation with socio-economic development (Mafia Island Marine Park General Management Plan, 2000). The marine park covers 822 km of coastline, almost half of the island of Mafia. While the park management has been largely successful, they have had some challenges, such as lack of funding for...
patrolling and enforcement. Within the park, a zoning policy was developed with three zones; Core/No-Take, Specified Use and General Use zones. Within the Core Zones there is no resource extraction but diving and research is permitted, within Specified Use zones there is no pull net fishing allowed and no fishing by non-residents and within General Use zones national fishing regulations apply and non-residents require a permit to undertake activities within the park.

**Figure 1: Zonation of the MIMP.** See figure legend for the different zonation areas of the MIMP.

There is little data on the effectiveness of the current management techniques and the Marine Park does not have the ability to carry out monitoring work in the area. There is currently little data and literature on the interactions between fish, invertebrates and coral within Tanzania. The aim of the current project is to implement and complete aspects of a five year survey and monitoring programme agreed between Frontier and MIMP. Objectives within the programme include but are not limited to:

- Collection of baseline biodiversity data on coral reefs within the MIMP
- Collection of baseline mangrove survey data and mapping of habitats
- Collection of baseline seagrass bed data and mapping of habitats
- Comparison of biodiversity in different ‘use’ zones of the MIMP
- Collection of socio-economic survey data on fisheries areas and fishing methods
• Collection of socio-economic survey data on mangrove harvesting, forest logging and coral mining
• Collection of socio-economic levels, including poverty, access to health care, education and impact of tourism
• Collection of socio-economic data on community relations with the MIMP
• Feasibility studies of potential aquaculture projects
• Development of a management plan and risk assessment report for the MIMP, based on evaluation of datasets.

An important practical indicator of the MIMP success is maintaining the health of its fisheries. Maintaining the fisheries can provide an indicator of overall community health and is also important to the local people, whose livelihoods depend on the marine resources. MIMP and Frontier have developed a proposal to monitor fisheries in the different zones of the marine park. Belt transects are used to estimate the diversity and abundance of fish, benthos and invertebrates (Hill et al., 2004). The aim of conducting baseline survey protocols is to assess the abundance, species richness and size of commercial fish within Chole Bay, the health of the coral reefs and the species richness of invertebrate indicator species. The hypothesis is that fish will generally be larger, more abundant and have greater species richness within Core zones compared to Specified Use zones. Reefs with higher hard coral percentage cover will have a higher number of fish and will be of a larger size, irrelevant of zoning. We also hypothesise that reefs with high invertebrate species richness will correlate with high coral cover and fish species richness.

2. Training

2.1 Briefing sessions

Research assistants received briefings after deployment on health and safety, medical issues, TZM project history, phase aims and objectives and general information on life in Utende (during the first few days of each month) as listed in Table 1.

2.2 Science lectures

Marine science lectures are conducted to train research assistants (RAs) in identifying marine families and species of fish and invertebrates. Training in benthic composition is also carried out where hard corals are surveyed by morphology instead of taxonomy. Additional lectures were delivered to develop a broader understanding of marine ecology and conservation and hence stress the need for research and accurate identification. The book Coral Reef Fishes, Indo-Pacific and Caribbean by Leiske and Edward (2001) was used as reference during study sessions.
### Table 1. Science lectures conducted during phase 141

<table>
<thead>
<tr>
<th>Core Science Lectures</th>
<th>Extra Science Lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to TZM</td>
<td>Fish morphology and ecology</td>
</tr>
<tr>
<td>Hazards of the Reef</td>
<td>Mangroves</td>
</tr>
<tr>
<td>Commercial Territorial Fish</td>
<td>Seagrass</td>
</tr>
<tr>
<td>Commercial Schooling Fish</td>
<td>Marine Protected Areas</td>
</tr>
<tr>
<td>Surveying and Monitoring Methods</td>
<td>Fisheries of Mafia Island</td>
</tr>
<tr>
<td>Benthic composition</td>
<td>Turtle Conservation</td>
</tr>
<tr>
<td>Invertebrate Identification</td>
<td>Whaleshark Biology</td>
</tr>
<tr>
<td>Angelfish Identification</td>
<td>Importance of Coral Reefs</td>
</tr>
<tr>
<td>Surgeonfish Identification</td>
<td></td>
</tr>
<tr>
<td>Butterflyfish Identification</td>
<td></td>
</tr>
</tbody>
</table>

### 2.3 Field Work Training

Field work training was provided through a series of lectures and practical sessions. All lectures were given either on camp or in the field. Lectures were given covering all fish families and species needed for surveys. Phase 141 saw a couple of additions to the fish list, although it remained largely the same as that of Phase 134. The current Commercial Fish Species List is designed to suit the needs of the MIMP’s long-term monitoring program and focuses on commercial fish families which are targeted by local fishing communities and indicators of reef health. Fish tests were completed by PowerPoint presentations and RAs were required to reach a 95% pass mark and staff a 100% pass mark before surveying could commence. When RAs initially failed to reach the pass mark, individual study periods were held and RAs re-tested until the required pass mark was achieved. After passing photographic ID fish, invertebrate and benthic tests, underwater sessions were held with staff to further test RAs. Fish size estimation training was carried out by snorkelling on shore and estimating the size of plastic fish on a line, held down by weights. RAs swam 1-2 meters above the fish and estimated their sizes. RAs were tested multiple times until they were able to accurately estimate the size of model fish to within 5 cm with a 95% pass rate for 15 fish. Benthic composition field training consisted of a PowerPoint lecture and tests as well as underwater training to ensure consistency between recorders.

### 2.4 Tropical Habitat Management BTEC

One four week BTEC was completed in Phase 141 by Shontay Greenwood. The candidate planned and conducted research and completed the necessary handbook sections whilst on the project. Internal verification was conducted by JF/CGR. The project looked at diver damage to coral reefs in the Mafia Island Marine Park and whether advanced divers caused less damage than novice divers. Due to the short
period of this study there were no conclusive results.

3. Research Work Programme
3.1 Survey Areas

Chole Bay, a highly tidal and bathymetrically complex inlet, is separated from the ocean by Kinasi Pass and Chole Pass, with an average depth of 20 m. The tidal range in the bay is approximately 3 m on the spring tide and 1 m on the neap tide, with a small intertidal area at mean low water. There are several fringing reefs located mostly between 6 – 18m; with many sand beds, coastal seagrass and coastal mangroves areas. Survey sites during phase 141 were located within the General Use zone from the shore, Specified Use Zone within Chole Bay and in the Core Zone inside and outside of the bay.

Figure 2. Satellite image of Chole Bay and the rough location of survey sites, showing the Core and Specified Use zones within the bay, General Use Zone is the area outside of the polygons (Google, 2014)

Milimani North
Milimani North is an area of sheltered fringing reef facing inward from the mouth of the bay and is located several hundred metres west of Kinasi pass and surrounded by sand and sea grass. Milimani contains a shelf of coral that gradually drops to around 20m depth and contains high amounts of foliose, massive and branching coral. Fish abundance is very diverse, with fish species ranging from moustache triggerfish to juvenile groupers, with large schools of soldierfish frequently seen sheltering in the submassive coral.

Milimani South
Milimani South is a 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.
Chole Reef
Chole Wall (3m) separates Utumbe from Kinası Pass and lies 6.06km from Utende. Chole shows high biodiversity within the bay, with high abundances of *Acropora formosia*, *Acropora validia* and *Montipora equituberculata*, Scleractinian corals dominating the benthos. There are many *Alcyonacea* species including *Anthelia Glaucuca, Cespitularia erecta* and *Xeniidea* sp, all present in high abundance. The bathymetry of the site comprises a steep shelving wall from 5-14m with a rich and biodiverse reef flat, falling away to a deep water channel filled with sandy rubble. Exposed to fast currents on the tidal ebb and flow, Chole Wall shows a high abundance of both commercial and reef fish species.

Utumbei Deep
Utumbei dive site is a continuation of Kinası Pass, leading into Milimani South (an area also known as Coral Gardens) and is the closest survey site to the mouth of Chole Bay. The bathymetry consists of a number of steep-sloped channels; with a maximum depth of 24 m. Utumbei is home to a high number of larger fish species, including Napoleon wrasse, rays and groupers. Although Utumbei straddles the border between the Core and Specified Use Zones, TZM is currently using it as a Core Zone survey site due to the inaccessibility of the Dindini and Jina Wall sites.

Dindini
Dindini lies 13.03 km from Utende (S7 55.007° E39 49.745° to S7 55.032° E39 49.674°) and is Mafia Island’s only true rocky wall habitat. Lying directly in front of surf pounded cliffs, Dindini comprises a sheer rock wall with many caverns, U-shaped tunnels and some deep caves. The reef crest is dominated by powder blue, purple and pink *Alcyonara*. The reef shelves gradually from the shore to 6 m and then drops down a near vertical wall down to 24 m before hitting the seabed and gradually sloping off to very deep water. The shelf is rocky with occasional blast scars (from dynamite fishing) leaving sand and rubble. Being outside of the bay, many large pelagic fish can be seen at this survey site as well as Napoleon wrasse and large groupers. The shelf of Dindini is extremely bountiful in triggerfish, particularly the redtooth triggerfish which has not been seen at any other sites this phase. The site is only accessible seasonally due to the exposed location and usually shows very good visibility. There is always a gentle northerly current and the top shelf can be highly dangerous in strong surf.

Nudibranch City
This is a dive site that can be reached from the shore and is around 12 m at its deepest point. It is easily navigated to; as it lies next to a water pipe that runs from the beach at Utende to Chole Island. This is a good site for night diving being accessible from the shore. There are many nudibranchs here, especially abundant in *Risbecia pulchella*. There are lots of puffer fish and moray eels found along the pipe. The reef has a sand bottom with patchy reef areas, some seagrass and algae. This site is within the General zone so
fishing activities are permitted here. We have had difficulty surveying this site due to strong currents found along the shoreline.

Table 2. Number of surveys at each site and their designations

<table>
<thead>
<tr>
<th>Designation</th>
<th>Deep</th>
<th>Shallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milimani North</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Milimani South</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Chole Reef</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Utumbe Deep</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Dindini</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Nudibranch City</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

3.2 Survey methodology

The methodology has been developed by Frontier and used to collect data at a number of locations, both across Tanzania and globally (English et al., 1987).

Baseline Survey Protocol (BSP) was conducted by a team of three to five individuals, each allocated a certain domain or possibly two depending on the numbers of volunteers available. Surveyors recorded information on: Territorial fish; Schooling fish; Invertebrates; Benthic Composition and Physical parameters. All surveys were undertaken using Self-Contained Underwater Breathing Apparatus (SCUBA). The protocol was conducted using a 100 m tape measure weighted with a 1 kg steel dive weight secured to the anterior end of the tape or with a piece of string attached to a rock on the site. Set as an 80 m transect, each transect consisted of three 20 m sections with a 10 m redundant section between them (0-20, 30-50 and 60-80 m). Surveyors swam slightly above the transect recording their allocated taxa within 5 m of the transect from the substrate to sea surface. Survey dives were aborted if the sea state became higher than a 3 on the Beaufort scale, for strong currents, or if any diver reached 70 bar. Transects remain at a relatively constant depth following the reef contour.

Communities were assumed to be distinct at different depths so surveys were classified as deep and shallow within sites, for all sites a contour was classified as being deep below 8 m.

Prior to the dive; the Physical surveyor recorded the date, survey site, number of fishing vessels on the reef, cloud cover (0-8), Beaufort sea state (0-8) and air temperature (°C). Upon descent, the Physical surveyor secured the end of the tape measure and reeled out 80 m of line onto the substrate, possibly securing it within coral or rocks to keep it in place in mild currents. The Physical surveyor would record the start and end time of the survey (when all other surveyors had finished recording), the maximum depth of the survey, the visibility (estimated in meters) and the water temperature at the bottom (°C).

The Schooling fish surveyor would “buddy” with the Physical surveyor but swim slightly in front to minimize disturbance to fish. The Schooling fish surveyor recorded all of the teleost species which generally occurred in groups and in the water column (see appendix for families and species).
After 5 minutes, the *Territorial*, *Invertebrate* and *Benthic* surveyors began surveying in that order. The *Territorial fish* surveyor recorded all species observed within the 25 m² box but swam in a generally straight line unless there was an overhang to check underneath. The *Invertebrate* surveyor swam 2.5 m either side of transect and thoroughly searched visually for all invertebrates and then recorded any they saw (See species list in Table 4). The *Benthic* surveyor looked at the benthos directly below the survey line and recorded the type (Table 3.) and distance on the line of any morphology change greater than 10 cm, this was recorded to within 1 cm on the tape measure. The TZM benthic methodology has been changed slightly for this phase to be brought in line with other Frontier project methodologies, so that sites may be comparable. The data is more in depth than previous phases, so it will still be possible to compare previous TZM data with the current data being collected. Due to the non-specialist nature of our surveyors we do not record hard coral species or genus but focus on morphology instead of taxonomy, this allows us to investigate the function of the reef as a habitat. The life stages of coral species have different morphological characteristics and some species display a range of morphologies. All hard coral were assumed to be hermatypic and all soft corals (determined by movement in the water) were ahermatypic. Both *Schooling* and *Territorial* fish surveyors noted numbers of fish seen and estimated which size category they were in (0 – 10 cm, 11 – 20 cm, 21 – 30 cm ... 61 – 70 cm and 70 cm +).

If volunteer numbers were low then the groups would be limited to *Schooling, Physical, Territorial* surveyors in that order on the outward leg of the transect and then *Invertebrate, Benthic and Physical* would survey on the return leg.

### 3.3 Statistical Analysis Method

Data was analysed by calculating the Shannon-Wiener diversity index of fish families and invertebrates as shown in the appendix. Statistics were carried out in R-Studio, where General Linear Model analysis was conducted between Hard Coral, Dead Coral, Fish Abundance, Fish Richness, Invertebrate Abundance and Invertebrate Richness, two at a time. Each variable was then compared between sites and zones using chi-squared tests.

### 3.4 Overall Results

Survey depths varied from 3.4 m to 14.4 m, hard coral cover ranged from 1% to 87% and dead coral and coral rubble ranged from 0% to 80%. Total number of fish seen on a survey (Fish abundance) ranged from 52 individuals to 936 individuals. Invertebrate abundance varied greatly between 19 individuals and 371 individuals.

Table 3. Summary statistics for GLM comparisons between the following variables, with significant interactions in bold text (Richness is the Shannon Wiener Species Diversity Index, H) Site and Zones were compared with other variables using Chi Squared. Sites which are significantly different are in parenthesis below statistic.

<table>
<thead>
<tr>
<th>d.f. = 35</th>
<th>Depth</th>
<th>Hard Coral Cover</th>
<th>Fish Abundance</th>
<th>Fish Richness</th>
<th>Site (d.f. = 5, $\chi^2$)</th>
<th>Zone (d.f. = 2, $\chi^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Coral Cover</td>
<td><em>P = 0.016, AIC = 2.08</em></td>
<td>P = 0.253</td>
<td>P = 0.253</td>
<td>P = 0.294</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead Coral</td>
<td>P = 0.980</td>
<td>P = 0.099</td>
<td>P = 0.099</td>
<td>P = 0.759</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Depth and hard coral cover show a significant linear relationship, but depth did not significantly affect any other variables (Table 3.). Hard coral cover significantly affected fish abundance but not invertebrate abundance and not richness of fish or invertebrates. Site significantly affected Fish Abundance, Fish Richness, Invertebrate Abundance and Invertebrate Richness but not percentage cover of hard coral or dead coral. Zone only significantly affected Invertebrate abundance.

3.5 Benthic Analysis

There was a large range of hard coral cover both within and between sites, with Milimani South, Deep site showing the highest mean coral cover at 64% and Nudi City showing the lowest coral cover at 1%.

![Fig. 2. Mean Hard Coral percentage cover per site and maximum depth of survey (m)](image)

As the maximum depth of the survey site increases, the percentage of Hard Coral cover also increases (Fig 2). Percentage cover of hard coral varied between sites, with Utumbe Deep having the most hard coral cover and the most varied percentage cover within the transects at each site (Table 3, Fig 3).
Fig 3. Boxplot showing the median, upper quartile and lower quartile values for proportion of hard coral cover within each site.

Fig 4 Mean hard coral cover per site (%) and mean fish abundance per site with a line of best fit.

There was a significant correlation between fish abundance and percentage cover of Hard Coral (Fig 4). Fishes in size category 1-10 cm were the most abundant at each site, accounting for more than 75% of all fish seen. The remaining 25% of fish were mostly within 11-20 and 21-30 size categories (Fig 5). Only at Dindini were fish in larger size categories frequently recorded.
3.6 Fish Analysis

There was a positive correlation between fish abundance and depth (Fig 6). This can be expected as Hard Coral cover also increased with depth. Fish Richness was not significantly correlated with depth when analysed with a General Linear Model, but was significantly different between sites when analysed with a chi-squared test (Table 3, Fig 7). Core and Specified Use zones have similar fish richness scores whilst General Use has higher fish richness, however this was not significant. Fish abundance was not significantly different between zones (Table 3) although the Core zone has the highest fish abundance (Fig. 8). This difference can be attributed to Utumbe Deep having significantly higher fish abundance than other sites (Fig 10).
Fig 7. Boxplot showing median, upper quartile, lower quartile, maximum and minimum values for Average Fish Richness within each zone; Core (C), General (G) and Specified (S).

Fig 8. Boxplot showing median, upper quartile, lower quartile, maximum and minimum values for Average Fish Abundance within each zone; Core (C), General (G) and Specified (S).

Fig 9. Boxplot showing median, upper quartile and lower quartile values for mean Fish Richness within each site.
Fig 10: Boxplot showing median, upper quartile and lower quartile values for mean Fish Abundance within each site.

3.7 Invertebrate Analysis

Invertebrate abundance was significantly different between zones, with the Core zone having a greater abundance than others (Table 3, Fig 11). Both Utumbe Deep and Dindini core zone sites had high invertebrate abundance (Fig 12). Invertebrate Richness differed at these two sites. Utumbe Deep had a similar Richness to other sites within the bay and Dindini had much lower richness (Fig 13). Dindini transects were dominated by sea urchins and these explain the high abundance and low richness found there.

Fig 11. Boxplot showing median, upper quartile, lower quartile, maximum and minimum values for mean Invertebrate Abundance within each zone; Core (C), General (G) and Specified (S)
3.8 Discussion

Underwater visual census techniques are ideal for surveying coral reefs as they are non-invasive and can be carried out with limited specialist equipment. However, they can introduce bias in several ways; errors in size and distance estimations, variation in visibility, fish moving between transects and species recording bias depending on fish distinctiveness (Harvey et al., 2004). Non-specialist surveyors can also introduce bias through error in identification and size estimates. However, with a strong training element and with limited species and groups being recorded this can lead to effective surveying (Darwall and Dulvy, 1996).
Hard coral cover increased as depth increased, this is the opposite of what was expected as hard coral is thought to be more abundant in areas where there is increased light, so it would be expected that percentage cover would be higher in shallow waters (Fig. 2). The deepest site is 14.3 m; this is still relatively shallow and therefore light must not be a limiting factor at this depth. It is possible that hard corals have been able to increase at deeper depths, as it is less likely to be affected by accidental boat damage at low tides and is less accessible to destructive fishing practices (Connell et al., 1997), however other studies show that shallower sites are quicker to recover from degradation, which is the opposite to what is found in this study.

Percentage cover of hard coral varied between sites, with Utumbe Deep having the most Hard Coral cover and also the most varied percentage cover within the transects at each site (Fig 3). As Utumbe Deep is a site within the Core Zone of the Marine Park, this result suggests that these areas have higher hard coral composition in comparison to other zones. However, Dindini is also in the Core Zone and had very little hard coral cover. This could be due to this site having a different topography to other sites, as it is situated outside of the bay and is characterised by a steep sloping wall. Nudibranch City was also found to have low hard coral cover but had a high composition of Sponge and Soft Coral. This could also be due to its topography and situation close to shore within Chole Bay.

There was a significant correlation between fish abundance and percentage cover of Hard Coral (Fig 4). This is to be expected as high coral cover provides a habitat for prey organisms and is even a food source itself to some fish (Bell and Galzin, 1984).

Only at Dindini were fish in larger size categories frequently recorded, this could be attributed to its location and topography outside Chole Bay and may also be due to its higher protection level within the Core Zone. Utumbe Deep, our other Core Zone and the Specified Use reefs had fish of similar size; this indicates that protection at both levels allows for larger fish. During surveys at Nudibranch City, a General Use Zone, there were no fish in the size categories above 11 – 20 cm; showing that general use zones had the smallest fish. Hence, marine protected areas with either complete or partial protection status can increase reef fish size; this is concurrent with data found in Mozambique and South Africa (Currie et al., 2012).

There is a positive correlation between fish abundance and depth (Fig 6). This is to be expected as Hard Coral cover also increased with depth. Fish Richness was not significantly correlated with depth, but was significantly different between sites (Fig 7). Core and Specified Use zones have similar fish richness scores while General Use has higher fish richness, however this was not significant. Fish abundance was not significantly different between zones (Table 3) although the Core zone has highest fish abundance.
This difference can be attributed to Utumbe Deep having significantly higher fish abundance than other sites (Fig 10). Artisanal fishing methods, such as pole-and-line fishing are used in the Specified Use Zone. These methods are well reported to have minimal impacts on the growth limit and number of fish in coral reef areas (Jennings et al., 1998), which explains why Specific and Core Zones show similar levels of fish abundance and diversity.

Sponges, brittle stars and urchins (non-diadema) were present in large numbers across the majority of survey sites, the presence of which would be expected in any healthy reef system. Low numbers of crab, shrimp and sea cucumbers were recorded, this may reflect the fact that survey work is carried out during daylight hours, when these species are less active and also the fact that these species are generally more prevalent in shallower waters (Richmond, 2002). Invertebrate abundance was significantly different between zones, with Core zone having a greater abundance than Specified and Core (Fig 11). Both Utumbe Deep and Dindini Core zone sites had high invertebrate abundance (Fig 12). This result suggests that protection within the core zone promotes a high number of invertebrates, whether the site is characterised by hard coral cover within the bay (Utumbe Deep) or low hard coral cover outside of the bay (Dindini). Interestingly, the Invertebrate Richness differed at these two sites. Utumbe Deep had a similar Richness to other sites within the bay and Dindini had much lower richness, (Fig 13) as transects were dominated by sea urchins and these explain the high abundance, low richness found there.

This study suggests that the existence of all levels of protection is biologically important, firstly for the protection and conservation of commercial fishing in the Mafia Archipelago (on which the majority of local communities are dependent) and also for the general promotion and preservation of biodiversity and biomass in the waters surrounding Mafia Island. Fishing abundance and richness was not significantly different between protection zones; this could be due to mobility and dispersion of fish but also possibly because fishing is still being carried out inside core zones. There is a lack of funding for patrolling and enforcement, which means it is not always at the level required to be effective. To ensure fishers are adhering to regulations, it is important that they understand the management plan in place and that they are aware of the zoning areas (Done et al., 1997).

4. Proposed work programme for next phase

The proposed work programme for TZM during Phase 142 includes:

- Continued collection of long term commercial fish data and coral reef health on reefs within MIMP, in Core, Specified Use and General Use Zones.
- Data collection in the mangroves to determine biodiversity of this habitat in Chole bay as well as
conducting socio-economic surveys.

- Continued collection of seagrass surveys to assess health and linkage of certain species of fish and invertebrates with this habitat
- Continued collection of Acanthaster planci sightings, depth and diameters and analysis of this data
5. References


https://mapsengine.google.com/map/edit?mid=zqCQsxDJODzI.ksrIK5fp9Ss


Kimirei, I. A., (2012): Importance of Mangroves and seagrass beds as nurseries for coral reef fishes in Tanzania, Nijmegen


6.0 Appendices

Appendix 1. Commercial fish lists used for surveys

Schooling fish list:

<table>
<thead>
<tr>
<th>Common name</th>
<th>Latin name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Snapper</strong></td>
<td><strong>Lutjanidae</strong></td>
</tr>
<tr>
<td>Black Snapper</td>
<td><em>Macolor niger</em></td>
</tr>
<tr>
<td>Bluelined Snapper</td>
<td><em>Lutjanus coeruleolineatus</em></td>
</tr>
<tr>
<td>Blackspot Snapper</td>
<td><em>Lutjanus ehrenbergi</em></td>
</tr>
<tr>
<td>Paddletail Snapper</td>
<td><em>Lutjanus gibbus</em></td>
</tr>
<tr>
<td>Flametail Snapper</td>
<td><em>Lutjanus fulvus</em></td>
</tr>
<tr>
<td>Twinspot Snapper</td>
<td><em>Lutjanus bohar</em></td>
</tr>
<tr>
<td><strong>Emperor</strong></td>
<td><strong>Lethrinidae</strong></td>
</tr>
<tr>
<td>Bigeye Emperor</td>
<td><em>Monotaxis grandoculis</em></td>
</tr>
<tr>
<td>Yellowspot Emperor</td>
<td><em>Gnathodentex aurolineatus</em></td>
</tr>
<tr>
<td>Blackspot Emperor</td>
<td><em>Lethrinus harak</em></td>
</tr>
<tr>
<td>Orangestripe Emperor</td>
<td><em>Lethrinus obsoletus</em></td>
</tr>
<tr>
<td>Spangled Emperor</td>
<td><em>Lethrinus nebulosus</em></td>
</tr>
<tr>
<td>Longface Emperor</td>
<td><em>Lethrinus olivaceus</em></td>
</tr>
<tr>
<td>Common name</td>
<td>Latin name</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td><strong>Goatfish</strong></td>
<td><strong>Mullidae</strong></td>
</tr>
<tr>
<td>Dash Dot Goatfish</td>
<td><em>Parupeneus barberinus</em></td>
</tr>
<tr>
<td>Sidespot Goatfish</td>
<td><em>Parupeneus pleurostigma</em></td>
</tr>
<tr>
<td>Longbarbel Goatfish</td>
<td><em>Parupeneus macronema</em></td>
</tr>
<tr>
<td>Yellowstripe Goatfish</td>
<td><em>Mulloidichthys flavolineatus</em></td>
</tr>
<tr>
<td>Yellowsaddle Goatfish</td>
<td><em>Parupeneus cyclostomus</em></td>
</tr>
<tr>
<td><strong>Barracuda</strong></td>
<td><strong>Sphyraenidae</strong></td>
</tr>
<tr>
<td>Great Barracuda</td>
<td><em>Sphyraena genie</em></td>
</tr>
<tr>
<td>Pickhandle Barracuda</td>
<td><em>Sphyraena jello</em></td>
</tr>
</tbody>
</table>

**Learn to family level**

<table>
<thead>
<tr>
<th>Common name</th>
<th>Latin name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeonfish</td>
<td><em>Acanthuridae</em></td>
</tr>
<tr>
<td>Unicornfish</td>
<td><em>Nasinae</em></td>
</tr>
<tr>
<td>Rabbitfish</td>
<td><em>Siganidae</em></td>
</tr>
<tr>
<td>Parrotfish</td>
<td><em>Scaridae</em></td>
</tr>
<tr>
<td>Wrasse</td>
<td><em>Labridae</em></td>
</tr>
<tr>
<td>Trevally</td>
<td><em>Carangidae</em></td>
</tr>
<tr>
<td>Fusilier</td>
<td><em>Caesionidae</em></td>
</tr>
</tbody>
</table>

**Territorial fish list:**

<table>
<thead>
<tr>
<th>Common name</th>
<th>Latin name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sweetlips</strong></td>
<td><strong>Haemulidae</strong></td>
</tr>
<tr>
<td>Slatey Sweetlips</td>
<td><em>Diagramma pictum</em></td>
</tr>
<tr>
<td>Black Sweetlips</td>
<td><em>Plectorhinchus sordidus</em></td>
</tr>
<tr>
<td>Blackspotted Sweetlips</td>
<td><em>Plectorhinchus gaterinus</em></td>
</tr>
<tr>
<td>Goldspotted Sweetlips</td>
<td><em>Plectorhinchus flavomaculatus</em></td>
</tr>
<tr>
<td>Oriental Sweetlips</td>
<td><em>Plectorhinchus orientalis</em></td>
</tr>
<tr>
<td><strong>Grouper</strong></td>
<td><strong>Serranidae</strong></td>
</tr>
<tr>
<td>Redmouth Grouper</td>
<td><em>Aethaloperca rogaa</em></td>
</tr>
<tr>
<td>Peacock Grouper</td>
<td><em>Cephalopholis argus</em></td>
</tr>
<tr>
<td>Coral Hind Grouper</td>
<td><em>Cephalopholis miniata</em></td>
</tr>
<tr>
<td>Darkfin Hind Grouper</td>
<td><em>Cephalopholis urodeta</em></td>
</tr>
<tr>
<td>Giant Grouper</td>
<td><em>Epinephelus lanceolatus</em></td>
</tr>
<tr>
<td>Fish Type</td>
<td>Scientific Name</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Potato Grouper</td>
<td><em>Epinephelus tukula</em></td>
</tr>
<tr>
<td>Whitespotted Grouper</td>
<td><em>Epinephelus caeruleopunctatus</em></td>
</tr>
<tr>
<td>Blacktip Grouper</td>
<td><em>Epinephelus fasciatus</em></td>
</tr>
<tr>
<td>Brown Marble Grouper</td>
<td><em>Epinephelus fuscoguttatus</em></td>
</tr>
<tr>
<td>Saddleback Grouper</td>
<td><em>Plectropomus laevis</em></td>
</tr>
<tr>
<td>Lyretail Grouper</td>
<td><em>Variola louti</em></td>
</tr>
<tr>
<td><strong>Triggerfish</strong></td>
<td><em>Balistidae</em></td>
</tr>
<tr>
<td>Redtooth Triggerfish</td>
<td><em>Odonus niger</em></td>
</tr>
<tr>
<td>Blue Triggerfish</td>
<td><em>Pseudobalistes fuscus</em></td>
</tr>
<tr>
<td>Yellowmargin Triggerfish</td>
<td><em>Pseudobalistes flavimarginatus</em></td>
</tr>
<tr>
<td>Halfmoon Triggerfish</td>
<td><em>Sufflamen chrysopterus</em></td>
</tr>
<tr>
<td>Scythe Triggerfish</td>
<td><em>Sufflamen albicaudatus</em></td>
</tr>
<tr>
<td>Clown Triggerfish</td>
<td><em>Balistoides conspicillum</em></td>
</tr>
<tr>
<td>Orangestriped Triggerfish</td>
<td><em>Balistapus undulates</em></td>
</tr>
<tr>
<td>Moustache Triggerfish</td>
<td><em>Balistoides viridescens</em></td>
</tr>
<tr>
<td>Picasso Triggerfish</td>
<td><em>Rhinecanthus rectangulus</em></td>
</tr>
<tr>
<td><strong>Spinecheek</strong></td>
<td><em>Nemipteridae</em></td>
</tr>
<tr>
<td>Arabian Spinecheek</td>
<td><em>Scolopsis lineatus</em></td>
</tr>
<tr>
<td><strong>Rays</strong></td>
<td><em>Dasyatidae</em></td>
</tr>
<tr>
<td>Giant Reef Ray</td>
<td><em>Taeniura melanospilos</em></td>
</tr>
<tr>
<td>Bluespotted Ribbontail Ray</td>
<td><em>Taeniura lymma</em></td>
</tr>
<tr>
<td>Bluespotted Stingray</td>
<td><em>Dasyatis kuhlii</em></td>
</tr>
<tr>
<td>Eagle Ray</td>
<td><em>Aetobatus narinari</em></td>
</tr>
<tr>
<td>Manta Ray</td>
<td><em>Manta birostris</em></td>
</tr>
<tr>
<td>Learn to family level</td>
<td></td>
</tr>
<tr>
<td>Butterflyfish</td>
<td><em>Chaetodontidae</em></td>
</tr>
<tr>
<td>Angelfish</td>
<td><em>Pomacanthidae</em></td>
</tr>
<tr>
<td>Damselfish</td>
<td><em>Pomacentridae</em></td>
</tr>
</tbody>
</table>
Table 1. Abiotic benthos recorded during BSP surveys

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt</td>
<td>Soft, dark sediment with high organic content, can easily be suspended in the water column and will settle after a short while.</td>
</tr>
<tr>
<td>Sand</td>
<td>Larger coarse stony sediment which sinks rapidly after suspension.</td>
</tr>
<tr>
<td>Rock</td>
<td>Clear geological feature with no visible corallites.</td>
</tr>
<tr>
<td>Rubble</td>
<td>Unconsolidated fragments of coral, shell or rock unattached to the substrate.</td>
</tr>
</tbody>
</table>
| Recently Killed Coral | (1) an unattached bleached coral fragment  
(2) solid coral skeleton fully bleached and algal growth started.                                      |

Table 2. Biotic benthos recorded during BSP surveys

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algae</td>
<td>Forms beds or turfs of macro-, micro- or coralline algae, includes any turf algal growth on non-growing tops of massive corals</td>
</tr>
<tr>
<td>Hard Coral</td>
<td>Scleractinians, hermatypic does not move when hydrological pressure applied</td>
</tr>
<tr>
<td>Soft Coral</td>
<td>Ahermatypic, soft corals which move when hydrological pressure applied in water column</td>
</tr>
<tr>
<td>Sponge</td>
<td>Soft and grow porous body structures to filter feed. Can be encrusting or free growing possibly moving with hydrologic pressure. Can be many shapes, sizes and colours</td>
</tr>
<tr>
<td>Anemones</td>
<td>An individual polyp, with brightly coloured tentacles protruding, often forms symbiotic relationships with anemone fish.</td>
</tr>
<tr>
<td>Seagrass</td>
<td>True flowering plants which have evolved to live in shallow sheltered water bodies, base of plants attached via rhizophora</td>
</tr>
</tbody>
</table>
Table 3. Hard coral morphological type and description

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branching</td>
<td>Hard corals which have extended protrusions of branches (e.g. <em>Acropora spp.</em> &amp; <em>Pocillopora spp.</em>)</td>
</tr>
<tr>
<td>Digitate</td>
<td>Small and stout digits which protrude, often forming a “finger”-like shape</td>
</tr>
<tr>
<td>Foliose</td>
<td>Leaf-like or forming leafy folds radiated upwards from a central point (e.g. <em>Turbinaria mesenterina</em>)</td>
</tr>
<tr>
<td>Tabular</td>
<td>Often with a digitate like form on top but attached to the substrate with a central stipend with a table-like top creating a flat platform</td>
</tr>
<tr>
<td>Laminar</td>
<td>Forming leaf-like plates at parallel which do not radiate from a central point (e.g. <em>Montipora sp.</em>)</td>
</tr>
<tr>
<td>Columnar</td>
<td>Large upward columns with rounded tops</td>
</tr>
<tr>
<td>Massive</td>
<td>Colony shape where height and width are similar, i.e. forming solid, rounded or boulder-shaped masses, not size-limited</td>
</tr>
<tr>
<td>Sub-Massive</td>
<td>Similar to massive corals, however these differ by having extra columns or wedges protruding from the base.</td>
</tr>
<tr>
<td>Solitary</td>
<td>Polyps solitary, free-living and among largest corals &gt;30cm. Corallites haractersied by radial septa around a central cavity (e.g. <em>Fungia spp.</em>)</td>
</tr>
<tr>
<td>Encrusting</td>
<td>Corallites in a flat plain with the substrate and the substrate below can be seen at the edges</td>
</tr>
</tbody>
</table>

Table 4. List of invertebrates surveyed, originally taken from the ReefCheck Indo-Pacific survey protocol, then adapted to better reflect the local invertebrate communities.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Common name</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porifera</td>
<td>Sponge</td>
<td>-</td>
</tr>
<tr>
<td>Cnidaria</td>
<td>Anemone</td>
<td>-</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>Crab</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Hermit crab</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Lobster</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mantis Shrimp</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Banded Cleaner Shrimp</td>
<td><em>Stenopus hispidus</em></td>
</tr>
<tr>
<td></td>
<td>Other Shrimp</td>
<td>-</td>
</tr>
<tr>
<td>Molluscs</td>
<td>Giant Clam</td>
<td><em>Tridacna gigas</em></td>
</tr>
<tr>
<td></td>
<td>Other Bivalve</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sea snail (gastropod)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sea slug (opistobranch)</td>
<td>-</td>
</tr>
<tr>
<td>Echinoderm</td>
<td>Sea Cucumber</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Brittlestar</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Featherstar</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Crown of Thorns</td>
<td><em>Acanthaster planci</em></td>
<td></td>
</tr>
<tr>
<td>Other Sea Star</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Urchin</td>
<td><em>(Diadema spp.)</em></td>
<td></td>
</tr>
<tr>
<td>Urchin</td>
<td><em>(Non-diadema spp.)</em></td>
<td></td>
</tr>
<tr>
<td>Polychaete</td>
<td>Segmental worm</td>
<td>-</td>
</tr>
<tr>
<td>Platyhelminthes</td>
<td>Flatworm</td>
<td>-</td>
</tr>
</tbody>
</table>