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Comparison Study of Fish Species Richness of Two Mangrove Forests on Misali Island: Eastern (Extractive) v. Western (CORE) Mangrove Forests

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Comparison Study of Fish Species Richness of Two Mangrove Forests on Misali Island:
Eastern (Extractive) v. Western (CORE) Mangrove Forests

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Acknowledgements

Thanks would like to be sent out to all of the Misali rangers who took care of us while we were on the island, cooking us our meals and answering any questions we had, as well as the fisherman in the area who kept us company during our two week stay and answered any questions we had. A special thanks goes out to Mohammed Said Suleiman and Haji Mohammed Haji, as they were our primary helpers and contacts. Thanks would also like to be extended to the homestay families for giving us a place to stay during our work period and feeding us. Thanks also given to Jaclyn Lucas, who took time out of her own schedule to assist me in my own work, especially since she was slightly injured in the process. She was a great helper in giving me someone to bounce ideas off of. Thanks goes out to Narriman Jiddawi for her assistance as being my advisor for this project and giving me initial direction. And finally, thanks goes out to the SIT staff, for which if they had not helped none of this would have happened. Said Hamad made sure that all was taken care of and that I always had proper plans, and Dr. Nat Quansah assured that I was going down the right path and that my project was properly focused. All of those in the office also were of much help because they assisted in preparing us for our two week long stay on Misali.
The fish species richness of two mangrove forests adjacent to non-extractive and extractive zones, respectively, was investigated on Misali Island, Tanzania. Observations were done at each site for seven samplings, recording the different species observed upon each visit. A general list of species found in the intertidal area was also composed to get an idea of what species use this region as well. A total of twenty-four species were observed between the two sites, leading to a similarity index of 0.29, representing very little similarity between the two stands. Two different diversity indices (Shannon-Wiener and Simpson’s) also supported the hypothesis that the CORE zone has a more diverse range of fish species than its counterpart area, while the richness index showed that the CORE zone was nearly threefold greater in fish species. These results may be caused by the physical, biological, and human impact dissimilarities between the two areas, allowing for a difference in fish species entering each area.
Introduction

Environmentally, Tanzania is regarded as as one of the 20 “mega biodiversity” regions of the world (Abdullah et al., 2000). Of this East African country, the Eastern Arc Mountains and the coastal forest center are one of twenty-five of the most important biodiversity areas world-wide (Abdullah et al., 2000). Zanzibar, an archipelago that is off the coast of Tanzania and also included in this area, hosts many endemic species that help give this region of Tanzania such distinction. These endemic species include both fauna and flora, including the Red Colobus Monkey, Pemba Flying Fox, and the Pemba White-Eye, as well as the endemic Pemba Palm Tree (Frontier-Tanzania, 2004b). The many different ecosystems that make up the Zanzibar archipelago help contribute to the high biodiversity. Stretching from the bountiful coastal waters with coral reefs and seagrass zones, as well as the diverse forests that inhabit the terrestrial section, Zanzibar can be considered a biological hotspot in Tanzania all its own.

Pemba, the northernmost island of the Zanzibar archipelago, has several smaller islands in the channel between it and mainland Tanganyika. Misali is one of these small islands, and has been under local conservation since the mid 1980’s (Abdullah et al., 2000). This island is approximately ten kilometers west of the city of Chake-Chake (Julius, 2005; Gougian, 2007), and a broad range of unique environments are present because of the strong conservation efforts put into place to protect this island and its abundant
resources (Daniels et al., 2003). The island is primarily dominated by coral rag forest, but has small stands of mangroves and many sandy beaches also on the terrestrial portion. A large intertidal range surrounds the whole island, with a 9.4 km stretch of coral reef encircling that (Frontier-Tanzania, 2004b).

The island itself and the area surrounding Misali is under the control of MICA (Misali Island Conservation Association), an NGO which was formed in 1998 (Daniels et al., 2003). MICA consists primarily of local fisherman from the sheiha’s that use the island’s waters as fishing grounds (Bryceson, 1994; Daniels et al., 2003). This assemblage of fishermen control the 21.58 km$^2$ area (Frontier-Tanzania, 2004b) of MIMCA (Misali Island Marine Conservation Area), which consists of the island and much of the water surrounding the island. As of 2005, the Pemba Channel Conservation Association (PECCA) took control of MIMCA and the rest of Pemba Channel, making MICA somewhat obsolete, but still a group used by the fisherman in the area for local organization (Daniels et al., 2003). But under this new control, PECCA has focused on the sustainable use of the natural resources in the Pemba Channel and Misali Island.

Under MIMCA, Misali waters have been divided into two separate zones: an extractive zone and a non-extractive (CORE) zone (Frontier-Tanzania, 2004b). The extractive zone makes up 19.28 km$^2$ of the MIMCA area, and is available to have resources taken from the waters by locals. Yet
the CORE zone is 1.4 km$^2$ of the western coast of the island past the intertidal zone (Daniels et al., 2003). In this area, only recreational activities and research are allowed to happen in this area, so no activities that extract or harm the resources are supposed to occur in this area. The fisherman utilize the extractive zone as their local artisanal fishing grounds (Bryceson, 1994), and some of the intertidal area for octopus, sea cucumber and other mollusk gathering.

There are no permanent settlers on the island, but it is monitored by rangers who live on the island year round and enforce the rules laid out by PECCA for conservation of the area’s natural resources (Frontier-Tanzania, 2004b). They rotate weekly between four rangers, having two to three rangers on the island at a time. They patrol the whole Pemba Channel, but lack of resources such as fuel make normal patrols difficult for the rangers to undergo, so they focus mainly on patrolling Misali Island. The island is also commonly shared with the local fisherman who spend approximately two weeks a month on the island camping so they can use the waters for fisheries (Frontier-Tanzania, 2004b).

Worldwide, mangrove ecosystems cover 150,000 km$^2$ of land, 35,000 km$^2$ in Africa, most of this area in East African countries (Frontier-Tanzania, 2004a). Misali holds several small stands of these limitedly studied areas of the Zanzibar archipelago. A total of 21,000 hectares of mangrove forest cover the two islands (Mushi, 2009). Approximately 7,000 hectares of forest
are located on the larger, more populated island of Unguja to the south. Pemba has 14,000 hectares of mangrove forest, comprising 14.2 percent of the terrestrial habitat (compared to Unguja’s 5.0 percent) (Frontier-Tanzania, 2004a).

These forests have been found to be one of the most productive ecosystems worldwide (Singkran & Sudara, 2005), believed to provide up to 25% of global biological production and large support for a majority of the world’s fisheries (Julius, 2005). Mangroves are known to support rich numbers of important species because of the physical habitat, high source of available nutrients, sediment stabilization and carbon fixation (Singkran & Sudara, 2005; Clausen, 2010). Zanzibar mangroves are known to produce between seven to eighteen tons of leaf litter a year per hectare, giving the mangrove forest their high level of nutrients (Gougian, 2007). Mangrove stands are also known to be great filters of the environment, showing a good correlation with decreasing anthropogenic waste levels in areas where present (Lugendo et al., 2006; Daniels et al., 2003). The availability of the pneumatophores, prop roots, and tree trunks allow for places of safety for many species, terrestrial and aquatic, including those belonging to crustacean and fish families (Hindell & Jenkins, 2004; Mumby et al., 2003). Because of this high availability of nutrients, clean environment and safety, many of the species that are found within a mangrove forest can be found to
be linked directly to valuable fisheries (Robertson & Duke, 1990 from Hindell & Jenkins, 2004; Lugendo et al., 2007).

The Misali Island mangroves have been found to be economically important for several reasons, including the accessibility of food, wood materials, and tourism attraction (Abdullah et al., 2000; Islam & Haque, 2004). Though now no wood is taken from the forests because they are a protected resource (Daniels et al., 2003). This is very important because destruction of the mangrove habitat normally causes dramatic decrease in species diversity (Singkran & Sudara, 2005, Islam & Haque, 2004). Preservation of these ecosystems is important because it has been noticed several important species use the area as a feeding ground or a nursery ground (Alongi, 2002). One important fishery species, *Lethrinus harak*, has been commonly observed using the mangroves by several other studies (Gougian, 2007). The mangroves also provide homes for crustaceans and gastropods, which many species will enter the stands to come and feed on during high tide (Islam & Haque, 2004). Because of how open the mangrove ecosystems are, they are believed to hold a direct impact on the local reefs (Laegdsgaard & Johnson, 1995; Frontier-Tanzania, 2004a). The health of the mangroves keeps some species of fish on the reef, helping keep the intrigue of the coral reefs of Misali a high tourist attraction.

Worldwide, there is a paradigm that is believed that mangroves are critical for sustaining production in coastal fisheries because they act as
juvenile nurseries for fishery species (Manson et al., 2005a, b). Juvenile fish populations are very abundant in many mangrove forests because of their high availability of nutrients and safety from predator species (Lugendo et al., 2006; Manson et al., 2005a, b). This is because many larval fish get caught in these areas that drift here from the offshore spawning areas (Laegdsgarrd & Johnson, 1995). But there is an uncertain correlation with how relevant the mangrove forest is to keeping a fishery stock in good quality, or if it is just a waypoint for the fish larva during a certain stage of its life cycle (Tongnunui et al., 2002). As many as 79 distinct fish species have been counted in Taiwan (Kuo et al., 1999 from Hindell & Jenkins, 2004), 60 in Madagascar (Laroche et al., 1997 from Hindell & Jenkins, 2004), and 42 in Australia (Halliday & Young, 1996 from Hindell & Jenkins, 2004), showing biodiversity is high in all areas where mangrove stands are found. Since mangroves are an open ecosystem and influence the health of the surrounding ecosystems, such as mudflats, seagrass beds, and coral reefs, they are vital in maintaining regional health. This has shown that species diversity in mangrove areas is higher than those areas that surround it, such as seagrass beds or mudflats, which are predominated by many fish, but low in diversity (Tongnunui et al., 2002; Mazumder et al., 2006). Only the reefs are found to have a higher diversity, because of their abundance of organisms from many different classes (Laroche et al., 1997).
The overall species richness of the mangroves for fish species is very important to the conservation of what may be Misali Island’s most intriguing attribute; the reefs (Frontier-Tanzania, 2004b). If mangroves were diminished on the island, then it could show a negative impact on the fish diversity of the reefs and other pelagic waters, which bring both the fisherman and the tourists to the island (Mumby et al., 2003, Manson et al., 2005b). During this study, fish species richness was to be observed to get a sense of what species use this ecosystem for some part of their lifecycle, and if there was a difference in species observed between the western and eastern mangroves. It was believed that the western mangrove stand would have a greater species richness than its eastern counterpart because of its proximity to the CORE zone.

**Study Area**

This study took place on the small island of Misali located off the western coast of Pemba Island. Along with Unguja Island as well,
these two islands and their many small surrounding islands make up the Zanzibar archipelago, which is part of the country of Tanzania. Misali Island is located approximately ten kilometers west of Chake-Chake, the second largest city on Pemba (Frontier-Tanzania, 2004a, b). The island has an approximate landmass of 0.9 km$^2$ (Gougian, 2007), consisting primarily of coral rag substrate. Much of the island is then covered in coral rag forest, but small patches of the island are made up of sandy beaches and mangrove forests.

There are a total of twelve mangrove stands located on Misali Island, but only two are of considerable enough size to consider studying (Frontier-Tanzania, 2004a). An expected total of five different mangrove species are expected to be found on the island, as well as one mangrove associate (Abdullah et al., 2000; Frontier-Tanzania, 2004a). For the purpose of this study, the two stands were adjacent to the two separate extractive zones of Misali: the western mangroves adjacent to the CORE zone, while the eastern is inside the extractive zone (Figure 2).

**Study Site A: The Western Mangrove Stand**

This stand is located near the southwest corner of the island, and is adjacent to the beach and intertidal areas of the CORE zone. The total area of the stand is approximately 3,500 m$^2$ (Gougian, 2007), perched mainly on top of coral rock that has been exposed by the sea. A small channel on the
south side runs into the stand from the intertidal zone, flooding the whole mangrove area. Flooding of the area only occurs during high tide because of the shallowness and proximity of the intertidal zone. Small pockets of water can be found during low tide, but only in deep pools that are worn out and are not able to be completely drained. Further into the forest, there are sandy areas where it seems the sediment has been deposited as tides switch, making a somewhat softer bottom above the coral rock and causing a noticeable divide in the stand between few trees located on top of the coral rock to the back portion where mangroves can be found standing in the water during high tide on top of the sand-covered coral rock.

The region is primarily dominated by both *Ceriops tagal* and *Rhizophora mucronata*, showing some kind of zonation as they seemed to have separate stands inside the forest. Small *Bruguiera gymnorrhiza* individuals were recognized inside the stand, but were not common. Also, a mangrove associate, *Pemphis acidula*, was common along the outside and along the channel of the forest.

*Study Site B: The Eastern Mangrove Stand*

This stand is located on the eastern most side of the island, neighboring East island, which is located in the middle of the areas intertidal zone. It is also adjacent to the large extractive zone, located very near where the local *wavuvi* do their *dagaa* fishing and not far from the area
where they do their *mishipi* fishing (Bryceson, 1994). It is estimated to be 17,640 km² in area (Gougian, 2007), nearly five times greater the size of the western mangroves. This area though is stationed on top of sand, which is uncommon for mangroves as they are usually stationed on top of a muddy substrate because of the high levels of detritus in the area. Coral rag outcrops border the most seaward sides of the stand, giving it some protection from incoming wave action. Just like it’s sister forest, this area is completely flooded during high tide and completely devoid of water during low tide, exposing the great network of prop roots and pneumatophores. During high tide, the water is very murky and visibility into the water is very limited.

The area is dominated by three different mangrove species, each having a unique zonation area within the stand. *Sonneratia alba*, *R. mucronata* and *C. tagal* are the three dominating species, comprising stands of their own in separate areas of the mangrove forest. Once again, *B. gymnorrhiza* was very sporadically found in the area, but not frequently enough to be considered to have an area considered a stand. *P. acidula* was once again observed along the high tide line of the intertidal area and beach.

*Intertidal Zones*

The intertidal zones surrounding both stands were examined to locate fish species that used the intertidal zones during low tide as the mangroves
were devoid of water. Both intertidal zones were located directly outside of each stand, and would flood as the high tides would return to the mangrove forests (Figure 2). Seagrass beds were also initially going to be used for this study, but were found to be too far from the mangrove sites and not always covered by the tides to be used. Thus decreasing the amount of data able to be gathered.

Methodology

Each of the two stands were located through examination of the island on the first day, as well as looking at the other sites to see if they were worthwhile to include in this study. The two stands were labeled “East” and “West” based on their geographical location on the island. Since fish species were the only things that were being counted in this study, the mangrove could only be visited when water was present, so working time was limited to high tides.

Each of the sites was visited a total of seven times during a high tide, whether in the morning or the afternoon, when light permitted observations. During observations, each stand was explored for time periods between 60-120 minutes depending on time of day and tide flow. Species that were observed were recorded, but a population count was not done for any of the species because of the low visibility in the East mangroves and the high numbers of fish in some of the larger schools, so guesses were not taken.
Quadrats and transects were not possible because of the small size of the mangrove forests. A small note about location in the mangroves was also recorded, hoping that some kind of trend could be distinguished. Identification of each species was done either at the site or through the use of four separate text (Frontier-Tanzania, 2004b; Lieske & Myers, 2002; Richmond, 2002; Anam & Mostarda, 2012).

For intertidal results, each area was traversed once for a period of three hours during a low tide, on days with similar weather conditions. Each small tide pool come across was examined for any possible species that could be found. Observations and notes were recorded about what species were found in general in each of the two zones, and the zones were combined to get a general sense of the species that could be found in Misali tide pools. Identification was done once again using the four texts previously noted.

Data was compiled based on which mangrove stand each species was observed, and a total count was done for total number of times each species was observed in each stand. A simple calculation was done to determine how many species a day was observed in each area, and then a similarity index was computed to contrast the two mangrove forests. Also run was an incidence-based estimator (ICE) value to give a species richness account. Shannon-Wiener and Simpson’s’s diversity indices were calculated for a
comparison between the two sites. Intertidal data was compiled on one chart to show the species that are found amongst the mangroves as well.

Results

A total of twenty-four species were found between the two mangrove forests (Table 3). Twenty-one of those species were observed at the western mangroves, whereas only seven species were observed at the eastern site. Three unique species could be found at the eastern mangroves, whereas a total of seventeen species were unique to the western stand. Of the twenty-four, only four species were common to both areas, including two species of moray eels (*Siderea picta* and *Echidna nebulosa*), *Lethrinus harak* and *Scolopsis ghanam*. All of the Gobiidae (Gobies) species were found exclusively in the western mangrove stand. It was also recognized that the density of fish observed in the western mangroves was greater than in the eastern mangroves, though a population count was never undertaken.

The total number of species observed every day was nearly three times greater in the western mangroves than in the eastern mangroves. With an average of 10.7 species a day observed, the species richness was much greater (Table 3). The largest number of species observed on one given day...
was seventeen, where the lowest number ever observed was nine. This is in contrast to the eastern mangroves, where the highest number ever observed on a given day was seven (Table 1). With an average of 3.6 species observed a day, the eastern mangroves showed low species richness (Table 3). Data for the eastern mangroves was slightly skewed because one day of observations there were no fish observed over a 1.5 hour timeframe.

Of those species recorded in the western mangroves, seven of the species that were observed were singulars, and there were no other individuals of that same species found in the mangroves on the same day. This is compared to only one of the eastern mangrove species (\textit{Oxycirrhites typus}) being observed singularly, and it was only observed once total. Six of the species that were recorded at the western mangroves never entered farther into the forest than the initial 15 meters of the channel, the rest were found mainly between the start of the channel and the beginning of the sandy divide area. Only the Gobiidae and Muraenidae (Morays) species were observed past the sandy divide in the western. All of the Gobiidae species were observed on top of the coral rag and would hide in holes when approached. In both zones, the Muraenidae would use the prop roots and holes to hide, either using it as protection or to stalk prey.
**Similarity**

The similarity index that was used was a simple calculation to compare the species present between the two areas. This was used as an initial value because they are often used when communities are so different a diversity index would not be appropriate, and also because diversity indices don’t often change when the sites have similar species but different proportions. With a value of 0.4, it shows that the similarity between the two mangrove forests is low, with a value of 1.0 representing perfect symmetry between the two areas, 0 representing no symmetry (Table 2).

**Species Richness**

An incidence-based estimator (ICE) species richness value was calculated for the two stands. Since this is an incidence-based value, species are simply noted as being present, and has nothing to do with a total population count. For the western mangroves, a value of 28.08 was calculated, compared to the value of 7.37 for the eastern mangroves, nearly a threefold difference (Table 2).

<table>
<thead>
<tr>
<th>Index</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>ICE</td>
<td>28.08</td>
<td>7.37</td>
</tr>
<tr>
<td>Shannon-Wiener</td>
<td>5.48</td>
<td>1.86</td>
</tr>
<tr>
<td>Simpson’s</td>
<td>0.06</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Table 2: Values for index including:
(1) similarity index (2) Incidence-based species richness estimator index (3) Shannon-Wiener Diversity index (4) Simpson’s Diversity index

**Diversity Indices**

Of the two diversity indices used, the Shannon-Wiener index is more useful because it takes more into account the species richness of an
area, whereas the Simpson’s Index is weighted more towards the most abundant of species. For the Shannon-Wiener index, values of 5.48 and 1.86 for the west and east mangroves, respectively, were calculated (Table 2). This is in comparison to the Simpson’s index values of 0.06 and 0.15 (lower values symbolize greater diversity), also respective for the west and east mangrove sites (Table 2).

**Intertidal**

A total of twenty-five separate species were observed during the intertidal observations (Table 4). Of these, thirteen had also been recognized in either one or both of the mangrove forests. 10 of these species were found in both tidal areas, but only 3 of them correlate to both mangroves (2 Muraenidae species and *Lethrinus harak*). Gobiidae species were found in both tide pool areas as well, as was a species of rockskipper fish (*Entomacrodus striatus*), a species very similar to gobies.

**Discussion**

This two week study of the Misali island mangroves provided a fish species inventory list for this ecosystem. The difference in the species observed may have to do with the proximities of each stand to important parts of the Misali ecosystem. Since the non-extractive zone was originally implemented to protect the high levels of coral cover and diversity, it only makes sense that the protection of this highly diverse area would also
increase the diversity in surrounding habitats, including the western mangroves (Poonian, 2008). Several of the species (such as *Chaetodon lunula* and *Terapon jarbua*) that were recognized were in some post-larval stage that utilize the mangrove habitat for a multitude of reasons before living out their adult life stage on the coral reefs and other surrounding ecosystems (Mumby *et al.*, 2003). Whereas with the eastern mangroves the proximity to the local fisherman’s main fishing area may inhibit the number of species entering the area.

A previous study showed that only fourteen species had been recognized between the two sites over a three week period (Gougian, 2007). This is less than two-thirds of the observed species in this study. Because of the CORE zones known high biodiversity (Daniels *et al.*, 2003; Frontier-Tanzania, 2004; Poonian, 2008), it is not a surprise to find that twenty-one (87.5%) of all species observed were located in the adjoining western mangroves. Also, the low total of species observed in the east mangroves (29.2% of total observed species) can be attributed to its proximity to the fishing area of the local fisherman. But it was found by Daniels *et al.* (2003) that fishing is not the only attributable reason to why species composition is so different in this area compared to the west. In this area, there are very few corals left because of destruction caused in previous years by destructive fishing methods, leaving a low potential for high diversity (Daniels *et al.*, 2003). This leaves the habitat open for fishery species such
as mature *L. harak* and *Gerres oyena* to enter and seek refuge without having to compete for resources with juveniles of reef species that utilize the mangroves.

Also lacking from the eastern mangroves were the large schools of pelagic fish that often congregate in the area where the *wavuvi* fish daily. Species such as *dagaa* and other small fish that are used as either baitfish or food reserves were not observed. This is disturbing because at high tide it would be expected that these small species would look for refuge from predators among the roots and other physical structures of the forest (Nagelkerken *et al.*, 2000). Much like the *Acanthurus triostegus*, *T. jarbua* and *Monotaxis grandoculis* were in the western mangroves, always in large schools of juveniles, it was expected to see more schooling species, such as *G. oyena* and *Herklotsicthys quadrimaculatus*, among the prop roots and high turbidity of the eastern mangroves (Islam & Haque, 2004). It would also be expected to see these species present in the eastern mangroves because of the distance from an area where predators may be found, providing further safety from the fishermen and predatory fish (Nagelkerken *et al.*, 2000).

**Similarity**

The similarity index of 0.29 directly shows how different these two areas were in comparison of species richness. A value of one would have
meant they were identical, with a value of zero meaning no similarity at all. But in this test, it was seen that there was little similarity based on species present. The number was higher than it would have been if the high common factor of the two Muraenidae species was removed, leaving a similarity index of 0.17. Both of these values are relatively low, showing the difference between the species richness. The only issue that can be seen from this index is that the sites were not similar in physical structuring, meaning that there should always be some kind of difference based on the differences in available niches in each environment. Because of the unlike environments, it is hard to get a proper handle on the areas without also assessing the impact of the extractive and non-extractive zones on each site, and how diverse the surrounding habitats are.

Species Richness

Species richness based on the ICE index also shows a higher richness rating for the western side, but does not take into account any kind of population analysis data. It is based solely on the number of species seen and the total number of days it was observed. This can be supported by studies comparing different ecosystems such as mangroves, seagrass beds and mudflats. In Nagelkerken et al. (2000), it was shown that species richness was nearly four times greater in mangroves than seagrass beds, and nearly seven times greater than mudflat areas. So even such a low comparison between two similar ecosystems shows how unalike these the
mangrove stands are. It is possible to once again attribute this to the lower
diversity in the extractive zone than in the non-extractive zone, but the
difference between these two local habitats should not be so great.

Diversity Indices

Fish diversity in Misali waters is expected to include over 403 different
species, giving way to over 43 different families of fish (Frontier-Tanzania,
2004b). The diversity of Misali waters should somehow relate to the
diversity of each aquatic ecosystem that plays a role in providing a habitat
for the fish to live out the entirety of its life in the area. So the low diversity
rating for the eastern mangroves represents little biodiversity in the
extractive zone. But the presence of so many species in the western
mangroves shows that the proximity of the CORE zone may have a direct
influence on its high diversity for such a small area.

Intertidal

The intertidal areas show another area of diversity and how different
the two zones are compared to one another. Once again a lower number of
species was present at the eastern side of the island, signaling that there
must be some impact on all habitats surrounded by the extractive zone.
Also noticeable was the presence of Gobiidae species in the eastern intertidal
area, showing that it may not be because of a lack of food availability but
some other factor that causes them to be absent from the mangroves.
Limitations

This study had many limiting factors because of tides, the season, and how little information was available to get a full understanding of the study area. One of the biggest limitations was the tide schedule, where high tide often fell at hours where there was little sunlight available to be able to see underwater. For this reason, either an underwater flashlight or better planning for tides would help with gathering more data.

Another problem was that the study time, the first two weeks of April, are the beginning of the low season for fish to be in mangrove forests (Mazumder et al., 2006). During the local summer months (Dec-Feb), fish diversity in the mangroves should be highest, with low periods coming during the winter months. A year-round examination would give a more accurate inventory of species that use the mangrove stands.

The biggest limitation was not knowing how large the study areas were or how similar they were in physical features. Since the two zones were so different, a thorough comparison between the two areas is difficult. A study that focused more on the mangroves and surrounding habitats would give a better sense of biodiversity between the CORE and the extractive zones.
Conclusion

This study brings about three key inferences in the varying species composition of the eastern and western Misali Island mangrove forests.

1. These mangrove stands are highly different in physical structure, allowing for different niches to be present and filled by different species. The high presence of holes and overhanging features in the western mangroves supply an ample amount of protection for those juveniles that are attempting to escape predation. Whereas in the eastern mangroves the only protection comes from the low visibility caused by the seaweed infiltration and the high number of prop roots and pneumatophores that provide structural interference for larger fish.

2. The diversity of the CORE versus the extractive portions of the island had previously been observed as being highly variably. The western side has, through all known studies, shown a higher diversity of fish species than its much larger extractive area counterpart. This higher diversity most likely affects the species composition of its respective mangrove stands, giving way to a wildly different species composition and richness.

3. The proximity of each of these mangroves to an important human resource zone in Misali waters also could alter the composition of fish species. The western mangroves was located adjacent to the CORE
zone and its intertidal section, which are non-extractive and therefore many of the fish species present are never directly impacted by human visitation. Being a protected area, it was expected that a greater diversity of fish would be present in all habitats located in and near the CORE, as was observed in both the mangrove and intertidal data. Whereas the eastern mangrove forest was located near the wavuvi fishing site and near the area where fishermen collect mollusk and crustacean during the low tides. This more harsh and direct impact on the fish stocks may cause what comes out to be a very low richness level for an area that would be expected to be more diverse than its smaller counterpart.

**Recommendations**

My initial recommendation is that this research can be redone if a more thorough methodology is put into action. Before starting the research, the individual should know what each of the mangrove ecosystems is like so they know what kind of a comparison they will be able to do between the two areas. Or if they are just going to do an overall biodiversity assessment, they need to be aware of tide schedules and be able to do work during low tides and night time so that they are able to get all fauna found in the area at any given time.
An initial study should be undertaken to look at all faunal species that can be found to inhabit each of the mangrove stands (like Gougian, 2007), so that a species list can be made for those who plan to do research in the area. This would require observations done at all times of the day and during both tidal periods. This way a species inventory of the mangroves can be created for those individuals who do future work, having something to base their research on. Along with this, mangrove health should be taken into consideration to indicate changes to the environment in the future and whether the ecosystem is under any type of stress.

A future comparison with the mangroves of Misali Island compared to other mangrove stands found within the PECCA boundaries. This can be done for stand health overall, to see the impact of human proximity to the mangroves or how effective PECCA is in terms of enforcement. It can also be used as a comparison to see what species of fish use the area, and whether you would get coral reef fish juveniles in the non-island mangroves, to see if they would traverse the deeper waters to locate a reef to live their adult life at. This would give a better idea at what species are dependent on the reef, and what fishery species don’t need a reef. If this kind of research is undergone, better protection of the mangroves could be enforced if it is found that important fishery species use one mangrove area more than another.
To further enhance the knowledge of the local fish species, it would be advised if a new inventory be done, this time taking observations from all aquatic habitats including seagrass beds, mangrove forests, coral reefs and deeper offshore waters. This would help enhance the knowledge of the interactions between these ecosystems and may be able to help set up a type of fishery that is self-sustainable.

A specific study should be done in assisting PECCA to assess how effective the methods they use to protect the islands natural resources are. This could be an overall analysis of health of reefs, mangroves, or forests based on data collected from past studies to see if there has been any change in ecosystem structure. They could set up a baseline for other islands in the area that are looking to be as productive as Misali.

Works Cited


Mazumder, D., Saintilan, N., & Williams, R. J. (2006). Fish assemblages in three tidal saltmarsh and mangrove flats in temperate NSW, Australia: a comparison based on species diversity and abundance. Wetlands


Figure 2: Study area consisting of all intertidal areas and the protected CORE zone of Misali waters. Green areas represent the two mangrove stands studies, and the black areas represent the visited intertidal areas. Shaded areas represent all intertidal area during spring low tide. Contour lines depict 5m changes in water depth. Picture modified from original form in Daniels et al. (2003).
Table 3: List of all observed species between the West and the East mangroves. Values included are total number of samples that each species was observed during. Species observed per day (n = 7)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convict Surgeonfish</td>
<td><em>Acanthurus triostegus</em></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Raccoon Butterflyfish</td>
<td><em>Chaetodon lunula</em></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Peppered Moray Eel</td>
<td><em>Siderea picta</em></td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Crescent Banded Grunter</td>
<td><em>Terapon jarbua</em></td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Indian Goatfish</td>
<td><em>Parapeneus indicus</em></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Bigeye Emperor</td>
<td><em>Monotaxis grandoculis</em></td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Pailtail Damsel</td>
<td><em>Pomacentrus trichourus</em></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Eyebar Goby</td>
<td><em>Gnatholepis cauerensis</em></td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Sand Goby</td>
<td><em>Fusigobius neophytus</em></td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Thumbprint Emperor</td>
<td><em>Lethrinus harak</em></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Snowflake Moray Eel</td>
<td><em>Echidna nebulosa</em></td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Shoulderspot Goby</td>
<td><em>Gnatholepis scapulostigma</em></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Arabian Threadfin Bream</td>
<td><em>Scolopsis ghanam</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mozambique Fangblenny</td>
<td><em>Meiacanthes mossambicus</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Black Goby</td>
<td>Gobiidae sp.</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ornate Goby</td>
<td><em>Istogobius ornatus</em></td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Whitemouth Moral Eel</td>
<td><em>Gymnothorax meleagris</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Circular Spadefish</td>
<td><em>Platax orbicularis</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Blacktip Mojarra</td>
<td><em>Gerres oyena</em></td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Goldspot Herring</td>
<td><em>Herklotsicthys quadrimaculatus</em></td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Longnose Hawkfish</td>
<td><em>Oxycirrhites typus</em></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Banded Sergeant</td>
<td><em>Abudefduf septemfasciatus</em></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Spotted Trunkfish</td>
<td><em>Ostacion meleagris</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Powderblue Surgeonfish</td>
<td><em>Acanthurus leucosternon</em></td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total Species Count** 21 7  
**Total Species Observed/Day** 10.7 3.6
Table 4: Species observed in intertidal areas of both western and eastern sides (Presence = yes Absence = no). Species present in mangroves as well were marked off as to what stand they were observed in, or if observed in both.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>West Side</th>
<th>East Side</th>
<th>Present in Mangroves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peppered Moray Eel</td>
<td><em>Siderea picta</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (Both)</td>
</tr>
<tr>
<td>Insular Halfbeak</td>
<td><em>Hyrophampus affinis</em></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Blackbanded Cardinalfish</td>
<td><em>Apogon cookii</em></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Crescent Banded Grunter</td>
<td><em>Terapon jarbua</em></td>
<td>yes</td>
<td>no</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Mozambique Fangblenny</td>
<td><em>Meiacanthus mossambicus</em></td>
<td>yes</td>
<td>no</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Blacktip Mojarra</td>
<td><em>Gerres oyena</em></td>
<td>no</td>
<td>yes</td>
<td>yes (East)</td>
</tr>
<tr>
<td>Thumbprint emperor</td>
<td><em>Lethrinus harak</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (Both)</td>
</tr>
<tr>
<td>Bigeye Emperor</td>
<td><em>Monotaxis grandoculis</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Scissor-tail Sergeant</td>
<td><em>Abudefduf sexfasciatus</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Three-spot Dascyllus</td>
<td><em>Dascyllus trimaculatus</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Caerulean Damsel</td>
<td><em>Pomacentrus caeruleus</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Dark Damsel</td>
<td><em>Pomacentrus aquilus</em></td>
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<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Threeline Damsel</td>
<td><em>Pomacentrus trilineatus</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Blackspotted Rockskipper</td>
<td><em>Entomacrodus striatus</em></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Picture Rockskipper</td>
<td><em>Istiblennius gibbifrons</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Eyebar Goby</td>
<td><em>Gnatholepis cauerensis</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Shoulderspot Goby</td>
<td><em>Gnatholepis scapulostigma</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Sand Goby</td>
<td><em>Fusigobius neophytus</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Convict Surgeonfish</td>
<td><em>Acanthurus triostegus</em></td>
<td>yes</td>
<td>no</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Powderblue Surgeonfish</td>
<td><em>Acanthurus leucosternon</em></td>
<td>yes</td>
<td>no</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Black-saddled Toby</td>
<td><em>Canthigaster valentini</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Rivulated Toby</td>
<td><em>Canthigaster rivulata</em></td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Racoon Butterflyfish</td>
<td><em>Chaetodon lunula</em></td>
<td>yes</td>
<td>no</td>
<td>yes (West)</td>
</tr>
<tr>
<td>Goldband Fusilier</td>
<td><em>Pterocaesio chrysozona</em></td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Snowflake Moray Eel</td>
<td><em>Echidna nebulosa</em></td>
<td>yes</td>
<td>yes</td>
<td>yes (Both)</td>
</tr>
</tbody>
</table>