Frontier Madagascar Environmental Research

REPORT 23

An initial rapid assessment of reefs and mangroves in Nosy Hara, Madagascar

2009

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Pegg, J., Gordon, L. and Steer, M. D.

ANGAP
Conservation International

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Nosy Hara
2009

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The Society for Environmental Exploration (SEE) has been conducting research into environmental issues since 2000 under the title of Frontier-Madagascar. The Frontier-Madagascar Marine Research Programme conducts research into biological diversity and resource utilisation of both marine and coastal environments, in Diego-Suarez Bay, in collaboration with ANGAP, Conservation International, and IBIS.

For more information:

Frontier -Madagascar
BP41, Antsiranana, 201
MADAGASCAR
Tel/Fax: +261 (0) 20 82 23117
E-mail:
frontier.madagascar@gmail.com

Society for Environmental Exploration
50-52 Rivington Street,
London, EC2A 3QP. U.K.
Tel: +44 (0) 20 7613 3061
Fax: +44 (0) 20 7613 2992
E-mail:
research@frontier.ac.uk
Internet: www.frontier.ac.uk

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	Ms. Shona McCann-Wood

FRONTIER-MADAGASCAR

Country Co-ordinator:	Miss. Elisabeth Middleton
Assistant Country Coordinator:	Miss. Chloe Searl
Principal Investigator:	Miss. Josephine Pegg
Research Officer:	Miss. Alison Evans
Assistant Research Officer:	Mr. Anthony King
Conservation Apprentice:	Mr. Luke Gordon
Malagasy Liason Officer:	Mr. Nicholas Clayderman
Dive Officer:	Mr. Daniel Shultz

Research Assistants:

Fran Billingsley, Hannah Tyson, Matt Hewitt, Katy Barton, Ruth Merrifield.

Also thanks to the staff of MNP Nosy Hara Special Reserve and the people of Ampasandave.

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Executive Summary

A rapid biodiversity assessment was carried out by the Frontier-Madagascar Marine Research Programme, of the status of the coral reef and mangroves in the Nosy Hara Special Reserve, Northern Madagascar.

Four coral reef sites were surveyed using the Baseline Survey Protocol methodology. Nosy Hara Special Reserve's reefs appear to be in relatively good health and have potential to be exploited for a variety of uses provided these are conducted in a sustainable manner. However, the lack of large fish, and low level of some invertebrate species, is cause for some concern and indicates conservation measures may need to be implemented.

Transect methodologies were used to survey 210 metres of mangrove forest. Clear zonation of two species of mangrove trees, *Ceriops tegal* and *Rhizophora mucronata* were recorded. Anthropogenic damage to the forest was observed on the landward side.

Nosy Hara Special Reserve provides an interesting comparison to Diego Suarez Bay. Although differing to some extent in their biological characteristics they face many of the same environmental threats and management challenges, for that reason inter-organisation co-operation should benefit both.

1. Introduction

1.1. Frontier History and Aims

The following report details the results of a rapid biodiversity assessment carried out by the Frontier-Madagascar Marine Research Programme; a collaboration between the Society for Environmental Exploration and L'Université d'Antsiranana. Initial assessments were made of the status of the coral reef and mangroves in the Nosy Hara area, Northern Madagascar

The Society for Environmental Exploration (SEE)
The Society is a not-for-profit organisation formed in 1989. The Society's objectives are to advance field research into environmental issues and implement practical projects contributing to the conservation of natural resources. Projects organised by The Society are joint initiatives developed in collaboration with national research agencies in co-operating countries.

Frontier-Madagascar Marine Research Programme (FMMRP)
The Society for Environmental Exploration (SEE) and L'Université d'Antsiranana have been conducting collaborative research into environmental issues in Diego Suarez Bay since 2005 under the title of Frontier-Madagascar. Prior to this the FMMRP was located in Tulear, southwest Madagascar. The Frontier-Madagascar Marine Research Programme conducts research into biological diversity and resource utilisation of both marine and coastal environments, and works with local stakeholders in the region, to protect Madagascar's marine life.

091 Staff:	Josie Pegg, Ally Evans, Anthony King, Luke Gordon, Nicholat Clayderman.
091 Research assistants:	Fran Billingsley, Matt Hewitt, Ruth Merrifield, Katie Barton, Hannah Tyson.

1.2 Nosy Hara Special Reserve Satellite Camp

Location

The Nosy Hara Special Reserve is situated in the north of Madagascar, in the Mozambique Channel. The reserve is managed by Madagascar National Parks (MNP, previously ANGAP) and encompasses a chain of islands, a section of mainland surrounding the village of Ampasandave and the surrounding seas (figure 1.).

Satellite camp programme

The staff and research assistants of FMMRP spent from the 9th-12th March 2009 at the Nosy Hara complex, during which time they divided into two teams to carry out coral reef and mangrove surveys. They were assisted during their stay by staff from MNP.

Purpose

The satellite camp's purpose was to gain an overview of the coral reefs and mangroves of the Nosy Hara area. FMMRP have been studying the marine life of Diego Suarez Bay for the last three years and are keen to study other sites in Northern Madagascar for comparative purposes. They also wish to gain a better understanding of the importance of Diego Suarez Bay in relation to Northern Madagascar's marine ecosystem, as well as to locate sites where the FMMRP team's skills and expertise can be utilised by other local conservation organisations. The FMMRP team were keen to learn from MNP staff about their experiences of managing the Nosy Hara Special Reserve, and offer suggestions based on their own experiences.

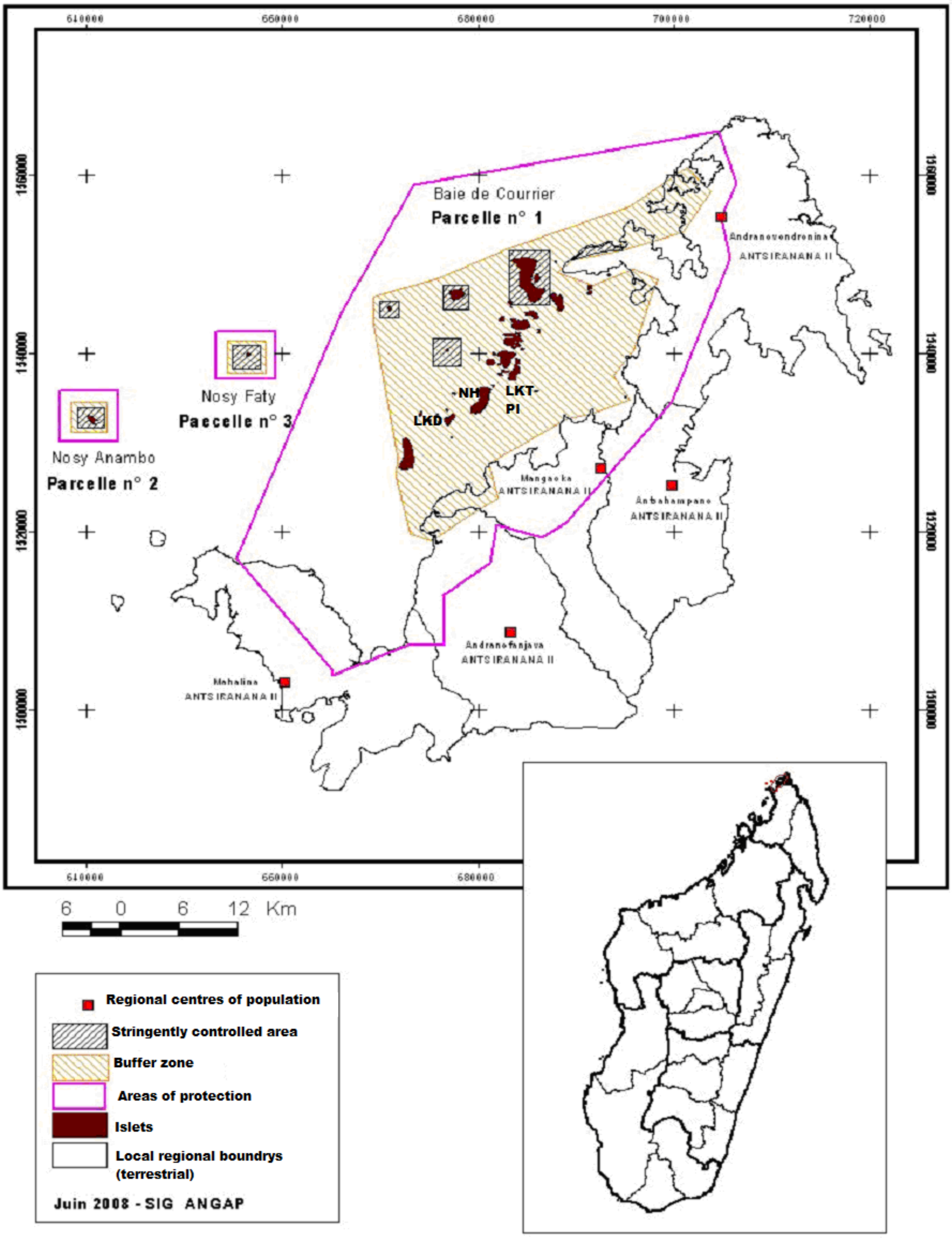

Figure 1. Map of Nosy Hara Special Reserve (Adapted from Madagascar National Parks, Plan de Suivie Ecologie, Parc National Nosy Hara, 2009) Survey sites marked LKD - Lakandava; LKT - Lakatandao; NH – Nosy Hara; PS – Piscine.

2. Coral reef survey. Baseline Survey Protocol

2.1 Introduction

Nosy Hara's coral reefs were surveyed using the Baseline Survey Protocol (BSP) methodology. BSPs provides data on benthic coverage, Underwater Visual Census (UVC) fish data, frequency of indicator invertebrates present, and a detailed account of the physical and environmental conditions of the site. It allows many aspects of the marine environment to be documented in a single survey. Two replicate transects were carried out at each site over two days (table 2.1).

Date	Site name	GPS	Number of survey transects completed
10/01/09	Lakandava	0674287 1532784	2
10/01/09	Lakatandao	0683239 1537721	2
11/01/09	Nosy Hara	0679553 1534890	2
11/01/09	Piscine	0682846 1537832	2

Table 2.1 Survey sites and effort

2.2 Materials and Methodology

The BSP is a four-person survey technique which can be carried out at a variety of depths using either SCUBA or snorkel. The sites surveyed within the Nosy Hara complex were all surveyed at shallow depths (0-4 m) using snorkel equipment. Each member of the survey team had individual duties:

- **Physical surveyor**

The physical surveyor took a bearing and laid a tape measure transect along a given depth contour, parallel to the shore. The first transect lay between 0-20 m (replicate *a*) and the second between 25 m to 45 m (replicate *b*) leaving a 5 m buffer zone between replicates. Environmental factors were recorded including depth, temperature and visibility at 0 m, 2 0m, 25 m, and 45 m. Water samples were collected (for future salinity and chemical analysis) at the beginning of each 20 m and rugosity was measured at the end of each 20 m transect. This was done by placing a 3 m chain along the tape measure following the contours of the substrate and recording the distance along the transect tape that it reached.

- **Fish surveyor**

The fish surveyor recorded the size and frequency of fish encountered along the transect in a hypothetical 5 m^3 box extending 2.5 m either side of the tape measure and 5 m above it. The size of any fish from a list of focal species (see appendix I) entering this space was estimated to the nearest 5 cm and recorded on a specially designed slate.

The fish and physical divers formed one dive team, allowing the fish surveyor time to observe the fish populations before they were disturbed by the presence of the other divers.

- **Benthic surveyor**

The LIT (Line intercept transect) surveyor recorded the benthic substratum which was found directly underneath the transect only and recorded the length against the tape measure (in cm) of each new substrate or coral genera. The end results of this technique were two 2000 cm lines with continuous descriptions of the underlying benthos, accurate to the nearest centimetre. The hard coral list was recorded to genus level only. This was done in order to reduce error in data collection, since differences between species within a genus are often only identifiable using microscopy, skeletal analysis and great experience.

- **Algae and invertebrates** (A&I)

The surveyor recorded any invertebrates within a 5 m wide corridor over the transect as well as generating an algal species list. The surveyor moved in a zigzag search pattern using the tape measure as the centre of the search zone. Any invertebrates were recorded to genus or family level, with the exception of some notable indicators which were recorded to species level. Algae were recorded on an ordinal scale from 0-5 (table 2.2). The benthic and A&I divers formed the second dive team, and followed behind the first pair.

Rating	Macroalgae
0	None
1	Rare
2	Occasional
3	Frequent
4	Abundant
5	Dominant

Table 2.2. Scale for determining algal abundance

A comprehensive fish species list was compiled for all sites by all competent surveyors from BSP surveys and informal survey (see appendix I).

2.3 Results

Physical

The sea temperature was between 29 and 30^{o}C. The pH was 6 and the salinity 34ppt. Underwater visibility was generally good and ranged between 5 and 11 metres. The sea state was calm to slight on both days. There was very little wind; its direction was predominantly north-westerly. Cloud cover ranged between 1-5 Oktas on 10/03/09 and 5-6 Oktas on 11/03/09.

Fish

There was little variation in the total numbers of fish, numbers of species and biomass between the four sites surveys. (figures 2.1, 2.2 and 2.3, see also appendix 1)

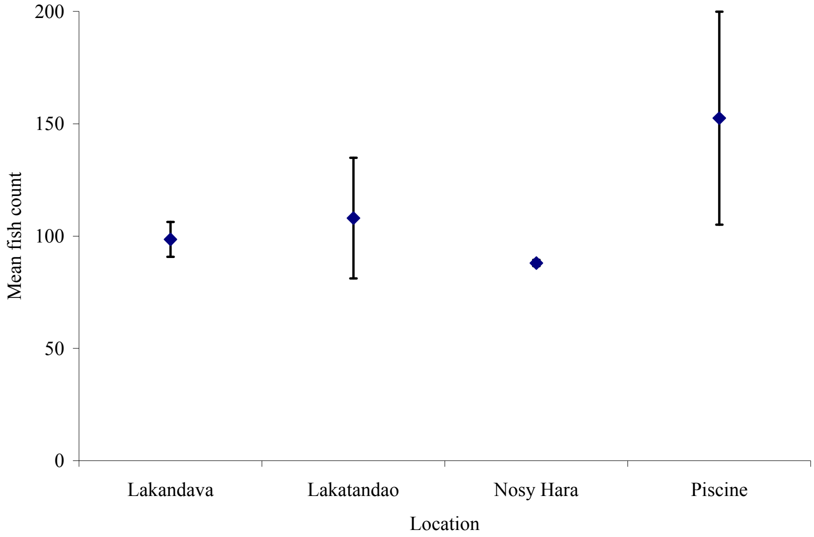

Figure 2.1. Mean fish count per 500m^3 transect at each of the four survey sites. Error bars denote one standard deviation from the mean.

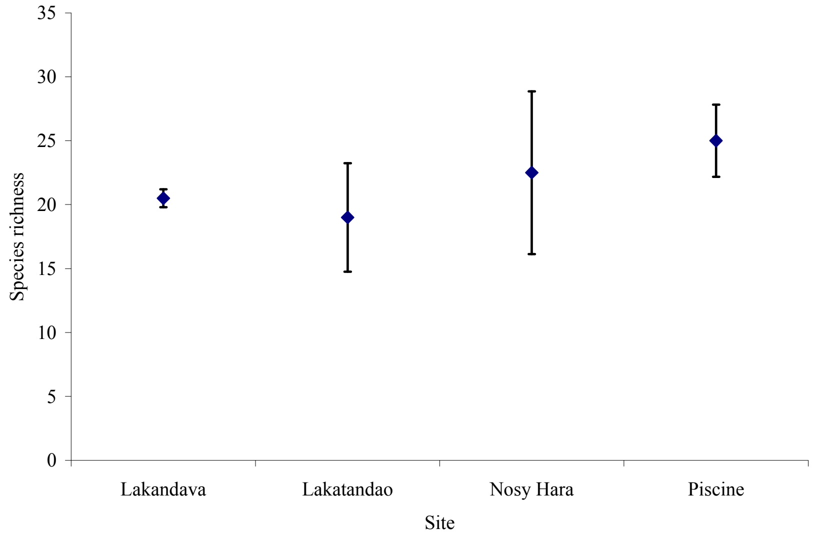

Figure 2.2. Mean species richness of fish per 500m^3 transect at the four survey sites. Error bars denote one standard deviation from the mean.

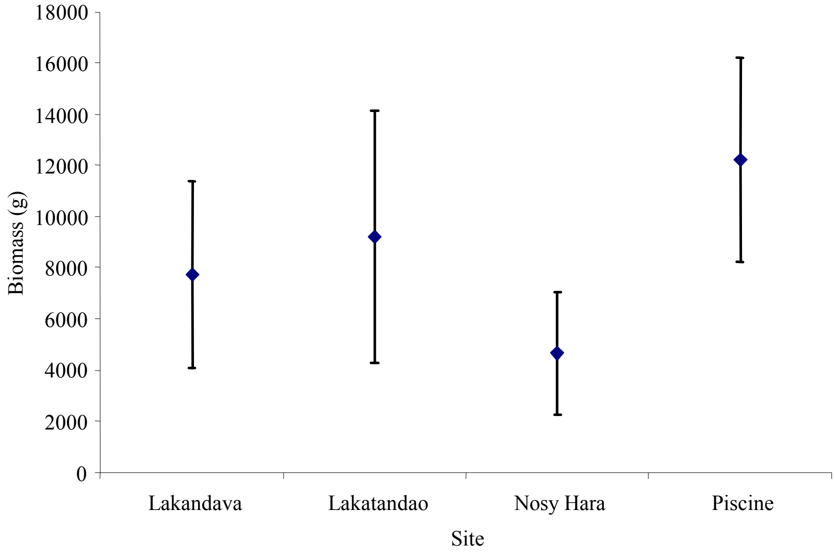

Figure 2.3. Biomass per 500m^3 transect for all species at the four survey sites. Error bars denote one standard deviation from the mean.

While relatively high numbers of fish were observed in each location, no fish larger than 40 cm were recorded (figure 2.4). Most fish fell into the 5 – 10 cm size bracket. Large numbers of slightly larger fish were observed at Piscine, these were predominantly Arabian spinecheek *Scolopsis ghanam* and onespot snapper *Lutjanus monostigma.*

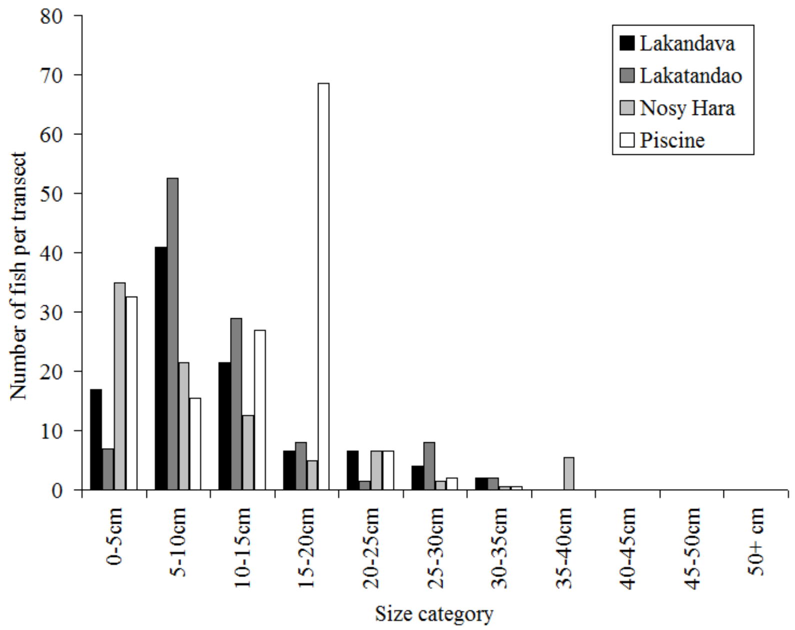

Figure 2.4 Size distributions for all species at the four survey sites.

Benthos

Hard coral was the dominant substrate at Lakandava and Piscine. Algae formed a significant proportion of the benthos at all sites. Algae was the dominant substrate at Nosy Hara and was present in an equal quantities to hard coral at Lakantandao (figure 2.5). Coral rubble made up a significant proportion of the substrate at Nosy Hara and Piscine.

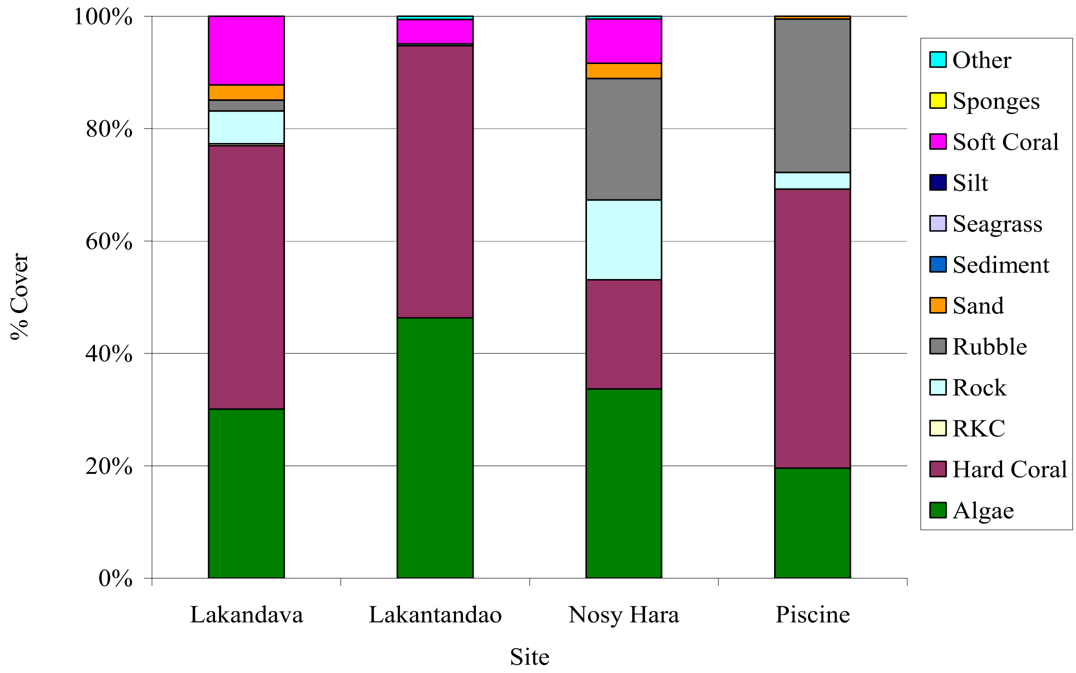

Figure 2.5 Percentage cover of all substrate types at the four surveyed sites. RKC = recently killed coral.

In total, nineteen genera of coral were recorded over all sites surveyed (table 2.3). *Acropora* was the dominant genera at all sites. Lakandava showed the greatest diversity, containing thirteen genera, but Lakatandao (n = 9), Nosy Hara (n = 10) and Piscine (n = 8) all showed relatively high levels of generic diversity. It is worth noting that, even though the hard coral cover was much lower at Nosy Hara than the other sites, the generic diversity was still comparable to Lakatandao and Piscine.

Family	**Genera**	**LKD**	**LKT**	**NH**	**PS**
Acroporidae	*Acropora*	30.83	40.18	7.25	43.70
	Astreopora	0.40	-	0.52	-
	Montipora	0.90	2.25	0.70	-
Faviidae	*Cyphastrea*	-	-	0.18	2.43
	Echinopora	0.58	-	3.23	0.55
	Favia	0.53	0.28	-	-
	Favites	0.25	0.77	-	-
	Goniastrea	-	2.03	-	-
	Montastrea	-	0.33	-	-
	Platygyra	1.70	-	1.45	-
Fungiidae	*Fungia*	-	-	-	0.33
Merulinidae	*Hydnophora*	0.35	-	-	-
Mussidae	*Lobophyllia*	-	0.68	-	-
Oculinidae	*Galaxea*	0.47	-	0.18	0.63
Pocilloporidae	*Pocillopora*	3.03	0.37	-	1.30
	Seriatopora	5.92	1.55	1.18	0.52
Poritidae	*Goniopora*	-	-	0.50	-
	Porites	1.48	-	4.25	0.20
Siderastreidaea	*Coscinaraea*	0.48	-	-	-
Total		**46.90**	**48.43**	**19.43**	**49.65**

Table 2.3. Percentage cover of each coral genus reorcded at the different survey sites. LKD - Lakandava; LKT - Lakatandao; NH – Nosy Hara; PS – Piscine.

Invertebrates

Nosy Hara showed considerably greater abundance and diversity of all invertebrates than the other sites (table 2.4). Mollusc numbers were low at all sites except Nosy Hara, where coral-boring bivalves were present in relatively large numbers. Sea squirts were fairly common at all sites and were the only invertebrate present in any significant numbers at Lakandava. The invertebrate population of Piscine was dominated by *Diadema setosum* urchins.

Algae

Overall, Lakatandao had the lowest levels of algae with all species present recorded as either rare or occasional (table 2.4). No species of red algae were recorded at either Lakandava or Lakatandao, but were abundant at Nosy Hara. The greatest diversity of algae was found at Piscine but none of the sites were dominated by a single algal species.

Phylum	Group	LKD	LKT	NH	PS
Echinodermata	*Echinometra* spp.	0.13	-	1.38	-
	Diadema setosum	0.13	-	0.50	5.88
	Ophiurida	-	-	0.50	-
	Other Asteroidea	0.13	0.13	-	0.13
	Crinoidea	0.13	0.25	3.13	-
	Echinoidea	-	-	2.50	-
	Holothuroidea	-	-	1.63	-
Mollusca	Octopoda	-	-	0.13	-
	Lambis spp.	-	0.13	-	-
	Cypraeidae	-	0.13	-	-
	Other Gastropoda	0.13	-	-	0.13
	Nudibranchia	-	0.13	0.13	0.13
	Opisthobranchia	-	-	-	0.63
	Tridacna gigas	-	-	4.63	-
	Ostreidae	-	-	1.13	-
	Pedum spondyloidum	-	-	21.25	-
	Other bivalvia	-	-	0.63	-
Crustacea	Brachyura	0.13	-	-	-
Annelida	Tube worm spp.	1.13	2.88	3.38	-
	Spirobranchus giganteus	-	-	-	0.13
Cnidaria	Actiniaria	-	1.50	0.13	0.75
	Jellyfish spp.	-	-	-	1.63
	Hydrozoan spp.	2.13	1.13	11.88	3.75
Hemichordata	Tunicata	37.63	20.38	43.00	9.63
Porifera	Sponge spp. (tube forms)	0.13	0.25	1.25	-
	Sponge spp. (encrusting forms)	-	2.00	3.38	-
	Sponge spp. (lumpy forms)	0.25	0.13	-	-
Total		**42.00**	**29.00**	**100.50**	**22.75**

Table 2.4. Mean number of invertebrates per 5 m^2 at each location. LKD - Lakandava; LKT - Lakatandao; NH – Nosy Hara; PS – Piscine.

Division	Type	LKD	LKT	NH	PS
Chlorophyta	*Neomeris* spp.	2.5	0.5	3.5	2.5
	Dictyosphaeria spp.	4	2	3.5	1
	Udotea spp.	0	0	0	0
	Halimeda spp.	2	2	3	3
	Valonia spp.	0	0	0	1
	Ventricaria ventricosa	2	0.5	1	0.5
	Bryopsis pennata	1.5	2	2	0
	Green filamentous	1	1	2	3
Phaeophyta	*Dictyota* spp.	0.5	0.5	0	0
	Turbinaria	0	0.5	0	1
	Padina spp.	3	0	3	1
	Brown filamentous	2.5	2	0	0
Rhodophyta	Branching coralline	0	0	4	4
	Encrusting corralline	0	0	0	3
	Red filamentous	0	0	0	2
Mean abundance		**1.19**	**0.69**	**1.38**	**1.38**

Table 2.5. Relative abundances of algae at each location. LKD - Lakandava; LKT - Lakatandao; NH – Nosy Hara; PS – Piscine

2.4. Discussion

Overall, the reefs appeared to be in healthy condition with a generally high biodiversity of fish, coral, invertebrates and algae.

The benthic substrate was dominated by hard coral. Nineteen coral genera were recorded, with *Acropora* being the dominant genera. Both the Nosy Hara site and Piscine had a fairly high proportion of coral rubble, the most likely cause of this is cyclone damage. Diego Suarez Bay, which opens eastwards into the Indian Ocean and hence is exposed to a greater degree to cyclone impacts from the east, has far greater signs of cyclone damage than the reefs of the Nosy Hara complex. Within Diego Suarez Bay over a quarter of the substrate is coral rubble, while live hard corals make up only 20%.

The high coral cover and generally healthy appearance of the Nosy Hara complex sites make them particularly suitable for recreational exploitation by divers and snorkellers. However, should the park be promoted to this end measures would have to be taken to ensure that damage resulting from these activities, such as boat or anchor damage, does not occur (Jameson *et al*., 1999, Tratalos and Austin, 2001).

No observations were made of the coral predator *Acanthaster plancii* or signs of its presence. However, this species has been recorded in Northern Madagascar to the south of the Nosy Hara complex (McKenna and Allen, 2003), and is renowned globally for its capacity to damage coral reefs. In surveys of the reefs of Northwest Madagascar (McKenna and Allen, 2003), *Acanthaster plancii* damage was the most frequently observed disturbance. Given the proximity of known populations, a monitoring programme to detect any potentially damaging outbreaks may be advisable.

A wide variety of fish species were present representing all the major coral reef families. There was little variation between sites in the overall diversity, number of fish or biomass. However, there was some between site variation in size ranges of fish recorded, in particular very high numbers of fish in the 15-10 cm size category were recorded at Piscine. In comparison to Diego Suarez Bay, the number, diversity and biomass of fish was higher within the Nosy Hara complex. The species' make up was generally similar between the Nosy Hara complex and Diego Suarez Bay and included most of the fish families commonly targeted by local fishers in Northern Madagascar. These families include Serranidae, Lutjanidae, Caesionidae, Letherinidae and Scarinidae. Considering the species compositions and size ranges recorded in this survey, Piscine appears to have the greatest fishery potential of the four sites surveyed. However the absence of fish recorded over 40cm may be an indication of overexploitation. As concerns sport fishing purposes, the species, and particularly the sizes of fish at all sites are less than desirable and other sites within the Nosy Hara complex may offer better prospects.

Nosy Hara site had a notably higher diversity and number of invertebrates than the other sites surveyed. Although the cause of this was not established by this survey, it was noted that this site also had a lower level of hard coral cover. The greater diversity of substrate types may provide more habitat niches for the benthic dwelling invertebrates, hence the greater diversity observed. Alternately, the reduced coral cover may have made those invertebrates present more visible, resulting in a skew in the data.

Nosy Hara was the only site at which holothurians or octopuses were recorded during the survey and then only at very low levels. However, it is impossible to say from this study whether these are naturally low levels or the result of anthropogenic intervention. Holothurians have been collected intensively for many years around Madagascar's coast and there is growing evidence to suggest that the fishery is experiencing problems. Sea cucumber fishing is now considered to constitute one of the major threats to the ecology of small islands that are commonly used as fishing bases (Cooke *et al.*, 2003), and may present a risk to the Nosy Hara complex's reef ecology. Similarly a holothurian fishery exists within Diego Suarez Bay; however local fishermen have reported collecting not only within the Bay itself but travelling to the Mozambique Channel to do so, although the Nosy Hara complex has not been specifically mentioned. Should MNP wish to take measures to protect this resource, it would have to be publicised to an audience beyond the reserve's limits to ensure immigrant fishermen were not in contravention of any conservation measures.

In summary, Nosy Hara's reefs appear to be in relatively good health and have potential to be exploited for a variety of uses provided these are conducted in a sustainable manner. However, the lack of large fish, and low level of some invertebrate species, is cause for concern and indicates conservation measures may need to be implemented. Although facing alternate seaboards and differing somewhat in their benthos and fish populations, the Nosy Hara complex and Diego Suarez Bay have many similarities, particularly in the potential threats they face. Further survey efforts would be useful to consolidate our initial findings.

3. Mangrove Transect

3.1 Introduction

Mangroves are a group of taxonomically diverse trees and shrubs adapted to conditions found in the intertidal zone. Mangroves, like hard corals, are found only in a band 23º to the north and south of the equator, and are the tropical equivalents to temperate saltmarshes. Their range is restricted by climate, temperature and freshwater supply either as rainfall or from rivers. Salinity, tidal fluctuations, exposure to wave action and sedimentation are also critical to the establishment and proliferation of mangrove stands. Mangroves have evolved to grow in anaerobic, saline soils between the mean tide level and upper reach of spring tide. They thrive in estuarine conditions, where in addition to tidal flow there is a constant source of fresh water bringing nutrients and sediment from the land.

Mangroves are important for a variety of reasons, both in terms of ecology and human value. They form a barrier between the sea and terrestrial landscape, reducing erosion of the land and acting as a sediment trap preventing any runoff from directly entering the sea. Coral, specific in its growth requirements, needs clear, oligotrophic waters. Mangroves as well as seagrass meadows help reduce sediment from reaching the water column, which would result in increasing water turbidity and smothering any sedentary reef flora and fauna (Nagelkerken, 2002). Fallen leaf litter and subsequent breakdown by microorganisms provides a release of nitrogen, phosphorus and other nutrients into the mangrove ecosystem for reuse (Holguin *et al.*, 2001). Algae such as cyanobacteria and diatoms grow within the mangrove ecosystem, with the roots and trunks of the trees providing a surface upon which to adhere and photosynthesise. Fallen detritus provides food for a variety of crustaceans such as the fiddler crab, mangrove lobster and penaeid shrimps. Molluscs including snails and whelks feed on fallen leaves or on algae, while oysters and mussels attach to the root systems to filter feed. Mangrove stands provide important feeding grounds for fish and the densely packed root systems provide excellent nursery areas for the juveniles of many coral reef fish. Mangroves have the ability to increase the biomass of coral reef fish communities. Birds are also attracted to the ecosystem, feeding in the rich mud, preying on the associated fish, or nesting in the dense evergreen canopy.

Many mangroves in Madagascar are subject to intensive human pressure for wood cutting, agriculture and other uses. Comparison of Landsat images and maps based on aerial photographs from the 1940s and 1950s indicate considerable change in mangrove cover over the years (Cooke *et al*., 2000). This survey contributes to MNPs ongoing mangrove monitoring. Furthermore, the mangroves within Diego Suarez Bay are naturally much smaller in size due to the topography of the bay and appear to have been reduced further still by harvesting, so provide an interesting comparison.

3.2 Materials and Methodology

Transect methodologies were used to calculate the number of stems per hectare and the biomass (kg m^{-2}), as well as assessing species composition. A single transect was set up perpendicular to the stand, running from the landward edge to seaward edge of the mangrove. The transect starting point was 12º16.238S 49º 07.555E and was laid on a bearing of 330º. It was 210 m length. It is the intention of the team to return and complete the transect to the seaward boundary at a later date.

A tape measure was laid along the forest floor following the direction of a compass bearing. Data was collected from all trees which fell into a 1m band to the right of the transect. Tree girth (circumference) measurements were made in mm at breast height following English's (1997) procedure and the species of tree was noted. This data collection is not as straight forward as it may seem and stipulations for measuring were as follows;

- If a tree forks below breast height measure each branch as a separate stem.
- If the tree forks at breast height or slightly above it, measure just below swelling caused by fork.
- It the stem has prop roots (as with *R. mucronata*) measure above highest prop root.
- If the stem as any irregularities or thickenings, measure slightly above/below.
- With saplings measure above the propagule around the developing stem.
- If the canopy is at breast height (as seen with stunted *C. tagal* stands) measure above the fluted lower trunk, or 20 cm above root collar.

The mangroves were identified using a mangrove field guide (Lovelock, 1993)

In order to convert the data collected on the mangrove transect, the diameter at breast height must be ascertained by dividing the circumference of the mangrove stem by π. This figure can then be used in equation 1,

$$Biomass = A_p DBH^B . \qquad (1)$$

Where *A* and *B* are allometric constants derived from Clough and Scott (1989), *DBH* is diameter at breast height collected from raw data and A_p is the antilog of *A*. Each tree species has different constants owing to their differing morphologies, which must be taken into account when calculating biomass. Only trees with a DBH of >10 cms were used in data conversion following the established protocol.

Notes were taken on the number and cause of dead trees and counts were made of animals along the transect.

3.3 Results

Ceriops tegal was overwhelmingly the dominant species from the landward margin of the stand. Closer to the sea *Rhizophora mucronata* started to appear (figure 3.1), and rapidly became the most important species in terms of biomass (figure 3.2). Although more *Ceriops tegal* trees were present between 110-160m than 60-110m, the biomass was less between 110-160m as on average the trees were smaller (figure 3.2). Between 50m and 60 there was a clear track, without any trees; whether this was natural or manmade is unclear.

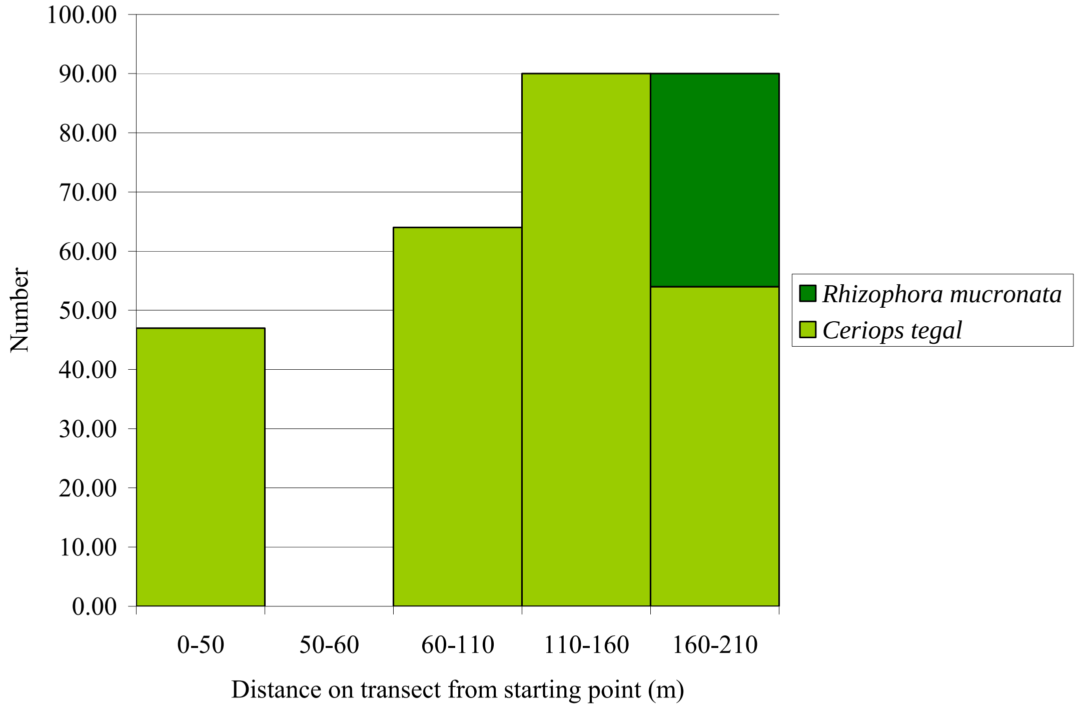

Figure 3.1 Number of mangrove stems on transect

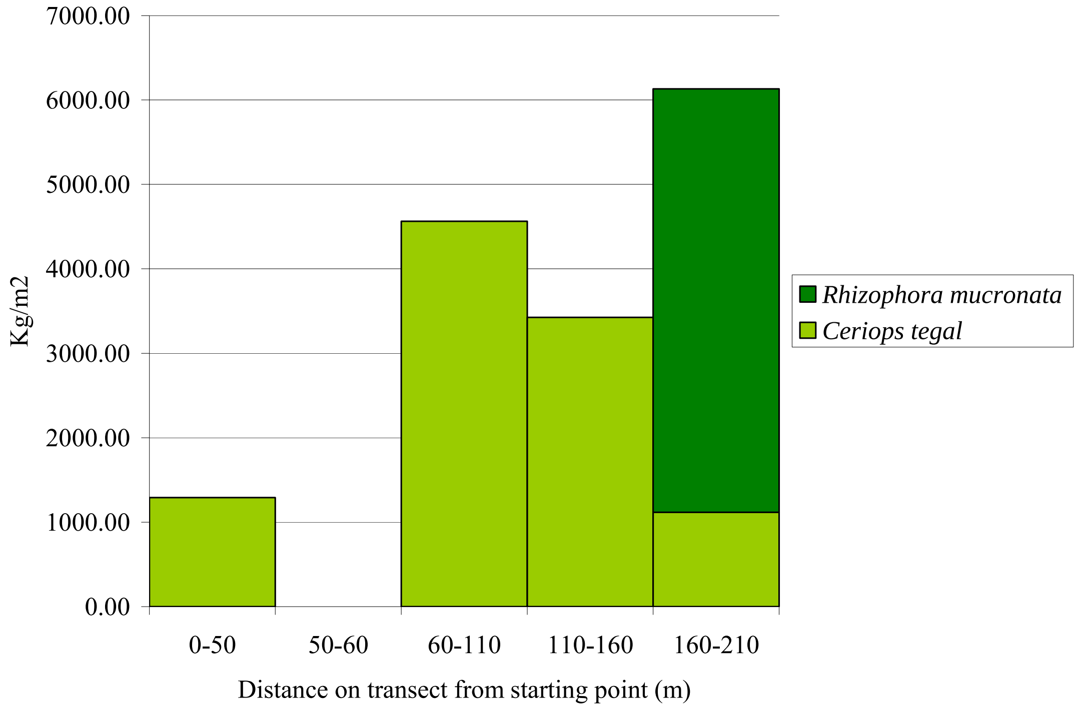

Figure 3.2 Biomass of mangroves on transect

There was a general decline in the occurrence of dead trees along the transect (figure 3.3). No dead trees were found from 160-210m. Anthropogenic-induced mortality was much more prevalent than natural mortality, but also showed more rapid decline with distance towards the sea.

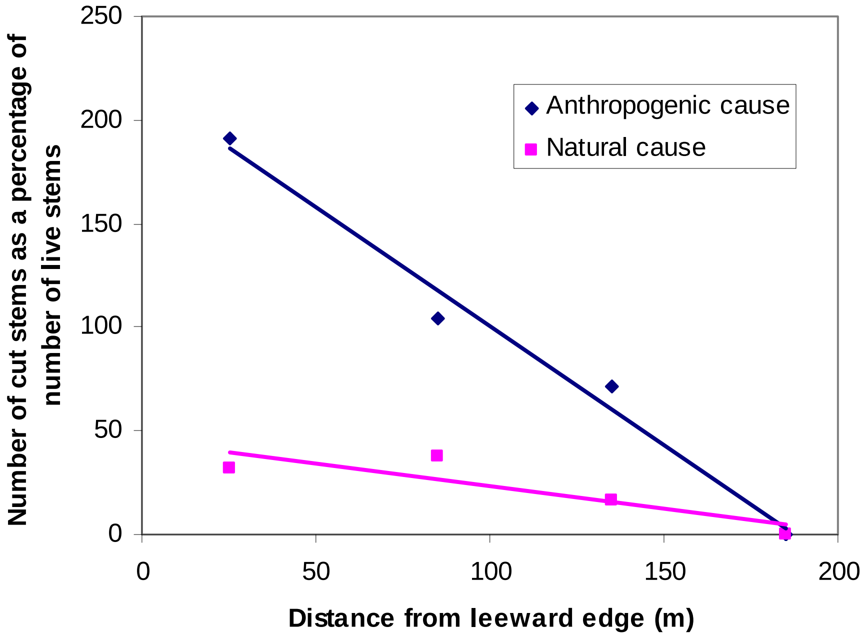

Figure 3.3. Natural and anthropogenic mortality of mangroves displayed as a percentage of the number of live stems.

Invertebrates were recorded along the length of the transect, including the section 50-60m where no trees were present. Crabs and molluscs were the most abundant. Interestingly, both showed decreasing densities moving towards the sea (figure 3.4). The result for the crabs, however, was strongly skewed by the very high number observed in the cleared area from 50-60 m. Mudskippers, spiders and dragonflies were also recorded in low numbers.

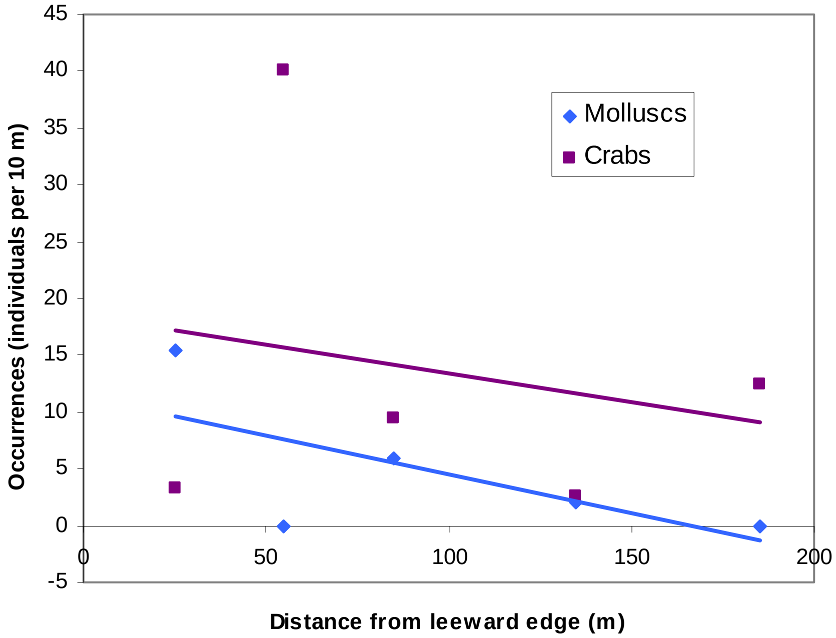

Figure 3.4 Densities of crabs and molluscs along the mangrove transect.

3.4 Discussion

There was a clear zonation pattern in the mangrove stand, the landward side containing almost exclusively *Ceriops tegal*. *Rhizophora mucronata* were present from 160m into the stand. As may have been predicted, where trees were removed by humans, most impact was observed on the landward side of the stand, with the level of dead trees from anthropogenic causes decreasing with distance into the stand.

The fauna recorded were typical of mangroves previously surveyed in Madagascar (Frontier Madagascar, unpublished data).

The presence of only two species may indicate a loss of diversity resulting from prolonged usage, however, as only a portion of the stand has been surveyed it is imprudent to draw definite conclusions.

Completion of the transect to the seaward extent will build a fuller picture of this mangrove stand.

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5. Appendix

Abundance of fish species observed in Nosy Hara Special Reserve during the two-day survey.

Family	Species		LKD	LKT	NH	PS	Total
Acanthuridae	*Acanthurus xanthopterus*	Yellowfin Surgeonfish			4		4
	Ctenochaetus striatus	Striped Bristletooth	10	3	4		17
	Zebrasoma desjardinii	Desjardins' Sailfin Tang		2			2
	Zebrasoma scopas	Brushtail Tang		7			7
Belonidae	*Strongylura incisa*	Reef Needlefish			11		11
Caesionidae	*Caesio caerulaurea*	Scissor-Tailed Fusilier		6			6
Chaetodontidae	*Chaetodon auriga*	Threadfin Butterflyfish		2	6	4	12
	Chaetodon guttatissimus	Spotted Butterflyfish			3		3
	Chaetodon lunula	Racoon Butterflyfish	2	1	1		4
	Chaetodon melannotus	Blackbacked Butterflyfish		1		4	5
	Chaetodon trifascialis	Chevroned Butterflyfish	17	16	4	5	42
	Chaetodon trifasciatus	Redfin Butterflyfish	4	4	12	4	24
	Chaetodon zanzibarensis	Zanzibar Butterflyfish	2				2
Gobiidae		Other Gobies			6		6
Haemulidae	*Plectorhinchus gaterinus*	Blackspotted Sweetlips	3	4			7
Holocentridae		Other Soldierfish				1	1
		Other Squirrelfish				1	1
Labridae	*Cheilinus chlorourus*	Floral Wrasse	4	2	1	3	10
	Cheilinus fasciatus	Red-Banded Wrasse	3			1	4
	Cheilio inermis	Cigar Wrasse				1	1
	Gomphosus caeruleus	Indian Ocean Bird Wrasse			4	1	5
	Halichoeres hortulanus	Checkerboard Wrasse			4		4
	Halichoeres scapularis	ZigZag Wrasse				1	1
	Hemigymnus fasciatus	Barred Thicklip Wrasse		1			1
	Hemigymnus melapterus	Blackedge Thicklip Wrasse			1	1	2
	Labroides dimidiatus	Bluestreak Cleaner Wrasse	6	5	2		13
	Thalassoma hebraicum	Goldbar Wrasse	1	2	6	2	11
	Thalassoma lunare	Crescent Wrasse	6	3		2	11
		Other Wrasse	4	5	15		24
Lethrinidae	*Lethrinus harak*	Blackspot Emperor	5	5	8		18
	Lethrinus mahsena	Sky Emperor	2			8	10
Lutjanidae	*Lutjanus monostigma*	Onespot Snapper	4			55	59
		Other Snapper				28	28
Monacanthidae		Other Filefish			2		2
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe Goatfish	1				1
		Other Goatfish		3	2		5
Nemipteridae	*Scolopsis ghanam*	Arabian Spinecheek				55	55
Ostraciidae		Other Trunkfish		1			1
Pomacanthidae	*Pomacanthus chrysurus*	Ear-Spot Angelfish				1	1
	Pomacanthus imperator	Emperor Angelfish	3				3
	Pomacanthus semicirculatus	Semicircle Angelfish		2	1	2	5
		Other Angelfish	1				1
	Abudefduf natalensis	Natal Sergeant	5	7			12
	Abudefduf sexfasciatus	Scissor-Tail Sergeant	3		3	2	8
	Abudefduf sparoides	False-Eye Sergeant	25		5	2	32
	Amblyglyphidodon leucogaster	Whitebelly Damsel	4		2	3	9

	Amphiprion akallopisos	Skunk Anemonefish		3			3
	Amphiprion latifasciatus	Madagascar Anemonefish		2			2

Family	**Species**		**LKD**	**LKT**	**NH**	**PS**	**Total**
Pomacanthidae (cont.)	*Chromis viridis*	Blue-Green Chromis	38	15	25	42	120
	Dascyllus aruanus	Humbug Dascyllus	5	8		12	25
	Neoglyphidodon melas	Black Damsel	10		5	7	22
	Pomacentrus sulfureus	Sulphur Damsel	1	7		4	12
		Other Damselfish	29	74	32	34	169
Scaridae	*Chlorurus sordidus*	Bullethead Parrotfish	11	6	1	13	31
	Scarus frenatus	Bridled Parrotfish				2	2
	Scarus ghobban	Bluebarred parrotfish	4	4	1		9
		Other Parrotfish				3	3
Tetraodontidae		Other Pufferfish			4		4
Zanclidae	*Zanclus cornutus*	Moorish idol		1	1	1	3
Total number of species			**29**	**30**	**30**	**32**	**121**
Total number of individuals			**213**	**202**	**176**	**305**	**896**

LKD - Lakandava; LKT - Lakatandao; NH – Nosy Hara; PS - Piscine