Frontier-Tanzania Marine Research Programme

Phase 131

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1. Introduction

1.1. Area and camp overview

The Frontier Tanzania Marine Research Program (TZM) is located on Mafia Island, off the coast of mainland Tanzania, East Africa (see Figure 1). Mafia Island is approximately 120km south of Dar es Salaam, 20km offshore of the Rufiji Delta and 850km south of the equator. Mafia is the central island of the Mafia Archipelago that consists of about 15 sandstone and coral rag islands, several of which are inhabited. Mafia is the largest island, measuring approximately 50km in length by 15km across at its widest point. There is an estimated population of 40,000 people living on the Mafia Archipelago, primarily in the south of the island.

Base camp lies inside Mafia Island Marine Park (MIMP) in the village of Utende (S07^{o}58.389 E39^{o}44.765). Just 300m from the camp is Chole Bay, a highly tidal and bathymetrically complex inlet, separated from the ocean by Kinasi Pass and Chole Pass, with an average depth of 20m. The tidal range in the bay is approximately 3m on springs and 1m on neaps, with a small intertidal area at mean low water.

Figure 1 - Map of study area

1.2. History and rationale of program

Frontier Tanzania was launched in 1989 and the first TZM project was located on 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 information, a management plan was formed and Tanzania's first multi-user marine park was gazetted in 1995. The MIMP is run jointly by the Marine Parks & Reserves Unit of Tanzania and the World Wide Fund for Nature (WWF).

After the marine park was gazetted, TZM moved south to the Songo Songo archipelago where mapping, surveying and fisheries work was carried out. TZM then moved along the coastline to Kilwa Kivenge. In September 1996, TZM moved to Mnazi Bay near to the Mozambique border. During this period, monitoring work on the coral bleaching event caused by El Niño took place to assess the recovery rate of the coral reef. In January 2001, TZM relocated north to Pemba, where biological surveys and socio-economic research were conducted with the aim of producing recommendations for a management plan for the marine resources around Misali Island. After the closure of TZM in Pemba in 2004, the programme re-opened in the new location of Mikindoni Bay in June 2005. From Mikindoni, TZM moved back to Utende on the east coast of Mafia Island in January 2006. Monitoring work was carried out in Chole Bay within the MIMP boundaries. In November 2007, the project moved to the mid-western coast of Mafia, outside of the marine park. In January 2010, Frontier TZM field camp was relocated back to Utende, within MIMP, where it will be based for the next 5 years (January 2010 to December 2015).

2. Aims

The aim of the 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:

- Collection of baseline biodiversity data on coral reefs within 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 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 MIMP
- Feasibility studies of potential aquaculture projects
- Development of a management plan and risk assessment report for MIMP, based on evaluation of datasets.

3. Methodology

3.1. Staff Training

3.1.1. Briefing sessions

Staff was briefed on issues relating to health and safety, medical issues, TZM project history, phase aims and objectives, safety and security on camp, and life on camp after deployment (during the first few days of each month) as listed in (Table 1).

Table 1 - Briefing sessions conducted during phase 131.

Briefings	Given By
Health & Safety	JP/AB
Medical brief	JP/AB
Introduction to TZM project	JP/AB
Camp life and duties	JP

3.1.2. Science lectures

Marine science lectures were conducted throughout phase 131 in order to aid RAs in identifying species required to complete surveys (Table 2). Additional lectures were well received and helped RAs develop a broader understanding of marine ecology and conservation.

Table 2. Science lectures conducted during phase 124

Science Lectures	Given By
Coral Reef Ecology and identification	AB/JT/SR/MM
Commercial Fish	AB/JT/SR/MM
Fish morphology and ecology	AB/JT/SR/MM
Surveying and Monitoring	AB/JT
Benthic	SR/MM
Invertebrates	SR/MM
Angelfish Identification	MM
Surgeonfish Identification	MM
Butterflyfish Identification	MM
Dangerous Animals	JT
Hazards of the Reef	JT/AB
Mangroves	AB/NH
Marine Protected Areas	AB
Fisheries of Mafia Island	AB

3.1.3. 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 131 saw a couple of additions to the fish list, although it remained largely the same as that of Phase 124. The current Commercial Fish Species List is designed to suit the needs of the MIMP long term monitoring program and focuses on commercial fish and families which are targeted by local fishing communities and can be indicators of reef health. Fish tests were completed by PowerPoint presentations and new staff and RAs were required to reach a 95% pass mark before surveying could commence. Where RAs initially failed to reach the pass mark, individual study periods were held and RAs re-tested until the required pass mark was reached. After passing written fish and coral 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 at the ocean floor by weights. RAs swam 1-2 meters above the fish and estimated their sizes. RAs practiced and were tested multiple times until they were able to accurately estimate the size of model fish to within 5cm. Benthic composition field training consisted of a PowerPoint lecture and tests as well as underwater training to ensure consistency between recorders

3.1.4. Tropical Habitat Management BTEC

Two 10 week studies were completed in Phase 131. Candidates planned and conducted research and completed the necessary handbook sections whilst on the project and were advised to complete the written report and submit it to LHQ upon their return to the UK. Internal verification of the assignments was conducted by AB. The project titles selected for these BTEC courses were:

- Community attitudes to bat populations on Mafia Island
- Crown of Thorns sea star distribution in Chole Bay

3.2. Research Work Program

3.2.1. Overview

Research began in February after dive training was complete and RAs had been trained to identify fish and invertebrate species and benthic categories to an acceptable level. RAs were also made to complete a number of practice surveys before data collection was able to commence. During this phase, surveys were only conducted once within the core zone outside the bay. TZM are reliant on MIMP boats and fuel in order to survey areas outside the bay, as the project's own boat isn't powerful enough to safely operate in the rougher conditions found outside the bay. MIMP was able to provide fuel enough for one survey session outside the bay, during which two transects were completed. This resulted in limited data collection taking place within the Core Zone, although a full series of surveys were conducted in the Specified Use Zone. The focus of the work programme in 131 was to attempt to continue the monitoring of key commercial species that had started in 113.

Other conservation work and ecological surveys completed during phase 131 included:

- Setting up a series of scientific lectures to give volunteers and MIMP employees a broader knowledge of the marine environment
- Continuation of work with Kitomondo Secondary School 'Environmental Ambassadors'
- Research into the setting up of a mangrove monitoring project
- Pilot surveys conducted within Utende mangrove stands.
- Beach clean-up of turtle nesting beaches on Juani Island

3.2.2. Survey Areas

Survey sites during phase 131 were located within the Specified Use Zone within Chole Bay and in the Core Zone, outside the mouth of the bay. The reef survey areas are described below.

Milimani dive site is located several hundred metres west of Kinasi pass and is surrounded by sand and sea grass. Milimani contains a shelf of coral that gradually gets deeper to around 20m depth, and contains high amounts of foliose, massive and branching coral. Fish abundance is very diverse, with fish species ranging from Napoleon Wrasse to juvenile Groupers, with large schools of Soldierfish frequently seen sheltering in the submassive coral. For Phase 131, Milimani was divided into two separate survey sites, Milimani North and Milimani South. Milimani North is an area of fringing reef facing inwards from the mouth of the bay and relatively sheltered. 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 Wall separates Utumbe from Kinasi Pass and lies 6.06km from Utende. Chole shows the highest biodiversity of all the sites within the bay, with high abundances of *Acropora formosia, Acropora validia* and *Montipora equitubercullatia*, Scleractinian corals, dominating the benthos. There are many *Alcyonacea* species including *Anthelia Glauca, Cespitularia erecta and Xeniidea* spp., 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 sandy rubble filled deep water channel. Exposed to fast currents on the tidal ebb and flow, Chole Wall shows a high abundance of both commercial and reef fish species.

Dindini lies 13.03km 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, Dinidini comprises a sheer rock wall, with many caverns and U-shaped tunnels, and some deep caves. The reef crest is dominated by spectacular powder blue, purple and pink *Alcyonara*. The reef shelves gradually form the shore to 6m, and then drops down a near vertical wall down to 24m before hitting the seabed, after which it gradually slopes 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. 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.

Jina Wall is situated only several metres south of Dinidini, directly after the Jina Island pass. The wall continues on from Dinidini, and conditions are very similar at the two sites, with a drop off from a coral ledge at around 6m that extends to around 25m depth. Large pelagic fish are found swimming along the wall, and potato grouper, trevally and snappers are found in abundance. Both hard coral and soft corals are found in high abundance, including high levels of digitate coral at the site.

4. Benthic Composition Surveys

Coral reefs are rapidly changing environments and as a result it is imperative that we record the general health of coral reef systems in order to monitor the extent and severity of decline and determine the greatest causes of risk to reef health. The complexity of the system is demonstrated by the many ecological, structural and functional factors that come into play when analysing coral reef condition: coral cover, macro-algal abundance, colony size, species composition, predator/grazer interaction, mortality and recruitment (Done, 1997; Kramer, 2003; Mrowicki and Fanning, 2008). Coral reefs are one of the most diverse ecosystems on earth, and Mafia Island is a relatively unknown secret. Frontier TZM aims to monitor any changes to the reef over time, so as to be able to understand the processes at work on the reef and provide management information for MIMP. Many different interactions and threats must be considered, including bleaching, fishing, pollution, waste disposal and coastal development.

The composition of the substratum is commonly assessed through benthic surveys. To classify benthos, visual census is one of the most common quantitative and qualitative sampling methods and is particularly well suited for the Frontier-Tanzania Marine Research programme as it is rapid, inexpensive and utilises non-skilled personnel and non-specialist equipment (Hill and Wilkinson 2004).

Benthic composition surveys have been carried out since phases 113 and were coupled with commercial fish surveys of abundance and size to allow for comparison between the benthic habitat and fish populations at each site. Their primary purpose was to identify the substratum of a total of four reefs (two inside the Specified Use Zone and two inside the Core/No Take Zone of the Marine Park) and evaluate the results, with reference to any significant trends that can be observed.

4.1. Methods used

The methodology for the collection of benthic habitat data has been developed by Frontier and used to collect data at a number of locations, both across Tanzania and globally (English et al., 1987). The benthic methodology has been changed within the past year to suit the long term monitoring proposal submitted by Frontier and MIMP. In previous surveys, 25m transects were laid down and substrates were sampled at 50cm intervals. However the TZM team decided it would be more appropriate to use a 50m transect, measuring substrates at 1m intervals, as it would facilitate the 50m UVC transects more. Nevertheless, the methodology has thus far gathered more than 12 months of comparable continuous data on the reef systems of Mafia Island.

Benthic composition data was collected in conjunction with commercial fish surveys. Surveyors recorded the benthic substrate type every 1m starting at 0m along a 50m transect set at a constant depth following the reef contour. This resulted in the collection of data at 50 points along each transect. At each site, 12 transects were completed; 6 on the back reef at shallower depths and 6 on the outer reef slope at deeper depth. In order to reduce inaccuracies in data recorded by volunteer RAs, identification of coral species is no longer required, and the identification process has been simplified to reduce error. Transects require division of coral species into categories based on morphological characteristics, with coral morphological diversity acting as a substitute for species diversity. However, morphology is not a perfect substitute for diversity as the life stages of coral species have different morphological characteristics, and some species display a range of morphologies. However, it is more accurate than attempting to identify corals to species level (which is often impossible without a microscope). TZM now simply record benthic data in the following categories (listed in Table 3): abiotic forms include rock, rubble, and sand; biotic forms include sea grass, soft coral and hard coral described by structure. Surveyors were trained in the identification of benthic organisms and substrates through a combination of lectures, field guides, photographs, and in-water training. A computer based photo test and an in-water point test were carried out in which the pass mark was set at 95%. Practice surveys were carried out until staff was satisfied that the surveyors' practical skills were consistent with their theoretical knowledge.

Table 3. Benthic composition categories displaying the codes during data collection

Category	Code	Category	Code	Category	Code
BIOTIC		**ABIOTIC**		**CORAL MORPHOLOGY**	
Hard Coral	HC	Sand	SA	Branching	BR
Soft coral	SC	Rubble	RB	Digitate	DG
Sponge	SP	Rock	RK	Laminar	LA
Sea grass	SG	Silt	ST	Tabulate	TA
Algae	AL	Dead coral	DC	Foliose	FO
Bleached Coral	BC	Other	OT	Solitary	SO
				Massive	MA
				Submassive	SM
				Columnar	CO

4.2. Results and Discussion

The composition of hard and soft coral was found to be similar across all four survey sites, with Milimani and Chole Wall exhibiting greater amounts of hard coral cover (Figure 2), specifically branching corals at Chole Wall and a high coverage of foliose and submassive corals at Milimani. Jina Wall showed a lower mean coverage of hard coral, with over 50% of the hard coral cover made up of encrusting coral species, which is typical of seaward reefs (Figure 3). The highest average soft coral cover was also found at Jina Wall, reflecting the greater depth and exposure to current and wave action experienced by the site.

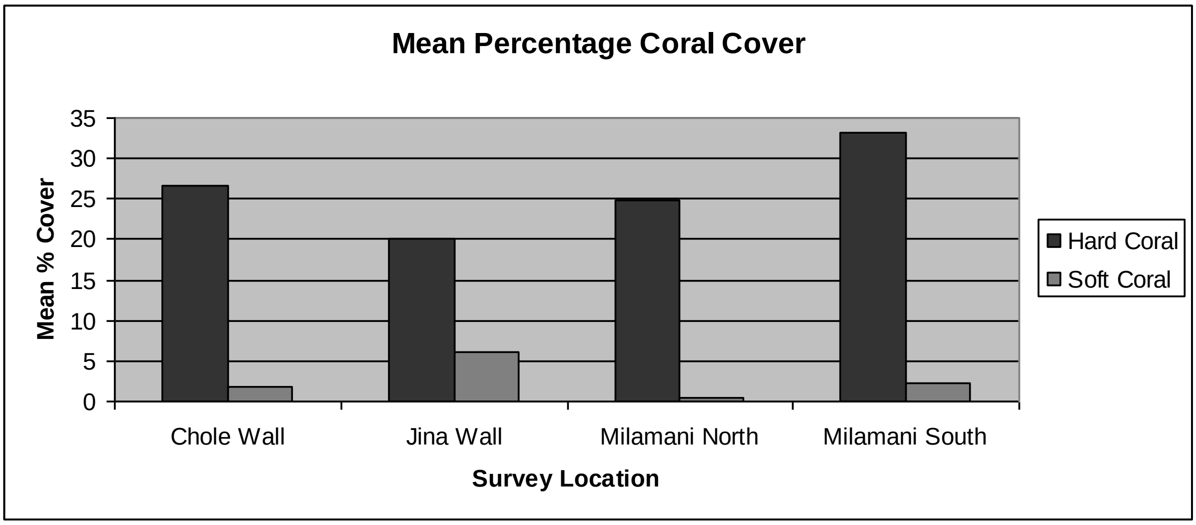

Figure 2 - Comparison of the substrate by hard coral and soft coral across survey sites

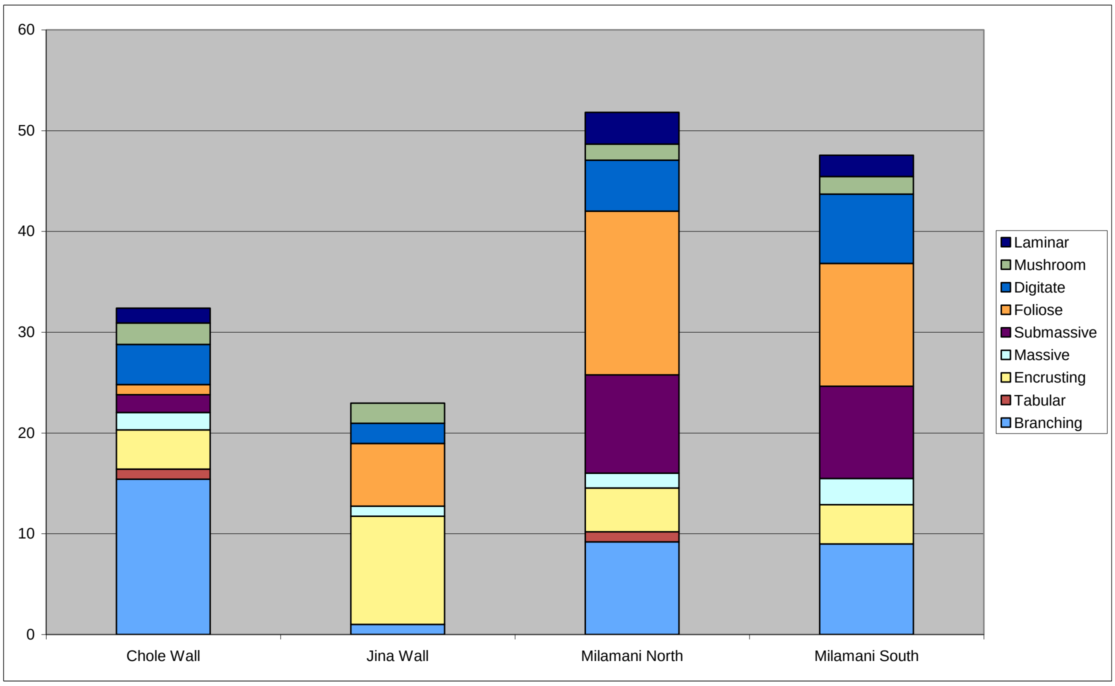

Figure 3 - Diversity of hard coral morphologies across survey sites

The currents inside the bay are generally calmer than outside the bay. This limits the growth of soft corals, which are more adapted to cope with stronger currents, and encourages the growth of some hard corals, particularly branching, whose large surface areas make them more susceptible to damage in strong currents. The results show large disparities between branching corals and soft corals at Milimani for this reason.

It should be therefore noted that the status of coral reef systems is regularly measured using a limited number of factors (size and abundance of important taxonomic groups etc). However, coral cover is not a reliable measure of resilience, since, a recovering healthy reef may have substantially less coral than one that is struggling and dominated by macroalgae. Coral cover is not an indicator of reef resilience and it can only become a definitive indicator of phase shifts, the latter referring to a reef that is unable to remain in or return to a coral-dominated state if the same site is monitored for many years (Alvarado et al., 2004; Hughes et al., 2010).

4.3. Recommendations

The current methodology for measuring the benthic profiles present across Chole Bay has proven effective, with volunteers easily able to learn how to carry out surveys and accurately categorize the type of benthos present. Benthic surveying will continue throughout Phase 132 so as to continue to add to the existing dataset and monitor and sudden changes in benthic makeup (e.g. large increases in dead coral as a result of bleaching, predation or disease).

5. Invertebrate Survey

5.1. Introduction

Phase 131 saw work from Phases 121, 122 and 123 continue, with the aim of monitoring invertebrates populations through the addition of an invertebrate survey to every underwater survey conducted. Invertebrate species provide a number of important indicator species for overall reef health. As a result of this, invertebrate surveys form a crucial part of TZM's baseline survey monitoring program. Collecting invertebrate data helps achieve the program's goals of allowing for the monitoring of changes across the survey sites, and also implements education and outreach in the form of volunteer training. It is important to utilise a survey method that will allow volunteer Research Assistants to collect data quickly and accurately with only a small amount of training. For our purposes, a low resolution survey methodology such as the one utilized by ReefCheck (an international coral reef monitoring organization) or an adaptation of the Underwater Visual Census methodology outlined by English and his colleagues (1997) would both fulfil these requirements. In cases where a more detailed interaction or a specific issue is being investigated rather than general monitoring and management based research, a more targeted survey approach could be used. For example, at the request of MIMP staff, all opportunistic sightings of the seastar *Acanthaster planci* (Crown of Thorns starfish) are currently being recorded (including location of sighting, depth and diameter of individual). In order to ensure that volunteers are adequately trained to collect consistent data, a survey of 20 invertebrate species and families has been constructed and added to our commercial fish and benthic baseline survey methodology. Our goal for this phase was to gather more data through surveys in order to assess the species composition and abundance of indicator species present at our survey sites, as well as the feasibility of adding further invertebrates to Frontier’s baseline survey protocol.

5.2. Methods used

The methodology for collecting invertebrate data is similar to that of the commercial fish census, where a team of survey divers swims along the transect line, recording the number of 19 pre-selected invertebrate individuals encountered within a 5m wide belt (2.5m either side of the transect line), ensuring that the entire area is thoroughly searched. These 19 indicator species were originally taken from the ReefCheck Indo-Pacific survey protocol, however the list was adapted slightly after analysis of Phase 124's data in order to better reflect the local invertebrate communities.

5.3. Results

Table 4. List of invertebrate species surveyed in Phase 131.

Invertebrate
Sponge
Brittlestar
Featherstar
Crown of Thorns
Other Sea Star
Nudibranch
Flatworm
Segmented Worm
Urchin (Diadema)
Urchin (Non-diadema)
Crab
Mantis Shrimp
Banded Coral Shrimp
Other Shrimp
Giant Clam
Other Bivalve
Sea Cucumber
Mollusc
Anemone

Thirty eight invertebrate surveys were conducted across the four survey sites this phase. We found that the surveys work well when there are three divers available to take part, and with more RAs this phase it has been easier to incorporate invertebrate surveys without drawing focus away from the commercial fish surveys.

The list of invertebrates to survey this phase (see Table 4) has been updated and seems much more appropriate than the one last phase, having added Molluscs, Brittle Stars and Sea Stars as separate categories.

Individuals of all indicator species were found at survey sites across Chole Bay, with the exception of Crown of Thorns sea stars. Although 15 Crown of Thorns sightings were recorded during opportunistic observations prior to beginning survey work, no individuals were recorded on surveys. The apparent absence of Crown of Thorns may be the result of a recent cull of the sea stars by MIMP staff in response to outbreaks of this species in the waters around Pemba, to the North of Mafia. The MIMP Crown of Thorns cull has apparently been successful in reducing populations of this voracious coral predator within Chole Bay, and further monitoring of the populations is required in order to assess how rapidly Crown of Thorns populations can recover.

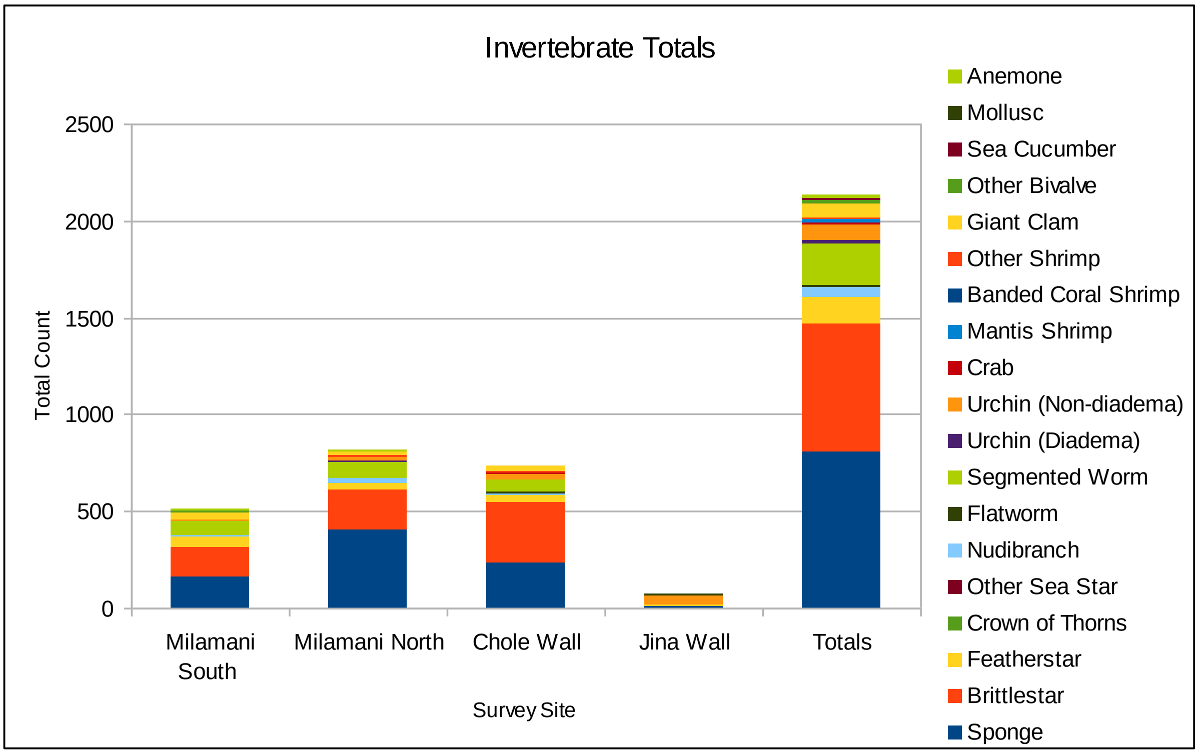

Figure 4 - Invertebrate counts across survey sites.

Sponges, brittle stars and segmented worms were also present in large numbers across the majority of survey sites, the presence of which would be expected in any healthy reef system (Figure 4). Whilst 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)

5.4. Discussion and Recommendations

The invertebrate data collection begun in Phase 131 builds on previous work carried out through 2011 and 2012. However there is currently no data available for past comparison, making temporal analysis difficult. By continuing with the newly established invertebrate species list and making invertebrate surveys a key part of the Baseline Survey Protocol conducted by TZM within Chole Bay, TZM aims to monitor large scale outbreaks or population decreases experienced by invertebrate species, as well as the impact of extractive practices on crab, shrimp, sea cucumber, bivalve and mollusc species.

It is important that volunteers are properly trained in accurate invertebrate search techniques, as it can be difficult to locate or even recognize many invertebrate species. Correct training will ensure consistency within invertebrate data collection and will remain a major part of RA training in Phase 132. RAs will also be required to pass an invertebrate test to a pass mark of 95%, as well as take part in invertebrate point dives before they are allowed to complete invertebrate surveys.

6. Commercial Fish Surveys

6.1. Introduction

Marine protected areas (MPAs) are a relatively new movement in conservation, that range from strict no take zones to communally managed multi-use parks. Multi-user marine parks aim to conserve resources and biodiversity and also improve local fisheries and livelihoods. Successful MPAs have increased abundance and biomass of targeted species, increased fish recruitment and migration of adults into neighbouring areas (Evans *et al.*, 2008; Lester, 2009; Jupiter and Egli, 2010). At the 2003 World Parks Conference in Durban, 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).

MIMP was established in 1995 as Tanzania's first multi-user zone marine park. With 14 villages and over 18,000 people living within the new park boundaries, it was clear from the onset that the community would need to be involved and benefit from the park for conservation of marine resources to be successful (Mafia Island Marine Park General Management Plan, 2000). 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 are 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.

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 marine resources. MIMP and Frontier have developed a proposal to monitor fisheries in the different zones of the marine park. The aim of conducting commercial fish surveys is to assess the abundance, species richness and size of commercial fish within Chole Bay. This phase has seen monitoring sites largely within the Specified Use zones of the park which will hopefully enable us to analyse the influence of protection on the size and abundance of commercially important fish within the park.

6.2. Methods used

RAs were trained through a series of lectures and fish points to identify a total of 58 commercial fish species or families (Appendix 1). The species list of commercial fish species was compiled from species commonly targeted and caught by fishermen in the local area. RAs were required to sit tests in identification until a 95% mark was reached in order to ensure consistency with regards to the quality of data being collected and standard surveyor identification.

48 surveys were intended to be conducted in total at the four study sites, with transects divided into two depth contours: shallower depths at the top of the reefs, and the outer reef slope at deeper depths. All surveys this phase were completed in the Specified Use zone (a total of 12 transects at each site, with six conducted at shallow depth and another six at deep). Although it would have been beneficial to carry out a complete set of surveys at Jina Wall, Mikidini and Dinidini in the Core Zone, this was not feasible due to TZM's own boat not being powerful enough to operate safely outside the bay and a lack of funding for fuel that would allow TZM to survey outside the bay using boats provided by MIMP.

SCUBA buddy teams descended at each site and began the survey on either the outer reef slope or top reef; all transects were separated by a minimum of 1 minute swim. Fish were either surveyed along a 50 meter transect using Underwater Visual Census (UVC) at 2.5 meters on all sides of the transect line, or using point counts where the observer would remain at a fixed point and record all fish within a 10 m 'sphere' around them. Fish were identified to family or species level (Appendix 1) and placed into 10 cm size categories. For the UVC method, one surveyor rolled out the transect line, maintaining constant speed and depth, whilst following the reef contour while the other recorded fish abundance and size categories on a pre drawn dive slate. Point count methods based on Watson and Quinn (1997) were also used at both sites to estimate fish abundance of the same commercial fish species. This involved the observer descending to mid-water column and spending 10 minutes at a fixed point on either the shallow back reef, or deeper outer reef, whilst recording fish abundance and size categories within a 10 m 'sphere' around the diver. Point counts were used to more efficiently record larger, more pelagic schooling fish that might not necessarily be recorded by the UVC transect method.

6.3. Results

This phase saw a continuation of our efforts to compare fish size and abundance, focusing on the specified use zone and the core zone of the marine park, with the main aim of analysis on the most important commercial fish amongst those we surveyed. These fish families include Emperors, Groupers, Parrotfish, Rabbitfish, Snappers, Sweetlips, Trevallys and Unicornfish, thought to be the most frequently caught by artisanal fishing techniques, based on observations of the team, and discussion with the MIMP research team. All fish featured in our commercial fish list (Appendices

Appendix 1) were recorded during the surveys or observed during fish point and reconnaissance dives.

Within MIMP there are three protection levels: Core, Specified Use, and General. The protection zones differ in the type of equipment allowed for fishing, with no fishing allowed in the Core Zone. In the Specified Use zone, fishing is primarily restricted to hand lines, with nets, traps and spear guns. We were able to survey mainly within the Specified Use zone this phase, and due to logistical constraints we were only able to conduct two transects in the Core Zone outside of the bay. However our findings will still be useful to indicate the differences in size and abundance of fish between Core and Specified Use protection zones and will provide data for long term monitoring of fish populations within the Mafia Island Marine Park and therefore the success of MIMP's management. The results highlight the importance of continuing surveys in more than one protection zone during the seasons where it is possible to collect this data to gain a cumulative data set indicating changes over time. Our findings may be useful to assess whether the different zones of the park were being protected efficiently, as little difference between the dataset might indicate that the differences in protection made no difference to the abundance and size of the commercial fish species that we studied.

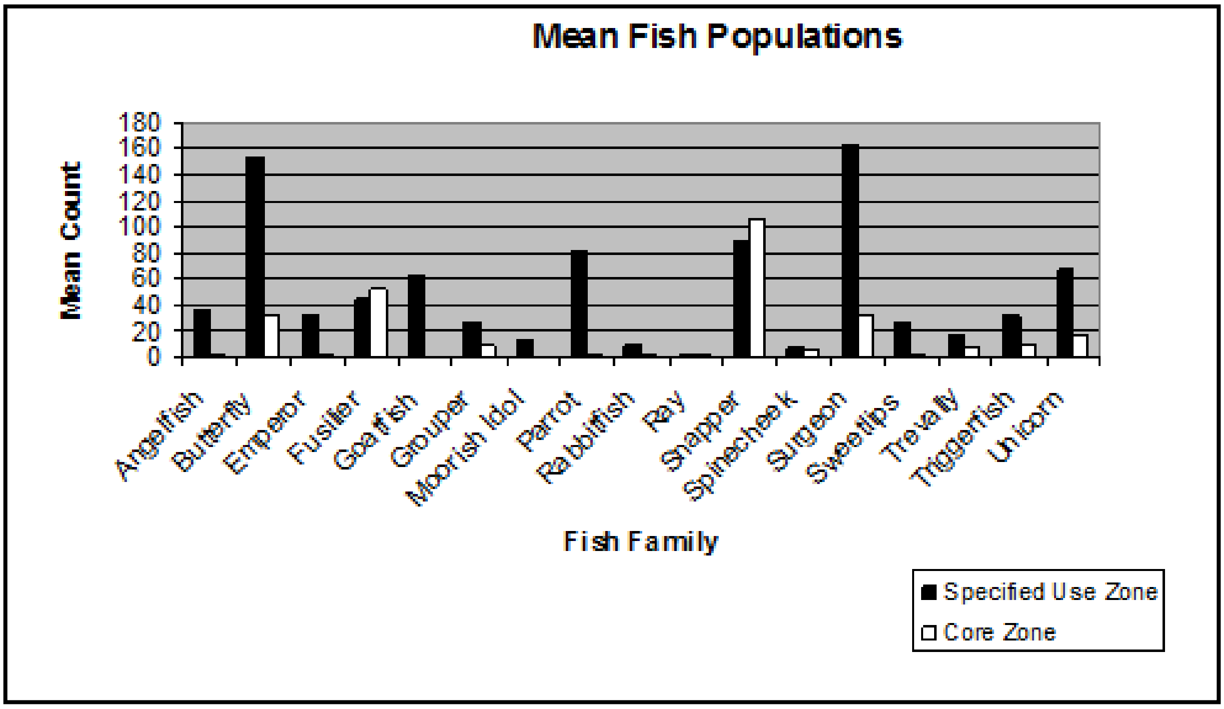

Figure 5 - Average Commercial fish abundance per survey for commonly fished families during Phase 131 for the Core and Specified Use protection zones in Mafia Island Marine Park.

Reef fish such as Angelfish, Butterflyfish and Surgeons show a greater prevalence within the bay (with average counts of 35, 153 and 163 individuals respectively), whilst schooling pelagic fish, such as Snapper and Fusilier are present in larger populations (52 and 107 individuals) in the Core Zone outside the bay (Figure 5). Trevally populations are highest within the Specified Use Zone inside the bay at the Milimani sites, (31 at Milimani North and 55 at Milimani South). Trevally are the focus of a high level of fishing activity, and their relatively large populations inside the Specified Use Zone suggests that restriction on fishing gear is an effective method for reducing the impact of extraction pressure on these fish. Snapper and Parrotfish populations remain healthy across all survey sites, which is a positive indicator for the effectiveness of MIMP's management and enforcement program as these species are targeted by local fishers (Figure 5). Triggerfish populations also remain consistent with data collected in previous phases, which is also positive as they play an important role in the control of invertebrate species such the Crown of Thorns starfish through predation (Figure 6). Further Core Zone survey sites will need to be identified and a larger number of Core Zone surveys must be carried out in Phase 132 before any significant conclusions can be drawn as to the difference (if any) in populations between Core and Specified Use.

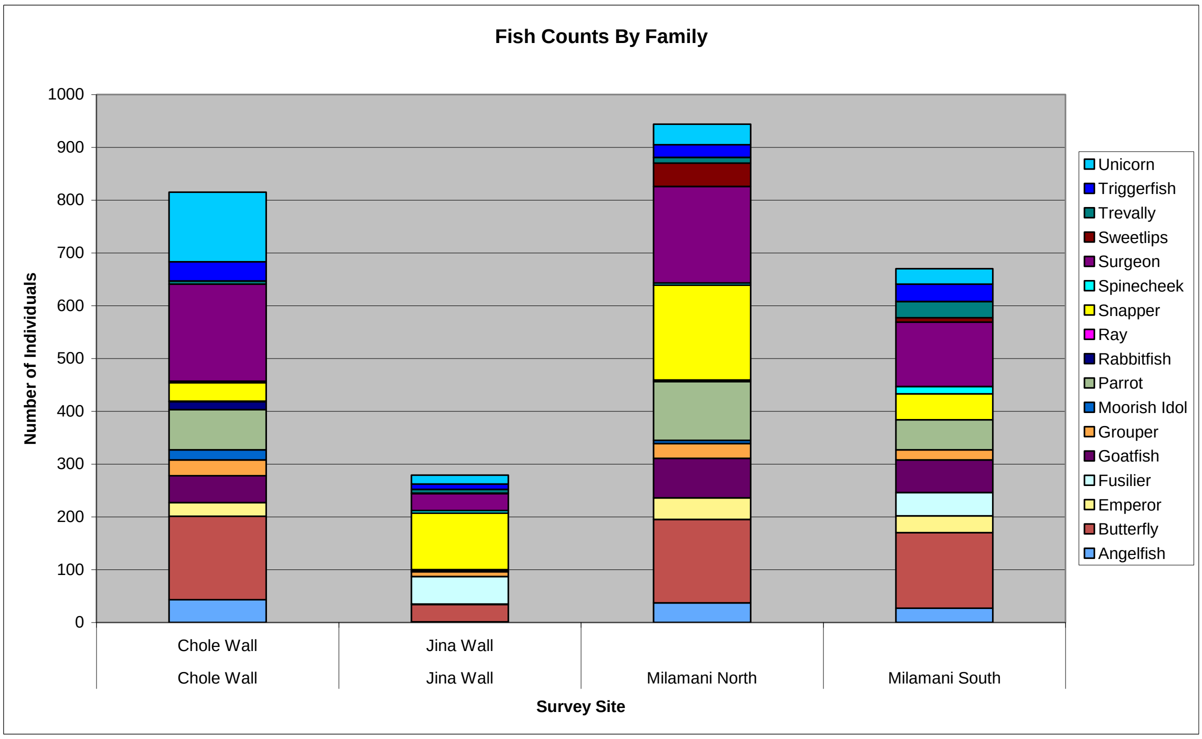

Figure 6 - Total fish counts by family across the four sites surveyed in Phase 131.

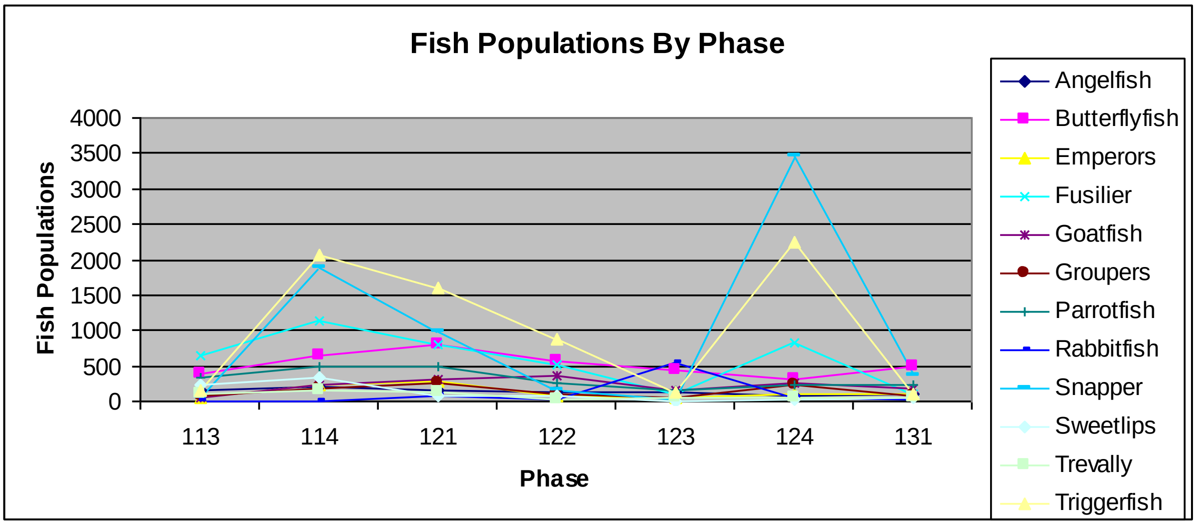

Figure 7 - Total fish counts by family since Phase 113.

6.4. Discussion and Recommendations

The aim for the data collected over the past year on commercial fish numbers and size since the arrival of Frontier within MIMP was to compare characteristics of fish in different management zones of the park, in order to review the efficiency of the Marine Park policies, and to be able to monitor fish community composition, as well as benthic coverage and invertebrate numbers. Without continuous data at the same sites in the core and specified use zones over more than one phase is it difficult to create a data set to analyse the differences between protection zones. Logistical issues and a lack of resources meant that only two surveys were carried out in the Core Zone, although new sites which are accessible to TZM have been identified for future Core Zone survey work. Areas outside the bay will remain inaccessible until September due to changing weather conditions, and it is therefore vital for Core Zone survey sites inside Chole Bay to be identified and surveyed if any comparisons between Core and Specified Use Zones are to be made. However, the data from this phase can be used to build upon in future surveys with the aim of creating a longstanding data set to produce more reliable scientific results.

Fish assemblages are known to be affected significantly by various invasive fishing techniques, such as dynamite fishing, purse-seine netting and other trawling methods (Currie *et al*., 2012). 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 of the growth limit and number of fish in coral reef areas (Jennings et al., 1998).

Fish size distribution has remained consistent with previous phases, will Groupers, Trevally, Snappers, Emperors and Parrotfish all showing a similar distribution in size of individuals recorded. All recorded species show a good number of individuals reaching reproductive sizes, suggesting that marine park management strategies are functioning and restrictions on fishing gear are effective.

Data collected throughout 2012 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.

As TZM's survey work within MIMP continues and the data collection grows, the scientific conclusions drawn from this research will become more scientifically reliable. It is important that throughout the year, all efforts are made in completing the full number of required surveys for each quarter, something that is made difficult by a lack of money for fuel and heavily disrupted by the recent switch to rolling volunteer deployments. The completion of a full data set next phase and the identification of new survey sites will enhance the information provided to the Mafia Island Marine Park on when assessing management strategies for the future.

Whilst the data set might not be as complete as we would have liked this phase due to changes in our dive sites and difficulties in accessing our sites, we believe that the current methodology and site selection are now suitable for long term monitoring of fish, benthic and invertebrate assemblages in the bay. The selected sites of Milimani and Chole Wall within the Specified Use zone are sites which can be easily accessed for monitoring, and also both represent the typical characteristics of sites within this zone. In the Core zone, Jina Wall is fully representative of the characteristics of sites within this zone. However, the prohibitive cost of reaching the site and the inaccessibility throughout a large part of the year as a result of poor weather conditions mean that it is essential that TZM identifies new survey sites within the Core Zone, whilst continuing to survey Jina Wall whenever possible. Continual monitoring of these sites using the same methodology should guarantee the opportunity to compare benthic compositions, fish communities and invertebrate numbers between the two zones. The exploration of the General Use Zone for possible survey sites is also required, with the location of two new potential sites identified in phase 124. Obtaining this information on a quarterly basis will also allow for analysis of temporal changes in the sites of monthly and yearly cycles. This information could be used to monitor the impact of fishing practices on the reefs within the marine park, and also to suggest changes in management strategy to the Marine Park personnel.

7. Additional Work

7.1. Whale Shark Project

In Phase 113, Frontier TZM started work in collaboration with the tourist group Whale Shark Safaris, in order to devise a monitoring program to collect data on whale sharks on Mafia Island. Whale Shark Safaris take tourists staying on the island to go and see whale sharks when they are present on the island, and our aims were to train their staff in order to collect data whilst on their excursions with tourists. Workshops and training sessions were held with the group in order to help the group collect data on the size, sex and characteristics of the whale sharks, and a data sheet was composed to be able to collect data effectively.

During Phase 124 TZM was unable to collect data for this project without the assistance of a tourist operator. However, we have held meetings with WWF researchers and all the whale shark excursion operators on Mafia Island in order to put a more concrete project in place recording whale shark behaviour with tourist interactions in the future.

Phase 131 saw several TZM staff assist with research conducted by WWF into the impact of whale shark safaris on animal behaviour, although TZM itself lacks the resources to conduct this research effectively by itself. It is hoped that cooperation between WWF and TZM will be able to continue once the whale shark season recommences towards the end of 2013.

7.2. Kitomondo Secondary School Project

TZM has continued the Kitomondo secondary school work started by Owen Jones. A group of around six Form 1 students visit the Frontier camp on a fortnightly basis, and spend 2 hour sessions on various environmental topics. Sessions involve lectures, discussions, practical lessons and potentially snorkelling and other excursions to help the students observe the impacts that their communities were having on the natural environment. Past phases have seen TZM conducting beach cleaning excercises with the Kitomondo school students, and it is hoped that this practical approach will continue in the future, so as to increase their conservation knowledge with the potential for setting up environmental days for the students to share their knowledge with the community. A long term goal for the project is to develop closer relations with the students' communities, and also to plan and carry out awareness raising and other events within those villages. The project has been successful so far, and the students attend sessions on a fortnightly basis, and have covered several environmental issues, including marine protected areas, biodiversity hotspots and global warming.

7.3. Cleaning of turtle nesting beaches, Juani

During phase 131, TZM conducted a beach clean at a turtle nesting beach on Juani Island. The beach clean was arranged through collaboration with Sea Sense, a Tanzanian NGO. Frontier were met on Junai Island by a Sea Sense representative and guided to the beach most in need of attention. The nesting beaches on Juani are managed by Sea Sense, an NGO which specialises in the conservation of marine species. Sea Sense monitor the beaches daily for turtle tracks to locate turtle eggs that are laid below the high tide mark, nests are then moved to a more suitable location to ensure that the survival rate for eggs is as high as possible. Unfortunately, Sea Sense lacks the resources or man power to maintain the beaches.

The currents surrounding the Island of Juani contribute to a lot of litter, both local and from further a field, to be deposited on the beaches. The litter is mainly composed of flip flops, plastic bottles and discarded or lost fishing gear. The nature of the rubbish means that it is non biodegradable and so has accumulated in large quantities. The quality of the beach environment is vital to the survival rate of hatchlings and in turn the continued use of the area as a nesting site. If female turtles approaching the beach to lay their eggs encounter large volumes of litter they may lay their eggs in a sub-optimum position, i.e. below the high tide mark. If the eggs are laid below the high tide mark, they may not remain at the correct temperature and may perish and rot if they become damp. It is thus essential that nests remain at the correct temperature in order not to bias the sex ratio.

The cleaning of beaches on Juani Island, will hopefully mean that turtles will be able to access the appropriate laying areas, and that hatchlings will have the best chance of survival. The beach cleaning event was a huge success with RAs completely clearing the beach of rubbish. Rubbish collected was then burnt on site in controlled fires in areas above the high tide mark. Having cleared the beach site, RAs were invited to attend a green turtle hatching at a later date. Volunteers were able to watch as hatchlings successfully made their first steps into the waters around Mafia unhindered by the litter on the beach. The volume of litter collected during the beach clean this phase suggests that regular beach cleans are necessary to ensure that the beaches remain as clear of debris as possible.

7.4. Mangrove Project

Phase 131 saw work continue on TZM's project to asses mangrove stand composition and health along the coast of Utende, based on work started by NH in Phase 124. It is hoped that this monitoring scheme will benefit both the marine and beach conservation volunteers, as well as providing a good back up project in case there are any problems with the boat or dive equipment. NH and AB led nature walks through the mangroves, identifying tree, invertebrate species. Snorkelling transects have also been piloted in order to begin identification of marine animals such as commercial fish and crustaceans. A number of terrestrial mangrove surveys were also completed, although further work is needed in order to fully asses that stands around TZM's camp. Socio-economic surveys have been planned in order to determine the usage of the mangroves by the local community. The long term aim of this project is to begin data collection of tree density, forest composition, and specie biodiversity in the mangroves.

12 mangrove surveys were conducted in Phase 131, with four species identified; *Avicennia marina, Sonneratia alba, Rhizophora murcronata* and *Bruguiera gymnorrhiza.* Survey methodology consists of a transect line stretching from the seaward low tide point through the mangrove stand to the hide tide point on the beach. Every 5m along the transect, the species of the nearest individual mangrove plant is recorded, as well as its height, girth at breast height (GBH) and the species of it's nearest neighbour (within 5m). Both the selected tree and its neighbour are also classified as tree, sapling or seedling depending on their size and growth phase. This allows the survey team to observe the natural zonation and recruitment potential of each stand being monitored, which is important for the mangrove populations around Utende as they have been under heavy pressure from local hotels and lodges which remove them to provide clear beaches, as well as from local populations harvesting mangrove trees for construction purposes.

8. Proposed work programme for next phase

The proposed work programme for TZM during Phase 132 includes:

- Continued collection of long term commercial fish data on reefs within MIMP, in Core, Specified Use and General Use Zones.
- Identify Core Zone survey sites within Chole Bay, in order to facilitate data collection in the Core Zone even in poor weather and reducing TZM's reliance on MIMP resources.
- Continue work with Kitomondo students to hold awareness raising days on the island, as well as lessons every two weeks.
- Continue environmental education and awareness raising with local children
- Research into the presence of invasive marine species (particularly macroalgae) inside Chloe Bay
- Continue regular beach cleans and turtle hatchings to maintain our relationship with Sea Sense.
- Continue data collection in the mangroves to determine biodiversity of this habitat in Chole bay as well as conducting socio-economic surveys.
- Continue to liaise with WWF in regards to whale shark monitoring.

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10. Appendices

Appendix 1 - Commercial fish list used for surveys

Common name	*Latin name*	Common name	*Latin name*
GROUPER	*Serranidae*	SPINECHEEK	*Nemipteridae*
Peacock Grouper	*Cephalophoilis argus*	Arabian Spinecheek	*Scolopsis Ghanam*
CoralHind Grouper	*Cephalophoilis miniata*	Thumbprint Spinecheek	*Scolopsis bimaculatus*
Giant Grouper	*Epinephelus lanceolatus*	GOATFISH	*Mullidae*
Potato Grouper	*Epinephelus tukula*	Longbarbel Goatfish	*Parupeneus macronema*
Blacktip Grouper	*Epinephelus fasciatus*	Dash and Dot Goatfish	*Parupeneus barberinus*
Whitespotted Grouper	*Epinephelus caeruleopunctatus*	Sidespot Goatfish	*Parupeneus barberinus*
Darkfin Hind	*Cephalopholis urodeta*	Yellow stripe Goatfish	*Mulloidichthys vanicolensis*
Brown Marbled CoralGrouper	*Plectropomus punctatus*	Yellowsaddle Goatfish	*Parupeneus cyclostomus*
Redmouth grouper	*Aethaloperca rogaa*	TRIGGERFISH	*Balistidae*
Lyretail Grouper	*Variola louti*	Titan/Moustache Triggerfish	*Balistoides viridescens*
Other Grouper	*Any other grouper species*	Halfmoon Triggerfish	*Sufflamen chrysopterus*
SNAPPER	*Lutjanidae*	Orange Striped Triggerfish	*Balistapus undulates*
Twinspot Snapper	*Lutjanus bohar*	Clown Triggerfish	*Balistoides conspicillum*
Black Snapper	*Macolor niger*	Redtooth Triggerfish	*Odonus niger*
Blackspot Snapper	*Lutjanus ehrenbergi/fulviflamma*	Picasso Triggerfish	*Rhinecanthus aculeatus*
Bluelined Snapper	*Lutjanus kasmira*	Yellow Margin Triggerfish	*Pseudobalistes flavimarginatus*

Paddletail Snapper	*Lutjanus gibbus*	Blue triggerfish	*Pseudobalistes fuscus*
Flametail Snapper	*Lutjanus fulvus*	Other triggerfish	*Any other triggerfish*
Other Snapper	*Any other snapper species*		
SWEETLIPS	*Haemulidae*	BARRACUDA	*Sphyraenidae*
Goldspotted Sweetlips	*Plectorhinchus flavomaculatus*	RABBITFISH	*Siganidae*
Blackspotted Sweetlips	*Pectorhinchus gaterinus*	GOATFISH	*Mullidae*
Slatey Sweetlips	*Diagramma pictum*	FUSILIERS	*Caesionidae*
Black Sweetlips	*Plectorhinchus sordidus*	JACKS / TREVALLY	*Carangidae*
Oriental Sweetlips	*Plectorhinchus orientalis*	PARROTFISH	*Scaridae*
Whitebarred Sweetlips	*Plectorhinchus playfairi*	SURGEONFISH	*Acanthuridae*
RAYS	*Batoidea*	NEEDLEFISH	*Belonidae*
Bluespotted Ribbontail Ray	*Taeniura lymma*	HALFBEAK	*Hemiramphidae*
Bluespotted Stingray	*Dasyatis kuhlii*	BUTTERFLYFISH	*Chaedontidae*
Giant Reef Ray	*Taeniura melanospilos*	ANGELFISH	*Pomacanthidae*
Manta Ray	*Manta birostris*	UNICORNFISH	*Naso*
Eagle Ray	*Myliobatidae*		
EMPEROR	*Lethrinidae*		
Spangled Emperor	*Lethrinus nebulosus*		
Blackspot Emperor	*Lethrinus harak*		
Longface Emperor	*Lethrinus olivaceus*		
Bigeye Emperor	*Monotaxis grandoculis*		
Yellowspot Emperor	*Gnathodentex aurolineatus*		
Other Emperor	*Any other emperor species*		