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MADAGASCAR MARINE CONSERVATION RESEARCH PROGRAMME

Nosy Be, Madagascar

MGM Phase 172 Science Report
30th March – 11th June 2017

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Contents

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1. Introduction

Coral reefs, which globally span ~527,072 km^2, maintain the highest levels of diversity among marine ecosystems containing thousands of fish, macro-invertebrate and micro-invertebrate, megafauna, scleractinian corals and octocorals (Veron *et al.*, 2009; Mora *et al.*, 2005). Many of these immense and fragile ecosystems are in decline due to increasing environmental stressors, including rising ocean water temperatures, run-off, sedimentation, ocean acidification, overfishing and pollution (Hughes *et al.,* 2003; Jackson *et al.,* 2001). Such pressures change the structure of reefs, causing them to shift from a scleractinian-dominated state to an algal, seaweed, and sponge dominated state (Bellwood *et al.,* 2004; Bell *et al.,* 2013). Long-term ecological impacts of phase-shifts include loss of invertebrate, fish, and coral diversity and abundance (Hughes, 1994; Jackson *et al.*, 2001; Bellwood *et al.*, 2004), which in turn destabilises the coral reef ecosystems relied upon by many for subsistence and income (Costanza *et al.,* 1997).

Madagascar, the fourth largest island in the world with over 5,000 km of coastline, supports extensive fringing reef systems, brackish and freshwater habitats, and shallow marine and pelagic environments (Cooke *et al.*, 2003). Around 3,500 km of the coastline is fringed with scleractinian coral reefs, which are highly productive, dynamic and fragile ecosystems. With 55% of the population of Madagascar living on the coast, over half of the nation is reliant on fisheries (Harris, 2011; Le Manach *et al.,* 2012). Following a military backed coup in 2009, foreign aid was withdrawn and fish catch has largely gone unregulated and underreported by an estimated 40%, leading to poorly managed fish and invertebrate stocks and the continuing depletion of commercially important species, such as certain Holothurians (sea cucumbers) and large fish species (Narozanski *et al,*. 2011; Le Manach *et al.,* 2012). However, with a new president elected in January 2014, there is hope that conservation and protection of reef ecosystems will become an issue of importance.

There are two fully decreed marine protected areas (MPAs) in Madagascar and multiple locally managed marine areas (LMMAs), however only 2% of the country's coral reefs are located within protected zones and the majority of fisheries are regarded as unsustainable (Harris, 2011). Even with imposed area and fishing restrictions, there is little enforcement and the exploitation of many marine invertebrate and fish species continues to occur, leading to increased levels of bio-eroders such as sea urchins that contribute to overall reef decline (Bigot *et al.,* 2003). Presently, much of Madagascar's marine resources are depleted, leaving a legacy of reduced fisheries catch, and a continuing decline toward an unstable level of overall species abundance and diversity.

To further understand the anthropogenic effects on marine ecosystems, as well as to implement successful conservation measures, baseline data is required on a wide range of ecological and biological parameters. Detailed scientific data regarding fish assemblages, influential invertebrate species abundances, and coverage of benthic substrata are needed to understand ecological processes. Frontier is a conservation NGO based in the United Kingdom that has worked out of the village of Ambalahonko on the island of Nosy Be in Northwest Madagascar since 2010. Trained scientists as well as volunteer research assistants have used baseline surveys to accumulate extensive data on fish and macro invertebrate assembles, as well as a preliminary assessment of seagrass diversity at sites within the Nosy Vorona Bight. As such this report aims to characterise adult and juvenile fish assemblages of specific marine biotopes, examine abundance of echinoderms and opisthobranchs across different habitats, and quantify marine debris in beach areas surrounding Ambalahonko.

1.1 Aim

The general aim of the research is to conductive extensive documentation to gain an understanding of the health of the coral reefs and mangroves in Nosy Vorono Bight in Northwest Madagascar. In order to gain a broad understanding of the current healths of the reefs, sites were chosen across coral dominated habitats, seagrass beds, and sponge dominated habitats.

1.2 Objectives

Further to the broad aim listed above, there are various objectives which must be completed to investigate the aim;

Objective 1 - To assess the fish community in Nosy Vorono Bight using data collected from underwater visual census.

Objective 2 – To assess the key invertebrate species, using data collected from surveys using Reef Check methodology.

Objective 3 - To assess the health of the mangrove sytems close to Ambalohonko using data collected every 10m along a transect with a 5x5m quadrat and a smaller 2x2m quadrat used to count the number of adults, saplings, and seedlings. The amount of dead trees, crab holes and pneumatophores are also counted.

2. Training

2.1 Briefing

Prior to the science lectures, volunteers are given a variety of briefing sessions from senior staff (Table 1).

Table 1. Briefing sessions conducted during phase 172.

Briefing Session	Presenter
Introduction to MGM Project	MJ
Health and safety	MJ/NP
Medical brief	MJ
Camp life and duties	MJ

2.2 Science Lectures

A number of science lectures were given, and documentaries shown throughout the phase (Table 2). Those used in previous phases were updated, new lectures and tests were created to aid in learning which proved successful. 'Extra curriculum' lectures or conservation programmes were shown to RA's at least once a week this phase, and documentaries were shown once every two weeks. These were presented by a mixture of the ARO's and were positively received by RA's.

Table 2. Lectures and documentaries provided during Phase 172.

Presentation	Contents	Presenter
Introduction to MGM	An early introduction to the different projects currently being undertaken by MGM and introducing their roles as RAs into the overall research agenda.	SC/EG
Territorial Fish Schooling Fish Invertebrates	These introductory level lectures are designed to introduce the various families and the species the RAs are likely to observe during surveys. These are split into Territorial and Schooling fish, and invertebrate lectures in order to slowly build upon the RA's growing knowledge. All lectures are followed up with a point out snorkel or dive.	SC/EG
Intro to coral	This lecture is designed to introduce RAs to basic coral biology, growth forms, and threats.	SC/EG
Survey methodologies	Lecture introducing volunteers to the survey methodologies used for each survey that we carry out.	SC/EG
Mangroves Ecosystems	Introductory lecture to mangrove ecosystems including ecosystem services, species found in Nosy Be, threats being faced by mangroves.	SC/EG
The Oceans	Introductory lecture to ocean hydrography including currents, tidal systems and upwelling and how these affect ecosytems and their biodiversity.	SC/EG

Sharkwater (documentary)	Documentary about the worldwide shark finning trade.	SC/EG
End of the Line (documentary)	Documentary about over fishing.	SC/EG
Racing Extinction (documentary)	Documentary about anthropogenic threats to ecosystems around the world.	SC/EG

2.3 Fieldwork Training

Fieldwork training consisted of a variety of lectures and species revision, followed by a computer test and in-water test.

3. Research Work Program

Baseline surveying of fish and invertebrate assemblages continued this phase after an extended dive ban. Survey methodologies and protocols are outlined below and staff research projects include;

Sarah Cryer: Anthropogenic impacts on coral reef health.

Ella Garrud: Small scale artisanal fishing impacts around Nosy Be.

3.1 Survey Sites

During Phase 172, fish and invertebrate assemblages were examined at several sites within the Nosy Vorona Bight in Northwest Madagascar (Fig 1; Table 3). Each site contained between one and two habitat types, and each habitat fell into either coral or sponge dominated.

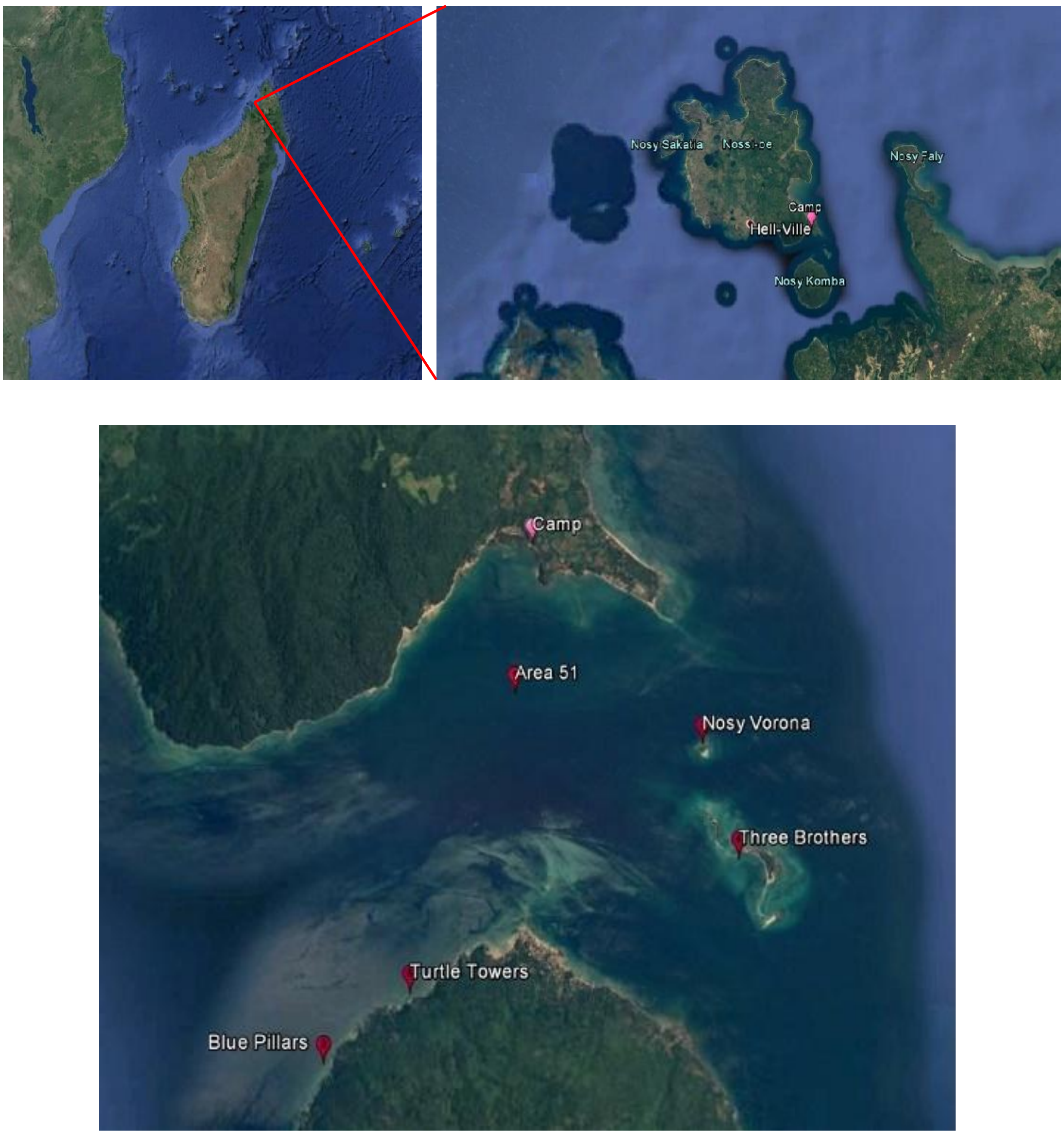

Figure 1: Location map of sites surveyed off Nosy Be and Nosy Komba during Phase 172**.** Only sites used in this phase are included.

Table 3. Description of the study sites surveyed and known sites in Phase 172: LC, healthiest reef classification; DC, degraded coral reef; Sg, seagrass-dominated; Sp, sponge-dominated habitat.

Site	GPS	Description
Nosy Vorona (LC)	13°25’30” S, 48°21’46” E	Fringing patchy reef formed around a small island. Moderate live coral cover with extensive coral rubble and patchy seagrass beds. Little terrestrial influence, strong current, artisanal fishing pressure. Temperature range 27°-31°C.
Three brothers (LC)	13°25’53” S, 48°21’50” E	Fringing mix of continuous and patchy reef formed around three distinct outcrops. Moderate live coral cover, little terrestrial influence, moderate fishing pressure. Temperature range 27°-31°C.
Turtle Towers (LC)	13°26’48” S 48°20’09” E	Large continuous reef with moderate live fringed coral reef. Adjacent to MRCI camp. A small scale MPA has been placed over this area to prevent fishing and anchor damage. Temperature range 27°-31°C.
Blue Pillars (LC, Sg)	13°27’06” S, 48°19’39” E	Large live and healthy coral reef. Extensive, dense seagrass beds. Temperature range 27°-31°C.
Area 51 (LC, Sp)	13°25’27”S, 48°20’71”E	Large live coral and sponge site in the middle of the Verona bight. Strong currents and often high sedimentation. Temperature range 27°-31°C.

3.2 Fish Surveys

3.2.1 Introduction

Examining the interconnectivity and relationships between proximal habitats in many coral reef environments is vital to understanding the dynamics of coral reef fish assemblages (Wilson *et al.*, 2010; Aguilar *et al.*, 2014). Habitat selectivity and specificity is documented within many species, and is shaped by a variety of processes such as responses to predation, foraging efficiency or reproduction (Sutherland, 1996; Wilson *et al.*, 2010). Species of fish within families Lutjanidae, Scaridae and Lethrinidae, for example, have been shown in various locations to recruit to mangrove or seagrass ecosystems, undergoing ontogenic phase shifts where they migrate to coral reefs as sub-adults or adults (Bell and Westoby, 1986; Nagelkerken *et al.*, 2002; Lecchini and Galzin, 2005; Wilson *et al.*, 2010). In addition, the adults of many fish species, which are not directly associated with live coral, still spend part of their early life history closely associated with corals (Jones *et al.*, 2004). Considering the decline of coral reefs and near-shore habitats worldwide, this is cause for concern; the knock on effects of coral loss or mangrove removal will undoubtedly affect species that have habitat specific recruitment, directly utilise these habitats as adults or depend on those that do (Bellwood *et* *al*,. 2002; Honda *et al.*, 2013). Given the rate of environmental deterioration worldwide, coupled with unregulated fishing practices in developed and developing countries, it is not surprising that our marine ecosystems are experiencing unprecedented stress (Harris, 2011; Honda *et al.*, 2013).

Previous studies have focussed on the local interconnectivity of coral, algal, rubble and/or seagrass habitats and their importance at different scales (Dorensbosch *et al.*, 2004; Wilson *et al.*, 2010; Berkstrom *et al.*, 2013). It is often suggested that the proximity of 'nursery' habitats to adjacent coral reefs plays a role in determining the species diversity and assemblages that are present (Baelde, 1990; Nagelkerken *et al.*, 2002). Whilst it is beyond the scope of this study to examine the complex ecological relationships and interconnectivity of habitats, the primary aim of this study was to examine the differences in adult composition across a number of proximal habitats in Nosy Be, Madagascar. Furthermore, understanding the reliance of fish species on certain habitats is vital to ensure appropriate management and protection of marine resources (Wilson *et al*., 2010), especially in developing countries such as Madagascar, where reliance on natural resource extraction is in some places the only means of survival (Le Manach *et al.*, 2012). Thus, the importance of coral habitat type for specific adult fish species or families was assessed.

3.2.2 Methodology

To examine the richness, diversity, and abundance of the different fish species and make a comparison between sites, Baseline Survey Protocols (BSPs) were undertaken at 5 different sites (Table 1). In each site, a minimum of 4 replicate surveys was performed to ensure accurate statistical analysis.

In each baseline survey, different research roles are performed: invertebrate surveyor, territorial fish surveyor and schooling fish surveyor. When there were not enough researchers present to perform all the different tasks, a selection was made to make sure an invertebrate surveyor; territorial fish surveyor and schooling fish surveyor were always present. All surveys were done using SCUBA. At each survey site, the visibility is measured or estimated by the physical surveyor, who also places the start of the transect line and measures out a line of 80m. Within a $5m^2$ box (2.5m on either side and 5m above the line) along this transect the other surveyors note down the abundances of all the inverts, schooling or territorial fish. All surveys were conducted within two hours of high tide either side, so as to standardise the conditions for the presence of fish. The schooling fish surveyor always goes first along the line, as schooling fish are more easily disturbed.

3.2.3 Results

A total of 12,630 fish were observed over a two and a half month period, from the end of March to the beginning of June 2017, representing 38 different families and 92 species. There is some variation in the number of families between the different dive sites, with the lowest number of families found at Blue Pillars (n = 10) and the highest at Nosy Vorona and Three Brothers (n = 31) (Table 4). The total number of species found at the different dive sites varied from 52 species in Area 51 to 75 species in Nosy Vorona. The Shannon diversity indices (Table 4) show the lowest diversity in Area 51 (1.93), which is where the lowest number of species is recorded. The most species were recorded at Nosy Vorona, this is not supported by the Shannon diversity indices which shows the highest diversity at Three Brothers.

Table 4. The total number of fish species and the total number of families recorded in each of the different dive sites during Phase 172 and the Shannon-Wiener Diversity index for all fish species in the different sites.

	Area 51	Blue Pillars	Nosy Vorona	Three Brothers	Turtle Towers
No. species	52	57	75	62	64
No. families	24	10	31	31	24
Shannon-diversity	1.93	1.38	2.36	2.58	2.23

The mean fish abundance per survey varies slightly between the different sites, with a mean of 19 species per transect in Area 51 and a mean of 27 species per transect in Blue Pillars (Fig. 2).

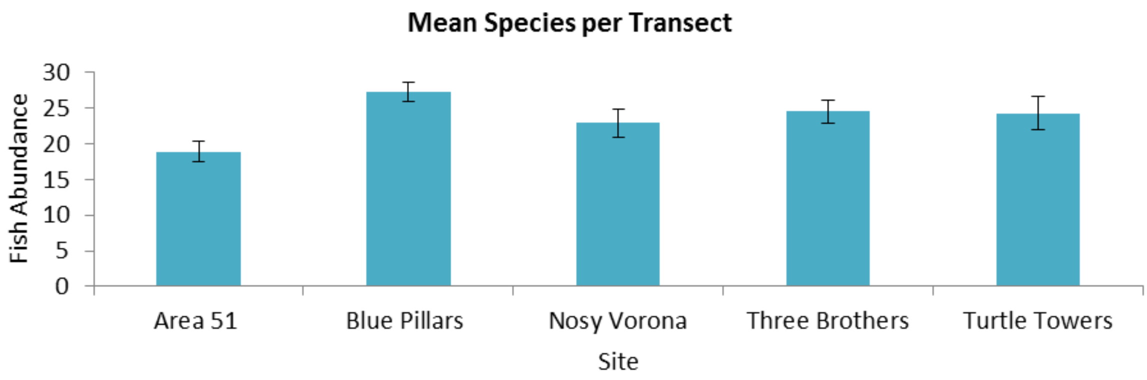

Figure 2: Mean number of species per transect at each site. Error bars show standard error for each site.

The abundance of fish was least at Blue Pillars with a mean abundance of 227, mean abundance was found at Three Brothers with a mean of 439 fish per transect (Fig. 3).

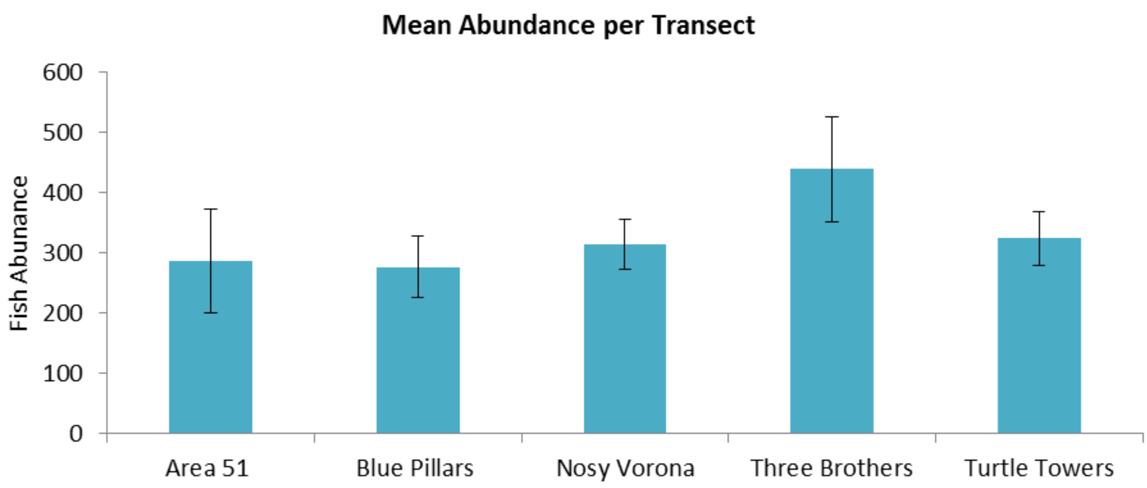

Figure 3: The mean fish abundance per survey in the different investigated sites, with standard error for each site.

3.2.2 Discussion

Area 51 on average has the lowest number of species per transect and the lowest number of total species recorded compared to the other investigated sites. From previous benthic surveys it is known that Area 51 has a larger proportion of sponge habitat in relation to coral, than the other sites. In previous phases the same pattern was found, where the lowest diversity of fish species were found in sponge habitats. This is likely explained by a high abundance of coral associated species, including those in the family Pomacentridae, Chaetodontidae, and Labridae. Furthermore, many species within these families rely on scleractinian corals, particularly branching corals, for shelter, protection, and as a food source (Reese, 1981; Bozec *et al.,* 2005; Cole *et al.,* 2008). Many wrasse feed upon small bivalves, decapods, gastropods, and algae, most of which are often in high abundances on many coral reefs and seagrass beds (Deady and Fives, 1995). These food sources are less abundant in sponge habitat, which may explain the low fish diversity and abundance in Area 51.

The differences between the number of fish species and families and the Shannon diversity indices are less evident between the other investigated sites. This may likely be explained by many of the reefs neighboring each other, therefore subject to the same biotic and abiotic influences. Furthermore, although the sites will differ in their exposure to environmental stressors depending on the distance from terrestrial environmental parameters to reef system, all sites occupy the same body of water, thus receiving similar flushing times and nutrient turnover.

3.3 Invertebrate Surveys

3.3.1 Introduction

Macro invertebrates can play a vital role in the food webs of marine ecosystems, as well as contributing to bio-turbation and bio-erosion of coral reefs, the latter of which can have an effect on successful coral settlement (Bak, 1993). The phylum Echinodermata consists of the classes Echinoidea (sea urchins), Asteroidea (sea stars), and Holothuroidea (sea cucumbers), as well as Crinoidea (feather stars) and Ophiuroidea (brittle stars) with over 6,000 reef dwelling species critical in the functionality and stability of coral reef ecosystems (Stella *et al.,* 2010). The symbiotic relationships of these invertebrate families with scleractinian corals, sponge, soft coral, sand, algae and seagrass directly and indirectly affect the overall health of reefs. In fact, 51 species of echinoderms are known to associate with scleractinian corals through direct consumption, as a habitat to live on or inside of, or for mating (Stella *et al.,* 2010). This causes a negative feedback loop with the loss of scleractinian corals, which increases the pressure for competition between echinoderms for resources, which degrades the scleractinian corals even further (Dumas, 2007 ; Stella *et al.,* 2010). Only 12 echinoderm species are known corallivores, however, with outbreaks of highly destructive species such as the asteroidean, *Acanthaster planci* (Crown of Thorns), the damage can still be expansive (Stella *et al.*, 2010).

The structural complexity of marine habitats depends on the species that live within microhabitats. Sessile animals that form the substrata of different biotopes compete with each other for space, largely based on life form, colonial or solitary, with different phyla of animals gaining success in certain areas (Jackson, 1997). Colonial species, including scleractinian corals, tend to dominate reef space, excluding solitary growth forms, such as many sponge species, forcing them to colonize areas off of the reef crest (Jackson, 1997). In sponge-dominated habitats, usually at greater depths than scleractinian corals, species are able to exclude most colonial corals even without direct contact by excreting allelochemical defences (Porter and Targett, 1988; Stella *et al.*, 2010). With climate change affecting sea-water temperatures and consequently many marine flora and fauna, it is possible that reef structure may change irreversibly, shifting towards more sponge dominated reefs (Bell *et al.*, 2013). Warmer water temperatures, causing a higher acidity level and an increase in dissolved inorganic carbon, prevent the growth of calcifying organisms including scleractinian corals, crustose coralline algae, and some invertebrates (Caldeira and Wickett, 2003; Raven *et al*., 2005; Schneider and Erez, 2006; Anthony *et al*., 2008; Jokiel *et al*., 2008). Historical evidence suggests that many sponge species, while still affected by climate change, are more resilient to warmer water temperatures and ocean acidification (Bell *et al.*, 2013). With the current state of coral reefs and continuing degradation it is possible that sponge dominated reefs may once again emerge (Bell *et al.*, 2013).

Distinct from both scleractinian coral and sponge-dominated biotopes, seagrass beds provide a unique habitat and are regarded as ecologically important nurseries for many macro-invertebrate species (Boström *et al.*, 2006). Seagrass beds with high levels of biomass provide shelter and different nutrient sources through the consumption of leaf tissue and of epiphytes that cover the leaves of many seagrass species that macro-invertebrates are unable to find in other marine microhabitats (Boström and Mattila, 1999; Attrill, *et al.* 2000). The difference in structure between these biotopes promotes a difference in echinoderm diversity due to different spatial niches and food resources and possibly less interspecific competition (Pante *et al*, 2006).

3.3.2 Methodology

In this phase, sampling effort was focused primarily on healthy coral sites and one sponge site to establish differences between them. Sampling effort is shown in Table 5. Fishing pressure around the island is high from artisanal fishers and spear fishers who also collect sea cucumbers.

Table 5. Number of transects completed at each site during Phase 172.

Live Coral		**Sponge**	
Survey Site	No. Of Transects	Survey Site	No. Of Transects
Blue Pillars	4	Area 51	7
Nosy Vorona	12		
Three Brothers	7		
Turtle Towers	6		

An 80m transect line was used to examine the species richness, diversity and abundances of echinoids, holothurians and asteroids. After the transect line was laid, the surveyor would swim in a u-shaped pattern down the transect, recording any echinoids, holothurians and asteroids and other invertebrates that were observed within 2.5m either side of the transect line

3.3.3 Results

A total of 21,313 echinoderms, 255 holothurians and 46 asteroideans were recorded over a three month period during Phase 172 (Fig. 4). Of the 21,313 echinoids recorded, 19,196 individuals were the echinoid *Diadema setosum*, while the remaining individuals were comprised of 4 separate species. Mean abundances of families across sites are shown in Table 6. Evenness of abundance is an important factor to consider for interpretation of echinoid diversity, as the over-abundance of *D.*

setosum had a large influence on the result. As such, this species was removed from the analysis for comparative purposes.

Table 6: Mean abundance of invertebrate families across 5 surveys sites around Nosy Be and Nosy Komba. Echinoids with and without *D.setosum* are included due to their significant abundance.

	Area 51	Blue Pillars	Nosy Vorona	Three Brothers	Turtle Towers
Echinoids	402	357	784	760	392
Echinoids, minus *D. setosum*	1	0	21	227	45
D. setosum	400	357	763	533	347
Holothurians	14	4	8	3	4
Asteroids	1	1	1	0	3

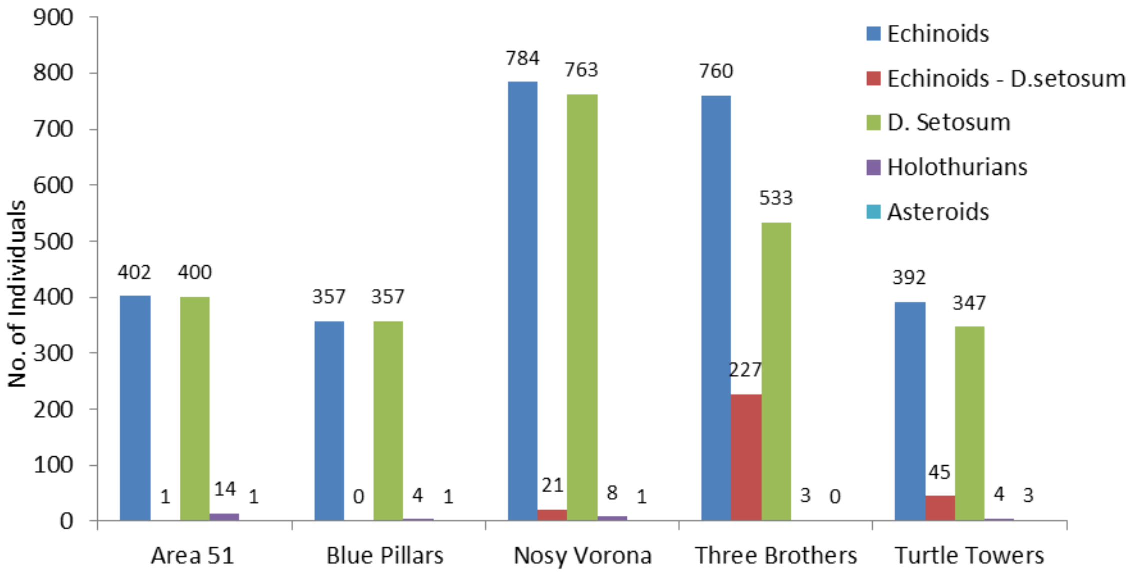

Figure 4: Average number of individual echinoids, *D.setosum,* Holothurians and Asteroids at each survey site.

Shannon diversity indices (Table 7) show the relative estimate diversity against survey effort. Levels of diversity were considered as 1 being low and 5 being high. As standard, results <2.0 were considered very poor diversity (Gering *et al.* 2002). Blue Pillars had the lowest level of invert diversity (1.37 and Nosy Vorona the highest (2.45).

Table 7: Number of species, families and Shannon diversity indices for each survey site.

	Area 51	Blue Pillars	Nosy Vorona	Three Brothers	Turtle Towers
No. of Species	13	8	14	10	10
No. of Families	3	3	3	3	3
Shannon Diversity	1.89	1.37	2.45	1.91	1.63

3.3.4 Discussion

Consistent with results from previous phases, the urchin, *D. setosum* were very abundant in all areas. This is likely the result of multiple influences, including low predation pressure on the reef, particularly balistids, and an abundance of food sources including algae and sponge (Vance, 1979). Triggerfish, a major predator of *D.Setosum,* were not sighted on any survery in Phase 172, triggerfish are at such a low abundance it is likely they are unable to keep *D. setosum* numbers balanced. Studies conducted in Kenya (McClanahan and Shafir, 1990) found similar results with high urchin abundance, specifically *D. setosum,* and *D. savignyi,* on reef in the absence of finfish predators. Furthermore, McClanahan and Shafir (1990) found that the urchin *Echinometra mathaei* exhibited dominance over the larger *Diadema* species, and excludes them in the absence of predators. This is contrary to the findings of this study, with *D. setosum* appearing to be the dominant species. A later study conducted (McClanahan, 1998) found that *E. mathaei* is the most susceptible to predation compared to other Indo-Pacific sea urchin species. The low number of *E. mathaei* observed suggests either they may have been over-predated or out competed by other holothurians.

A high abundance of sea urchins on reefs can be productive for coral settlement as many sea urchins are herbivorous grazers, removing algae from the reef, and simultaneously creating space for coral recruits to settle (Smith *et al.*, 2009). In fact, urchin abundance is usually higher on over-fished reefs where predators and herbivorous competitors are scarce (Hay, 1984; McClanahan, 1990). In a study conducted by Smith (2009), the presence of herbivores was required for coral settlement, and while sea urchins contribute to algal grazing when herbivorous fish (largely parrotfish and surgeonfish) are removed, an overabundance of urchins may induce a phase shift to urchin dominated reefs, which could alter the entire reef structure (Hay, 1984; Smith *et al.,* 2009). Different herbivorous species target different types of algae and exhibit different methods of grazing the reef, and the variety of which can be productive for coral growth and the limiting of which can be damaging (Smith *et al.,* 2009). Many sea urchins are considered bioeroders as they burrow into the framework of the reef and can erode coral skeletons that they inhabit. Studies have attributed up to 75% of all bioerosion on reefs to sea urchins, weakening the structure of scleractinian coral and the stability of coral reef ecosystems (Bak, 1993; McClanahan and Shafir, 1990). Whether this is a process occurring on reefs in the Nosy Be area remains to be quantified. This demonstrates the importance of maintaining diversity of fish and invertebrates on coral reefs. Overfishing and other human induced effects of removing large, predatory fish from reefs have long lasting, top down effects on the rest of the species that inhabit coral reefs.

3.4 Mangrove Ecology

3.4.1 Introduction

Mangrove ecosystems are found at the interface between land and sea. Mangroves typically grow in tropical and sub-tropical latitudes and survive in extreme growth conditions with winds, high temperatures and muddy, anaerobic soils which are flooded with incoming tides (Kathiresan and Bingham, 2001). Mangrove trees show several adaptations to live in this harsh environment, surviving high salt concentrations (Tomlinson, 1986; Kaiser and Attrill, 2011). Three different mechanisms exist to cope with the high salinity: exclusion, elimination or tolerance. By exclusion, the plant reduces the amount of water needed and limits the salt intake, some species have specialised glands in the leaves that excrete the excess amount of salt, while others transfer salts into senescent leaves or into the bark (Hogarth, 2015).

The soil in which mangroves grow is often completely waterlogged and limits the plant root system in efficient oxygen uptake. The root systems of mangrove trees are modified to grow above the soil and the different species display different types of aerial roots (Fig. 5). These root modifications give the mangroves their typical and characteristic appearance.

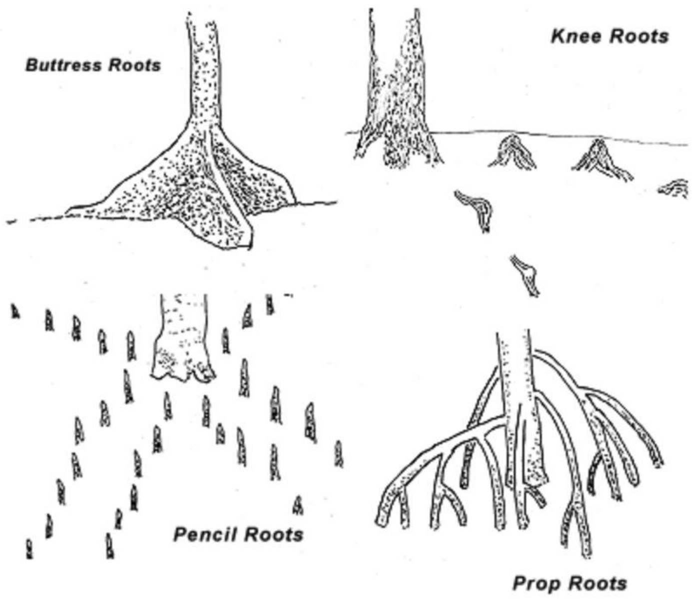

Figure 5: The different types of root modifications in mangrove trees (Wet tropics, 2017).

The importance of mangrove ecosystems and their conservation is often neglected as the extent of the ecosystem services and goods provided by them is highly underestimated (Alongi, 2011). This undervaluation is reflected in the amount of research and media attention received by the mangrove ecosystem. Only 11-14% of all published research on coastal habitats is carried out on mangrove forests and other coastal ecosystems (salt marshes and seagrass meadows), while 60% of the research is devoted to coral reefs (Schmitt Klaus and Duke, 2015). The ecosystem services and goods provided by the mangrove ecosystem are however, of undeniable value.

Mangrove trees provide fuel wood, timber, construction wood, but also medicinal products and dye or insecticides as direct products (Dahdouh-Guebas *et al.*, 2000). Mangrove ecosystems protect and stabilise coastlines; they trap sediment that is harmful for adjacent coral reefs, provide an important carbon sink and support coastal fisheries by providing nursing and feeding habitat for juvenile fish (Kathiresan and Bingham, 2001; Kathiresan, 2012). Unfortunately, coastal ecosystems particularly suffer from human pressure and overfishing. Habitat destruction and the effects of climate change are only a few of the many threats to these vulnerable environments (Donato *et al.*, 2011). More research to understand this ecosystem and asses its health and research towards the conservation and restoration of mangrove forest is crucial.

Although Madagascar has the highest surface area of mangroves in the Eastern African region, only 9 of the 70 known mangrove species have been recorded here. The mangrove systems around Ambalahonko contain 6 different species in four families: *Rhizophora mucronata*, *Ceriops tagal*, *Bruguiera gymnorrhiza*, *Avicennia marina*, *Sonneratia alba* and *Lumnitzera racemosa* (Tognetti, 2017*)*. Several of the endemic bird species of Madagascar are found in the coastal areas, where they make use of the mangrove habitat (Tognetti, 2017). The high diversity of fish populations found in the mangroves also benefits the adjacent coral reefs and high fish diversity has been noted for reefs associated with mangroves (Rasolofo, 1993).

In Madagascar, mangroves are threatened by the development of urban areas, overfishing and erosion caused by deforestation. Several mangrove areas have been converted to rice farming and shrimp aquaculture, which have an irreversible effect on the ecosystem. A loss of 3.6 million hectares of the mangrove population since 1980 is estimated in Madagascar (Giri and Muhlhausen, 2008). The local community has restricted the cutting of the mangrove trees around the village and started with the restoration of the area by planting mangrove seeds. Due to physical and logistical difficulties, not all present mangrove species have successfully been replanted and Frontier will hopefully be able to help with these restoration efforts. A functioning tree nursery in the Frontier basecamp, producing strong and healthy mangrove seedlings, will provide us with a useful tool for future mangrove restoration projects. In this preliminary study, different methods and conditions to grow different species of mangrove trees are investigated. The results will help us find the most feasible and effective methodology, which will be used in future restoration efforts.

When successful, mangrove nurseries prove to be a great help for the reconstruction and replantation of mangrove forests. As the season for flowering, fruiting and seed production does not always overlay with the ideal planting season in the degraded areas, nursery grown seedlings may provide a solution to avoid this mismatch (Ravishankar and Ramasubramanian, 2004). The survival rate of nursery grown seedlings is higher than that of naturally grown seedlings, as their root systems are healthier and stronger.

3.4.2 Methodology

The mangrove area surrounding Ambalahonko is mapped by using a handheld GPS (Garmin, Schaffhausen, Switzerland). By walking along the edge of a mangrove patch, the outline is registered on the GPS; observations about the species composition are also noted down. This information can then be uploaded in mapping programs to provide a clear overview of the mangrove area.

To assess the composition and the health of the mangrove ecosystem, transect lines are followed from the seaward edge of the mangrove forests until the edge of the terrestrial forest. Every ten meters, a 5x5m quadrat is laid out on the left side of the transect line. Within these quadrats the number of adults (height: >1 m, circumference: >4 cm), saplings (height: >1m, circumference: <4 cm) and seedlings (height: <1 m, circumference: –<4cm) is counted per mangrove species. The total amount of dead trees is also counted and noted down. In the left corner of every quadrat, a smaller 2x2m quadrat is laid out, in which the number of crab holes and pneumatophores is counted.

The tree nursery itself is modified so it resembles the ideal growth conditions for mangrove trees. The roof is made from coconut leaves, which allow some rainfall to come through and limit the penetration of sunlight and thus mimic the presence of tree canopy. The sides of the nursery are covered with mosquito nets to regulate the shade. Soil for the mangrove seeds is collected in the mangrove forest surrounding Ambalahonko. Water bottles are used as flower pots to plant the seeds. For this study, seeds of three different mangrove species; *Avicennia marina*, *Rhizophora mucronata* and *Ceriops tagal* are collected. All seeds are collected in the morning and are taken from the mother tree itself. Ripe seeds can be recognised by the yellow colouration of the cotyledon. All the seeds are examined for incidence of diseases or pests. The *R. mucronata* and *C. tagal* seeds are planted within the same day, while the *A. marina* seeds are soaked in brackish water overnight. The soaking removes the seed coats and reduces the germination time by two to three days. After planting, all the seeds are watered with a 70% fresh, 30% salt-water mixture.

To find the most suitable condition for the growth of mangrove seeds, different fertiliser types and watering methods are used in this experiment. A total of 4 conditions were investigated. Ten seeds of each of the three species are grown without fertilizer and watered every morning with a 70 % fresh -, 30% salt – water solution as a control condition and to compare the success rate of the different species. Ten *C. tagal* seeds, two *R. mucronata* seeds and one *A. marina* seed are used under different conditions. In one of the conditions, the seeds are not watered and thus only receive the water entering the nursery through the coconut leaves. Adding dried, crushed banana peels to the soil fertilises the second group of seeds. Potassium, the main nutrient found in banana peels help with root development and promotes good water and nutrient flow in the plant. A third group of seeds is fertilised, using crushed eggshells. Eggshells consist of calcium mainly and calcium is known to be important for proper root and stem development. Calcium helps in breaking down other nutrients in the soil, such as nitrogen, which are vital for plant development. The last group of seeds is fertilised with zebu manure. Manure contains the three main plant nutrients: nitrogen, phosphorus and potassium. The manure also has large water content and is therefore beneficial to keep the soil moist.

3.4.3 Results

The data collection for the mangrove projects is not yet finished at the end of this phase. Therefore, the data is not yet complete, but they do give an indication of the results of these projects. A first assessment of zonation pattern of the mangrove area surrounding Ambalahonko is shown in Figure 6.

Figure 6: A Map indicating the presence of the different mangrove species along the transect line.

At the seaward side, a strip of *S. alba* occurs, followed by a pure stand of *R. mucronata*. The landward side is characterized by a mixed stand of *R. mucronata* and *A. marina*, with a limited amount of *B. gymnorrhiza* trees scattered in between. The landward side is characterized by a mixed stand, dominated by *C. tagal*. When investigating the correlation between the number of crab holes and the number of pneumatophores in each quadrat, a positive correlation was found (Fig. 7).

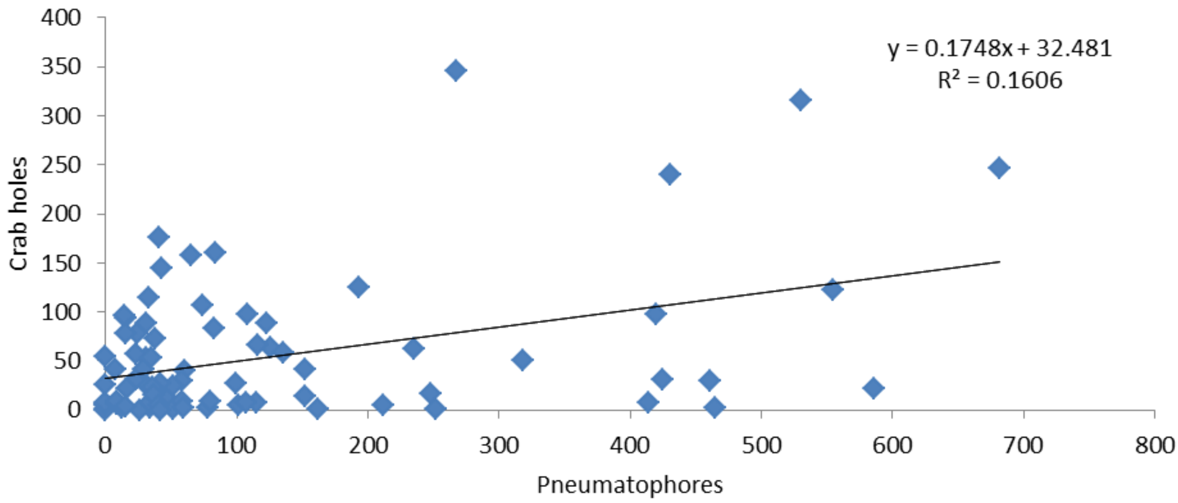

Figure 7: Correlation between the number of crab holes and the number of pneumatophores in the mangroves to the west of the village of Ambalahonko.

The success rate of the different species in the tree nursery is represented in Table 8. The highest survival rate is found for *C. tagal*, with a successful growth of 96 %. *R. mucronata* has the lowest survival rate with 66.7% survival rate.

Table 8: Survival rate of the different species, planted in the tree nursery.

Species	Planted	Survived	Survival rate
R. mucronata	15	10	66.7%
A. marina	14	11	78.6 %
C. tagal	50	49	96.0 %

Table 9 shows the survival rates of the *C. tagal* seeds, grown under different conditions. The rate is 100% for all the different conditions, except for the seeds that got fertilised with eggshells. These seeds had a survival rate of 90%.

Table 9: Survival rate of the *C. tagal* seeds grown under different conditions.

Condition	Planted	Survived	Survival rate
Control	10	10	100 %
Banana peels	10	10	100 %
Egg shells	10	9	90 %
Zebu manure	10	10	100 %
No watering	10	10	100 %

3.4.4 Discussion

The first results of the assessment of the mangrove stand around Ambalahonko indicate the presence of a zonation pattern. Figure 2 shows us that the typical mangrove zonation pattern found in different mangrove stands on the coast of eastern Africa, is also found in our local mangrove stand (Matthijs *et al.*, 1999). The tidal inundation of the mangrove face challenges the mangroves with different harsh conditions. Salinity gradients, water logged soils and thus high concentrations of toxic substances such as sulphide are only few of the challenges faced by mangrove trees. It is hypothesised that different tolerances to these flooded conditions contribute to the spatial patterns observed in the mangrove ecosystem (Matthijs *et al.*, 1999). *S. alba* is a typical pioneering species and thus grows successfully along the seaward edge (IUCN, 2015).

This is perfectly shown in the monospecific band of *S. alba* in the mangrove stand next to Ambalahonko. *C. tagal* is a slow growing, but hardy mangrove species, it does not tolerate shade well but is highly tolerant for salinity fluctuations and high salinities. Therefore *C. tagal* is expected to be dominant at the landward edge of a mangrove stand. This expectation was met in our study. As is shown on the map, there is a mixed, but dominated by *C. tagal*, mangrove stand at the landward edge of the forest (Fig. 2.). *R. mucronata, B. gymnorrhiza* and *A. marina* are all species that are typically found in the mid-intertidal zones (IUCN, 2015). This is also represented in our results as we found a mixed stand of these species and *C. tagal* in the mid-intertidal.

We expect to find a positive correlation between the number of pneumatophores and the number of crabholes in the mangrove ecosystem. Pneumatophores are a good indicator of tree density and we thus expect a more productive, dense area when the number of pneumatophores is high. Mangrove trees produce a lot of nutrient rich litter which, together with mangrove propagules forms the diet of many mangrove crabs (Hogarth, 2015). A higher density of crabs is thus expected to be found in an area with a high pneumatophore density. We found there was no correlation between crabholes and pnuematophores. This could be due to the various factors, human error whilst counting, different species having more pneumataphores and the mangroves closest to the sea being inundated during every high tide, and even during some neap low tide. These conditions would be expected to be less preferred by crabs. The almost constant inundation washes away the tree litter, and thus the food source of the crabs and crab holes.

The survival rates of the mangrove seeds reflect the growth strategy of the different species. *C. tagal* is a slow growing but hardy mangrove species (IUCN, 2015). The seeds of this species show germination and leave growth relatively slow, compared to the seeds of *A. marina.* The survival rate of the *C. tagal* seeds is however the highest. *A. marina* is a pioneer species and invests in a fast root and shoot growth to have an advantage in colonising new areas (IUCN, 2015). This strategy is visible in our results, as the seeds of *A. marina* show root, shoot and leave growth significantly earlier than the two-other species. *R. mucronata* has a strategy somewhere in between; the seeds show a late shoot growth, but when they start shooting the large leaves develop fast.

At this point in the study, it is too early to draw any conclusion regarding the different conditions in which the seeds are grown. This will be discussed later, when more data is obtained and the whole study is completed.

3.5 Marine Litter

3.5.1 Introduction
Pollution in the marine environment, especially plastic debris, has become ubiquitous in marine environments and is a source of global concern due to its longevity and impact on marine organisms (Derraik, 2002). An extensive review of published research has shown that between 60-80% of all marine debris is plastic, and sources of plastic pollution are varied, but include equipment from fishers/fishing fleets, other ship traffic, including container ships, deliberate littering or careless handling of waste (Derraik, 2002). Proximity to industrialised areas, suburban areas and river mouths, and our over-reliance on disposable products are also significant contributing factors to the amount of marine debris observed in a given area (Derraik, 2002).

Impacts from marine debris are varied, but affect many species globally. Direct deleterious effects may be caused by macro or micro plastics, and may occur as a result of ingestion, exposure to toxic substances adsorbed to plastic surfaces, or entanglement (Derraik, 2002; Wright *et al.,* 2013). Discarded or accidently released fishing equipment, such as nets that continue to ‘ghost fish’ and indiscriminately kill organisms for an extended period of time, are also of ecological concern. Indirect ecological consequences have also been documented, through the introduction of foreign or invasive species attached to drifting debris (Derraik, 2002).

Collection of marine debris is one of the most effective ways to have a meaningful positive environmental impact, and assess potential sources of environmental pollution so that management strategies can be implemented that aim to curb input of non-biodegradable items. Frontier Madagascar regularly undertake beach cleans, and the following is a summary of items collected, a discussion of potential sources of marine debris, and suggestions for management strategies that may reduce the amount of marine debris in the area surrounding Ambalahonko.

3.5.2 Methodology
Beach cleans were typically undertaken twice per week, approximately one hour either side of low tide. Volunteers and staff would venture to the right of camp, passing Ambalahonko village and a small stream, or left to Black Rocks, collecting debris as they go between the water and tree line. For each piece of litter, the type and zone (sand, mangrove, tree line) in which it was collected was recorded. Upon collection, debris was sorted into flammable and non-flammable items for burning, or storage respectively. During Phase 172, a total of 11 collections took place to the left, and 11 took place to the right of base camp.

3.5.3 Results
During Phase 172, a total of 3341 pieces of marine debris were collected from sand, mangrove and tree areas along the coastline proximal to Ambalahonko Base Camp. 678 pieces were collected from mangrove areas, 2661 from sandy areas and 56 pieces from the treeline furthest from the water (Figs, 8-10). Plastic (unidentifiable plastic objects, plastic bottles and plastic bags) accounts for more than 50% of the total amount of debris found (Fig. 10). Along the left hand side of the beach plastic accounted for more than 70% of total debris (Fig. 9). Beach cleans on the left side of camp resulted in a higher amount of collected debris compared to the right side (55.4% and 44.6% respectively). 78 batteries in total were collected during this phase, 77 of which were found on the right-hand side of the beach, where the village of Ambalahonko is situated.

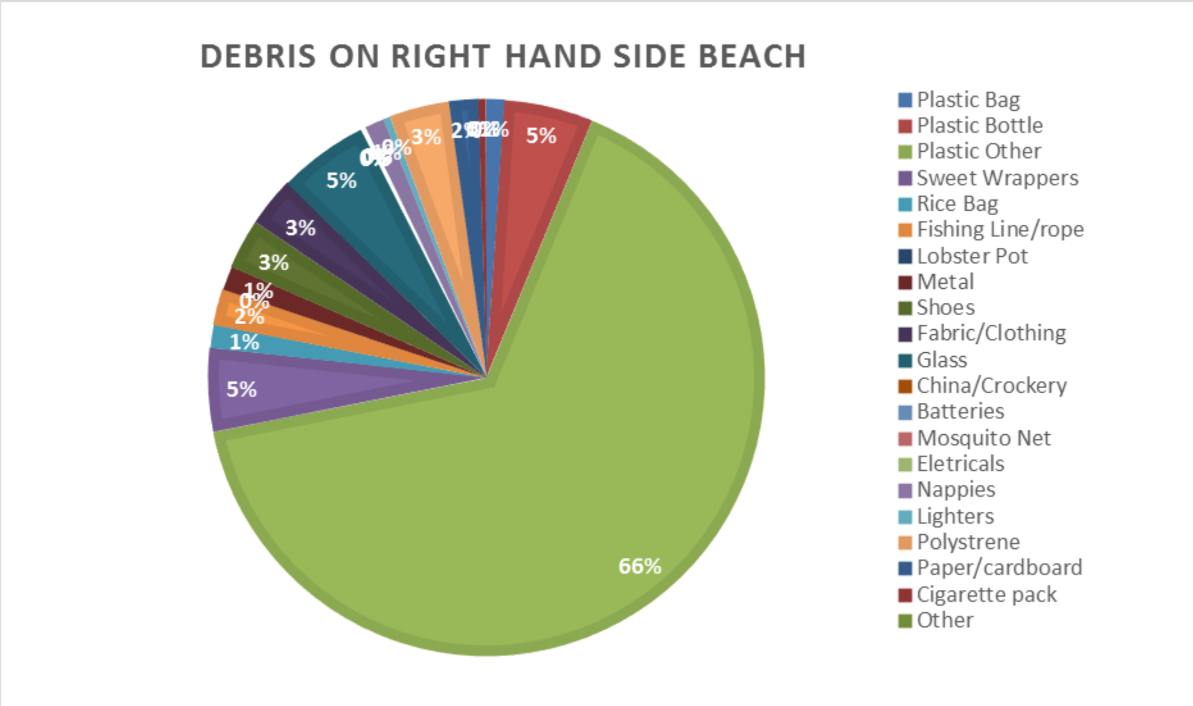

Figure 8: Composition of the debris collected during beach on the right hand side of Ambalahonko base camp.

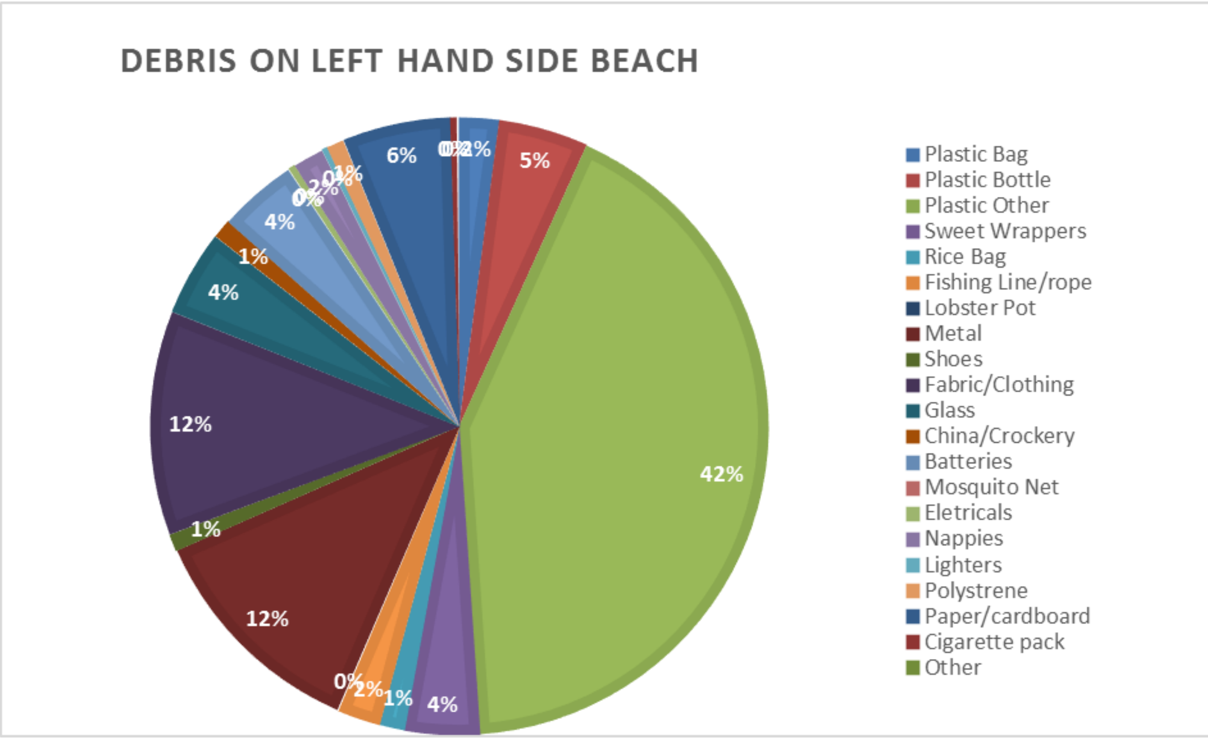

Figure 9: Composition of the debris collected during beach on the left hand side of Ambalahonko base camp.

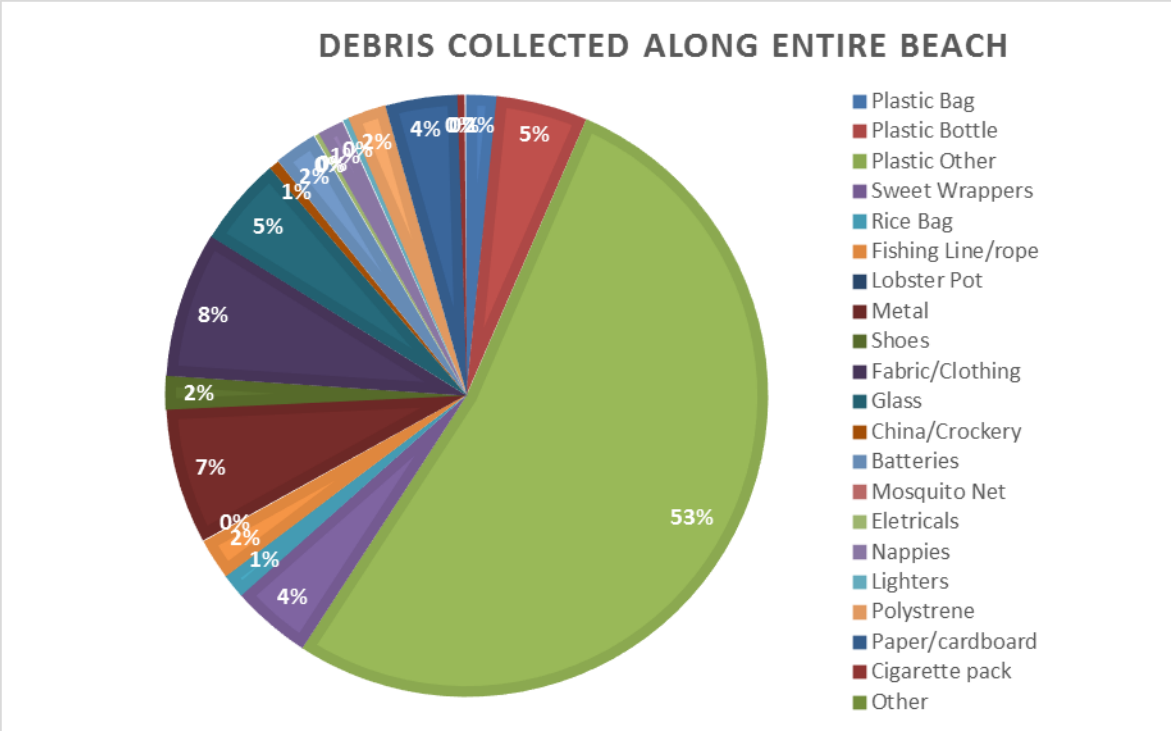

Figure 10: Composition of the debris collected during beach cleans to the left and right of Ambalahonko base camp.

3.5.4 Discussion

Consistent with previously published works, plastic items were the most common type of debris collected, and many were smaller fragments of unidentifiable origin and unknown age (Derraik, 2002; Santos *et al.*, 2008). The higher amount of certain debris types collected on the right side of camp can be explained by the location of the Ambalahonko village. Beach cleans on the right side include the beach area in front of the village; this is also the area where the highest amount of debris is collected.

There is a lack of education about the impacts of anthropogenic litter on the marine environment, a lack of litter collection and processing facilities, and a current lack of alternatives to the use of single use plastics. The introduction of Environmental Awareness Days, of environmentally safe waste disposal systems, the involvement of local communities in beach cleans, and a discussion about possible alternatives to the use of plastic products would be an excellent starting point for raising awareness and eventually reducing marine pollution.

For the longer term, like most countries, a general move away from reliance on single use plastic items is absolutely essential. This also holds true for batteries, which were frequently collected and are especially toxic. The distribution of battery collection strongly shows that they come from local use and are less likely to be brought in with the tide. Some progress could be made to reduce battery waste if funding was available to buy small solar panels that could then in turn charge reusable batteries.

3.6 Research Projects

A Preliminary Assessment of Small Scale Fishing Activity In Nosy Be, Madagascar.

Author: Ella Garrud

3.6.1 Introduction

Madagascar is the fourth largest island and the fifth poorest maritime country in the world, with approximately 75% of all households living below the poverty threshold (Le Manach *et al*., 2012; Barnes-Mouthe *et al*., 2013). Many of the people rely heavily on the ocean to survive, using marine resources both as a source of food and income, particularly in coastal communities (Le Manach *et al*., 2012). Over 50% of the population of Madagascar live by the coast and up to 87% of adults in some coastal communities are employed by the small-scale fisheries sector (Barnes-Mouthe *et al*., 2013).

There is no standard definition of small scale fisheries worldwide (Panayotou, 1982), however, in Madagascar they are typically those which are near-shore, fished by local people using small fishing vessels which have no motor, use a variety of gear and techniques and use very little modern technology (Mathew, 2002; Narozanski *et al*., 2011). Their catch is mainly used for subsistence or is sold to local markets (Mathew, 2002).

There is currently very limited information on the extent of the small-scale fisheries sector in Madagascar (Barnes-Mouthe *et al*., 2013). In the Madagascan government, the Ministry of Fisheries and Aquatic Resources is responsible for all fisheries, and other Government bodies are responsible for related activities, such as environmental regulation and planning of marine protected areas. These sectors are chronically underfunded and understaffed, and there is currently no official document that states the Government's fisheries policy, and any legal framework that does exist is incoherent and ambiguous. Consequently, small scale fisheries catches are often underestimated when being reported to official agencies such as the Food and Agricultural Organisation (FAO) of the United Nations, or remain completely unreported (Le Manach *et al*., 2011). Illegal, unreported and unregulated fishing (IUU) is known to be a major impediment towards sustainable fisheries management worldwide because the sustainability of fisheries is overestimated due to incomplete data (Sumaila *et al.,* 2006). Le Manach *et al.,* (2011) reconstructed the catch data reported to the FAO by the Government of Madagascar and found that the estimated reconstructed total is twice as high as the official reported data. This can partly be attributed to the data that is unreported and underestimated by the small-scale fisheries sector (Pauly *et al.,* 1997; Le Manach *et al.,* 2011).

There has currently been no research into the fisheries around the island of Nosy Be, Madagascar. The purpose of this study is to make a preliminary assessment of the fishing activities in the southeast area of the island with a particular focus on small scale fisheries. The aims of this study are to investigate what species of fish are being caught, the volume of fish being landed, the areas in which people fish, what gear is being used, how much fish is sold for in the local markets in Hellville, whether certain species are being targeted and whether any bycatch occurs. From this it will hopefully be possible to estimate a catch per unit effort for the different gears being used and species being caught.

3.6.2 Methodology

The proposed aims will be achieved by a number of different methods. Firstly, the researcher will set up informal interviews with a local artisanal fisherman and accompany him on his pirogue on fishing trips in order to obtain a better understanding of fishing methods that are being used in the area.

Secondly, after this initial stage, questionnaires will be used to gather data from at least 30 local small scale fishers on what species they catch, whether certain species are being targeted, where they fish and what species they catch in each area, what gear they use and whether they catch any bycatch. Thirdly, the researcher will make visits to the local fish markets in Hellville. Using photography analysis as the main method, the variables that will be collected are the species being sold, the average price for each species, and the number and size of the fish being sold.

3.6.3 Potential Outcomes

If this research is successful it will give an insight into the fishing activities of the southeast area of Nosy Be. The methods of this study could be used to collect data on the small-scale fisheries of other areas of Nosy Be and mainland Madagascar. The results of this study can potentially be used to implement sustainable fisheries policies for the area with the help of the people in the village of Ambalahonko.

4. Proposed Work Programme for Next Phase

4.1 Benthic Surveys

Benthic surveys will be introduced back into the science program. Using line-intercept transects to assess benthic categories (coral morphology, rubble, soft coral, sponge, etc). The precise lifeforms that will be used next phase are being discussed within the science team. This method also allows the documentation of live/dead coral. Benthic data is crucial when assessing the health and current status of coral reefs and compliments fish data.

4.2 Opisthobranch/Platyhelminthes Surveys

Opisthobranch (sea slugs) and Platyhelminthes (flatworms) are very good ecological indicators, meaning the abundance and diversity of such species can suggest the health of a coral reef system. The lack of species on a tropical reef will most likely suggest the health of the reef has been compromised, and on the contrary a high abundance and diverse group suggests a healthy functioning ecosystem.

The current proposed methodology for assessing abundance and diversity of these species is a belt transect (size is being discussed within the science team). The data provided with the belt transect methodology allows a quantity per area calculation. As these group of species are relativiely hard to identify, quality assurance can be conducted with a photograph taken of each species found on the transect. Generally a buddy pair of divers systematically search along the belt transect, and on an encounter they take a photograph, the length using a ruler/slate, and the substrate in which is the specimen is found upon.

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