SIT Madagascar Biodiversity and Natural Resource Management/ New York University

Point Study of Human Impacts on Vegetal Cover and Species Diversity of Seagrass in Southwest Madagascar

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Contents

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Introduction

Seagrass communities are unique marine ecosystems that have generally been underappreciated as keystones in coastal ecology. Though usually less studied than coral reefs and mangrove forests which occur in relation to them, seagrass meadows have become more widely studied and their inherent value within the greater biosphere has been better documented within the last decade (de la Torre-Castro & Rönnbäck 2004). In total, seagrass species number near 58 with the highest species diversity in the Indo-Pacific bioregion. Within the extensive meadows that seagrass communities form in the intertidal and subtidal zones, many species of vertebrate and invertebrate marine organisms burrow, feed and breed, conferring measurably higher faunal biodiversity on seagrass meadows than on unvegetated areas (Eklöf *et al.* 2005). In addition to supporting diverse faunal communities, seagrass meadows are responsible for maintaining oxygen levels in intertidal sediments through the release of O2 from the lacunae into otherwise hypoxic environments and seawater chemistry by maintaining pH (de la Torre-Castro *et al.* 2008). Seagrasses grow in a range of sediment types and depend on several abiotic factors. These conditions include temperature, water motion, anaerobiosis, nutrient availability, presence of epiphytes, solar irradiance, infection and herbivory. The nutrient limitations of seagrass species depend on sediment types. Though the dynamics are contested within the literature, it is generally agreed that major limitations for seagrass are nitrogen and phosphorous availability (Short *et al.* 1987, Erítemeijer & Middelburg 1993). Seagrass communities are among the most productive ecosystems in the biosphere, comparable even to mangrove and boreal forests due to their above-ground vegetation, root systems and support of epiphytic algae. In the Western Indian Ocean region, seagrass support fisheries for commercially important species which feed directly on seagrass tissue or consume the benthic invertebrates which depend on the meadows (de la Torre-Castro *et al.* 2008). Among their ecosystem services are the protection of juvenile fish and other developing fauna, buffering wave action, thereby reducing coastal erosion, and affordance of protein and bait resources to coastal villagers who gather organisms in the intertidal zone (Gullström et al. 2010, Duffy 2006, de la Torre-Castro et al. 2008). The latter of these, a subsistence activity called gleaning, is especially relevant in the WIO where many coastal communities depend on gleaning and fishing for livelihoods (Tucker 2010, 2008).

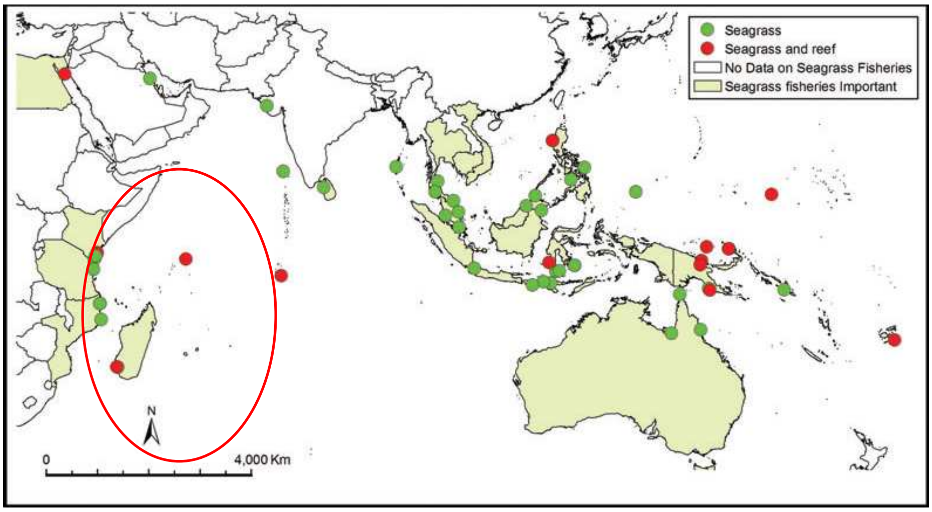

Figure 1 Indo Pacific region showing seagrass and coral reef distribution, Western Indian Ocean circled in red (Unsworth & Cullen 2010).

Madagascar's Bay of Ranobe, a coastal lagoon ecosystem within the WIO on the island's southwest coast, is populated by nine species of seagrass which occur in extensive mixed beds (Fig. 1, 2) (Gullström *et al.* 2010). Accompanying the seagrass meadow is the world's third-largest coral reef system and mangrove forests toward the southern end of the coast. Some of the environmental problems affecting the Bay of Ranobe are high sedimentation, seawater warming, damage to ecosystems by intensive fishing and population increases, and algal blooms due to nutrient loading from fertilizer runoff and effluent (www. reefdoctor.org). These ecosystems have been changed by increases in the populations of coastal villages and the corollary increase in the dependence on marine food resources. The location of this study encompasses the villages of Mangily and Ifaty (Fig 2). The Vezo people who inhabit these villages are culturally and historically fishers and fall into two subsistence-defined groups. The *Vezondriake* are "sea-Vezo" who depend primarily on fishing and gather marine organisms and live on beaches while the

Vezompotake are "mud-Vezo", people who use marine resources and also cultivate in mudflats for subsistence (Tucker et al. 2011). The residents of Mangily and Ifaty are *Vezondriake*. A 2007-2008 study found that the Vezo people earn about $1.50 per day and average about 3.6 years of formal education (Tucker et al. 2008). This study further determined that the *Vezondriake* mainly sell finfish, octopus and sea cucumber to traders for export and about 84.2% of total income comes from marine foraging (Tucker et al. 2008, 2010). The *Vezondriake* fish using outrigger canoes called *laka* and use nets and lines to trap and drag in catch (Fig 1 b.) (Tucker et al. 2010).

a. 

b. 

Figure 2. a. Bay of Ranobe (Lagon de Ranobe) (www.reefdoctor.org) b. Seagrass meadow in the Bay of Ranobe with pirogues and gleaners (Pierre 2012).

This study seeks to determine the existence of a relationship among the human activities of the *Vezondriake* occurring in the Bay of Ranobe, the overall cover of seagrass vegetation relative to bare sediment, and the species diversity of the seagrass beds. Using methods adapted from the global seagrass monitoring network SeagrassNet, this study will estimate the percent cover of seagrass vegetation and specific species vegetation. Based on the known effects of mechanical damage on seagrass regeneration, I predict that areas closer to human settlements which depend on fishing and gleaning will have a lower overall percent cover of seagrass vegetation. Because most measures of ecosystem health are normally inversely correlated with mechanical damage, I predict that species diversity will be highest in the area with the least human activity occurring (IUCN 2008). To meet its objective, this study will couple quantitative analysis of seagrass health with a socioeconomic survey concerning household dependence on marine resources and gleaning activity.

Methods

Study Site

The Bay of Ranobe at Madagascar's southwest coast is the location of the world's third largest coral reef system. The bay is classified as a coastal lagoon within which two study sites are located in the intertidal zone abutting the villages of Ifaty and Mangily on the landward sides of the reef. The Mangily intertidal zone is dominated by gleaning of shells for sale to tourists, some fishing and movement of pirogues toward and away from the beach. At the Ifaty intertidal zone, movement of pirogues, fishing and hand-gathering of benthic organisms for consumption dominate. The seagrass species known to be present in the Bay of Ranobe are *Cymodocae serrulata, Cymodocae rotundata, Thalassia hemprichii, Halodule whrightii, Halodule uninervis*, *Thalassodendron ciliatum*, *Syringodium isotifolium, Halophila ovalis* and *Halophila stipulacea* (Appendix E). The study was conducted for four days between April 9 and 22, 2012 during the lowest tides between 10:30 and 15:00. Sampling methods were adapted from the SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat (Short et al. 2006). The Mangily site is located approximately 4 kilometers north of the Ifaty site.

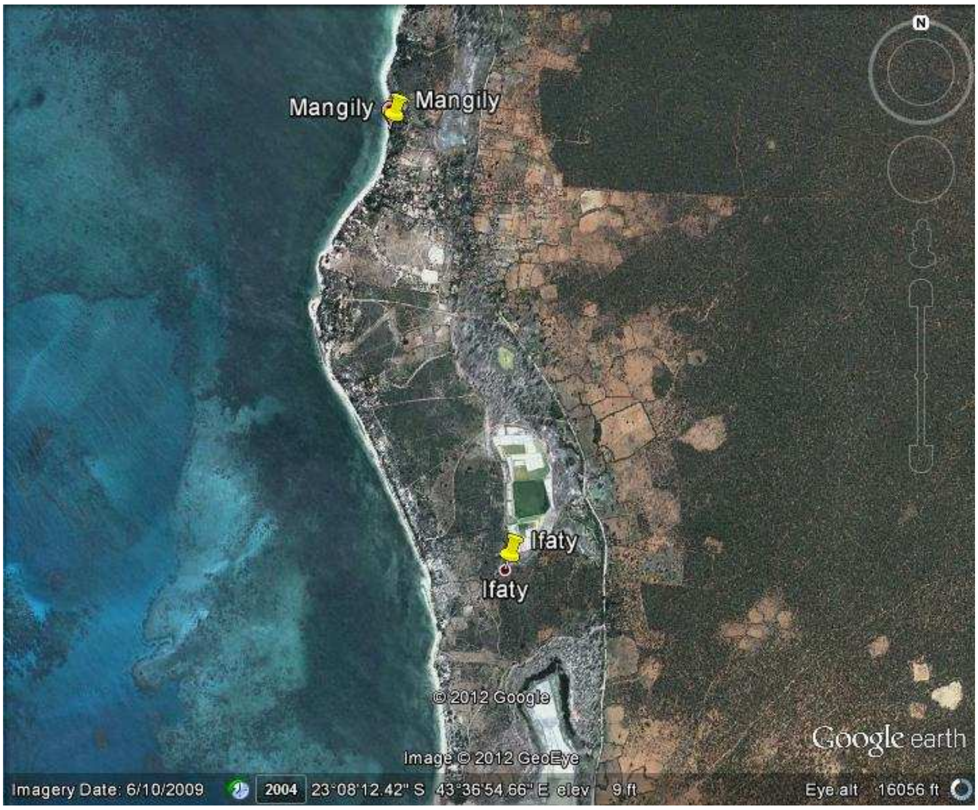

Figure 3 Satellite image of the study area showing the locations of villages (Google Earth 2009)

Seagrass Survey Methods

At the Mangily and Ifaty sites, two stations were established at areas of high human use and lower human use based on observation of coastal activities and proximity to a village. These stations were Mangily A (low human use), Mangily B (high human use), Ifaty A and Ifaty B. Ifaty A was located in front of the compound of the Reef Doctor organization and Ifaty B was located in front of the village of Ifaty. Mangily A was located in front of a hotel north of the Mangily village and Mangily B was marked in front of the busiest area of the village of Mangily. The three cross transects laid at one study site were considered one population, one sample was equal to one 50 meter cross transect and a subsample was equal to one quadrat with an area of .25m² along one cross transect. At each station, three fifty-meter cross transects were established within the continuous seagrass meadow, the outer edge being defined as the seaward limit of strap-leaved seagrasses (Short et al. 2006). For each station, the transects ran parallel to the beach. The start point for Transect 1 (nearshore) was always established 100 meters away from the shoreline at a perpendicular angle in the westerly direction. Surveyors used a compass to find the bearing of the shoreline and walked perpendicularly to the beach for 100 meters to reach the zero point of Transect 1 (nearshore). Transect 3 (offshore) was established 150, 100, 150 and 150 meters from the zero point of Transect 1, also perpendicularly relative to the beach, for Ifaty A, Ifaty B, Mangily A and Mangily B, respectively. The distances between the zero points of Transect 1 and Transect 3 differed among sites because of different bathymetry at each site, thus the distinction "offshore" was a subjective label dependent on both distance from shore and depth. Transect 2 (mid-depth) was established at the midpoint between Transects 1 and 3. The transects were marked using a 60 meter measuring tape that was laid southward of the zero point, or to the right while facing the shore. The tape was weighted down at both ends to prevent it from moving with the current. This process was repeated for each of the four study stations (Fig 2, Mangily not shown). GPS coordinates were taken for the zero points of each 50 meter cross transect. Along each cross transect, 12 quadrats were placed at random distances on the landward side of the transect tape (Appendix H. These distances were taken from the SeagrassNet survey manual (Short et al. 2006). Surveyors walked or waded approximately 1 meter away from the transect tape in order to avoid clouding the water with sediment. At 0, 25 and 50 meters along each transect, the water depth and time of day were recorded. Between 2 and 4 surveyors participated in estimating the percent cover for each site.

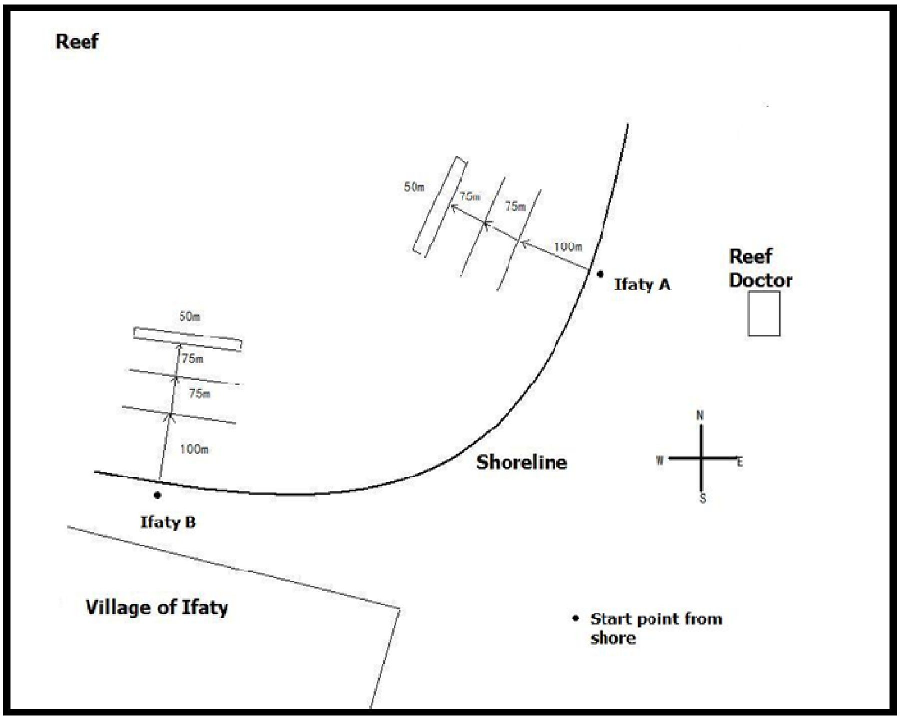

Figure 4 Sketch map illustrating Ifaty study station (Mangily not shown)

For each quadrat, we estimated the *per cent* cover of seagrass vegetation using the "seagrass percentage cover photo guide" from SeagrassNet as a reference (Short et al. 2006). Present species of seagrass were identified for each quadrat. For this study, percent cover was estimated based on the overall leaf coverage relative to visible sediment, the presence of algae and the quadrat area covered by seagrass shoots. Surveyors stood above the quadrat to consider overall percent cover and also did a tactile assessment by moving the leaves with their hands to reveal the area covered by shoots. Visual estimation of seagrass cover by non-scientists has been proven reliable in comparison to digital image analysis software and researchers' assessments and was therefore a valid *in situ* means of assessing *per cent* vegetation cover (Balorain et al. 2010; Blaun, Blanquet 1972).

Demographic Survey Methods

Semi-structured interviews using haphazard collection methodology were conducted in Ifaty and Mangily. Twenty questions were developed in English and translated to Malagasy (see Appendix F). The sample size per village was 20 subjects representing 20 households. The household was defined as the group of adults and children living in one compound of huts within the village. The target group was the matriarch of such a compound, usually the oldest female resident. This group was targeted for their traditionally senior authority in domestic affairs and because of the tendency for leaders of a household to meet and exchange information among them, lending them insight into trends and changes over time. The sampling method sought a participant in intervals of every five compounds. Surveys were conducted individually in the participant's compound. Anonymity was maintained for each participant by ascribing each one a number. Each participant was asked prior to the interview for their consent in participation and was informed that she could stop the interview at any time. Information was given freely without payment. Responses were translated from Malagasy to French and from French to English for this report.

Results

Seagrass Percent Vegetation Cover

The highest estimated percent cover for one quadrat encountered among the four sites was %100 at Mangily A (low human use). The lowest percent cover encountered for one quadrat was 0% at Ifaty B (high human use) (Appendix 1). The mean percent cover values were 49.8% for Ifaty A, 30.6% for Ifaty B, 64.7% for Mangily A and 55.1% for Mangily B (Fig. 3). The difference between the percent cover values of A stations (low human use) and B stations (high human use) was 19.16% for Ifaty and 9.58% for Mangily (see Appendix A). The percent cover values of the quadrats were ranked by percentiles (5^{th}, 25^{th}, 50^{th}, 70^{th}, 95^{th}) (Fig. 3) to show the distribution of values for each study station. The highest median percent cover was encountered at Mangily A, where the 50^{th} percentile of subsamples was above 70% overall vegetation cover. The lowest median percent cover value was found at Ifaty B, where the 50^{th} percentile of subsamples were above 30% overall vegetation cover.

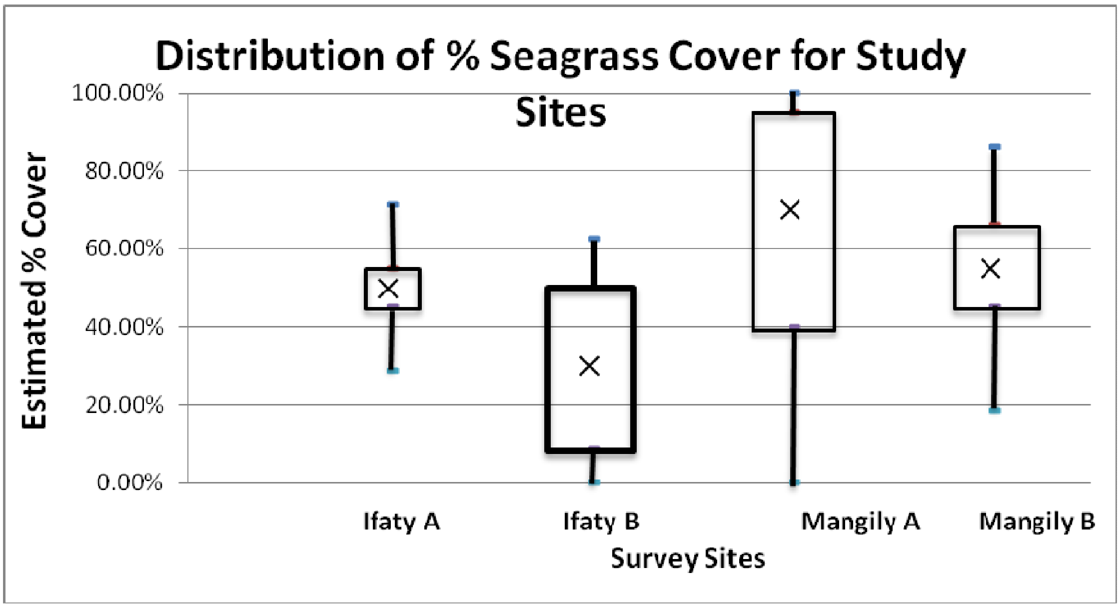

Figure 5 Percentile distributions of % seagrass cover values for all subsamples.

Species Specific Percent Cover

Among the four study sites, we encountered only seven of the nine species present in the Bay of Ranobe. These were *S. isotifolium, T. hemprichii, T. ciliatum, C. rotundata, C. serrulata, H. whrightii and H. uninervis.* The species with the highest overall percent cover for both stations was *S. isotifolium*. The species with the lowest overall percent cover for both stations was *H. uninervis*. The dominant species for the Ifaty sites were *S. isotifolium* and *T. hemprichii*, with the latter dominating in Ifaty A and the former in Ifaty B. The Mangily station was dominated by *T. ciliatum* where this species had a mean percent cover of 26.9% for all quadrats. *T. hemprichii* had the highest presence in the Ifaty quadrats, on average comprising a mean percent cover of 45.6% for all quadrats. Seagrasses of the genus *Halodule* were observed the least frequently and comprised an average of 7.2% of all quadrat area for both Ifaty and Mangily stations.

Species Diversity

Using the estimated for species percent cover, species diversity was quantified using the Shannon-Weaver Diversity Index. The equation for this index is

$$H = \Sigma\{(n) \times \ln(n) + (\ldots) \times \ln(\ldots)\}$$

where *H* is the diversity index and n is the percent cover for each species present in the subsample. The highest median *H* value for all quadrats was 1.027 at Mangily B and the lowest median *H* value for all quadrats was the Ifaty B site where *H*=.053 (Appendix A). The median *H* value was also highest at Mangily B and the *H* value for the Ifaty B and Mangily A sites differed by .3, thus these sites overall had similar seagrass species diversity. Because the transects were laid at three distances from the shore, it was not possible to determine whether a linear correlation between distance from shore and species diversity exists. For all subsamples there was no evident linear relationship between species diversity and percent cover of seagrass (Fig. 5).

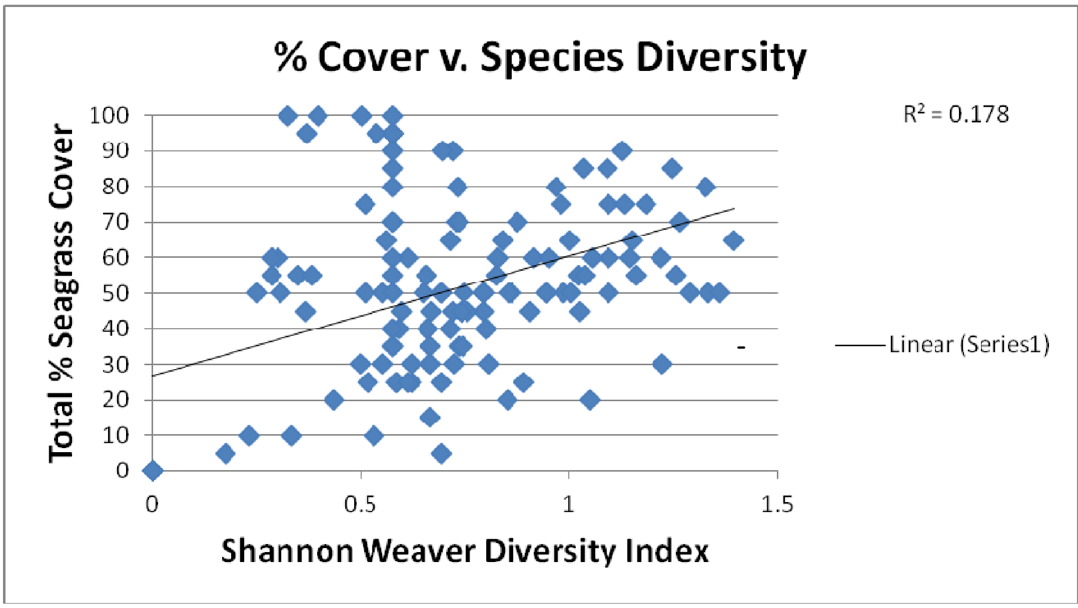

Figure 6 The relationship between estimated % cover and species diversity index for each subsample-- no linear relationship.

Demographic Surveys

The population of Ifaty and Mangily are estimated to be about 5,000 and 10,000 respectively. The demographic surveys showed that more residents of the sampled households in Ifaty than Mangily were gleaners. On average, the number of gleaners per household in Ifaty was 4 while the mean was half of this value for Mangily (Appendix E). The number of functioning pirogues that a family owns may indicate the amount of fishing activity occurring in a village. Because it is well known that the primary subsistence activity for the Vezo people who inhabit both villages is fishing, we extrapolated that one pirogue is representative of at least 2 livelihood fishers per compound. We found that the mean number of pirogues per household for the Ifaty sample was 2.1 while the number for Mangily was 2.05. Though the means were similar, we also noticed that the Ifaty sample overall owned more working pirogues than the Mangily sample. To better understand how reproduction in Mangily and Ifaty has changed over time, we separated the participants into age classifications of 1 (20-39 yrs), 2 (40-59 yrs), and 3(60-90 yrs). We found that the average numbers of children for classes 1, 2, and 3 were 2.9, 6.6 and 6.8 for Ifaty and 3.8, 5.8 and 7 for Mangily, respectively (Appendix E). Almost all women for both Mangily and Ifaty were married and we found that more young women (class 1) were gleaners than older women (class2, 3).

Discussion

The relationship between gleaning and fishing activities and the percent cover of seagrass is an inverse relationship, where proximity to a human settlement confers a lower median percent cover of seagrass vegetation. The human populations in the bay of Ranobe are historically dependent on coastal fisheries for their livelihoods, however recent differences in the demographic and vocational composition of the coastal villages of Ifaty and Mangily may be affecting differences in the percent cover of the seagrass beds of the intertidal zone. The mean percent cover of seagrass was greater in the low human use areas of Ifaty A and Mangily A than in the high human use areas. In these areas we observed that fewer pirogues were leaving from or returning to the shore and based on a visual assessment, fewer gleaners waded into the seagrass to look for fish and invertebrates at the A sites.

At Ifaty A the subsamples within median 50% of the three samples had between 45-55% overall cover of seagrass vegetation while the median fifty percent at Ifaty B had a larger range between 8.5-50%. The statistical analysis shows that the median cover was higher for Ifaty A than Ifaty B, supporting the assertion that proximity to human settlements negatively impacts overall seagrass vegetation cover.

Additionally, *in situ* observation showed that more quadrats in the Ifaty B population had 0% vegetation cover than any other sampled population. The quadrats with 0% vegetation cover were all located along Transect 1 (nearshore) and had 100% sediment cover. Because the frequency with which gleaners can walk into the seagrass beds is limited to the number of low tides each month, the frequency of gleaning can be assumed to be the same for both Mangily and Ifaty. It might be inferred that the intensity of nearshore coastal subsistence activities is greater near Ifaty B than other study sites.

The median 50% of subsamples from both the Mangily A and Mangily B populations had higher percent cover values than the median 50% from Ifaty A and B. The Mangily sites also had visibly more continuous and dense seagrass communities in the surveyed areas. This indicated that there may be overall less mechanical damage occurring near the village of Mangily than at Ifaty. The observation of a higher median value for percent cover of seagrass at Mangily A than Mangily B supports the assertion that the proximity of a seagrass bed to a human settlement negatively impacts the percent cover of seagrass vegetation and the difference in the median values between Mangily A and B (15%) and Ifaty A and B (20%) are within 5% of each other. The wide distribution of the median 50% of subsample percent cover values shows that there is greater variation in the values for Mangily A and B. The cause for this wide distribution may be related to the difference in volume of gleaners and pirogues in the intertidal zone during low tide at Mangily and Ifaty.

This hypothesis is supported by the responses to question 20 of the demographic survey (Appendix G). The mean number of gleaners per household in Ifaty was approximately twice the value for Mangily, however the mean number of pirogues representing the number of fishers per household was about the same for both villages (Appendix E). This suggests that more households depend on gleaning for subsistence to supplement fishing income in Ifaty. There are numerous possible causes for this difference in gleaning activity. Economic diversity in Mangily is supported by a tourism sector that offers jobs to local communities. Hotels, restaurants, pirogue rentals, food sales and souvenir sales afford different opportunities to earn wages in Mangily that do not exist in Ifaty. Additionally, survey participants all responded that they had observed changes in the ocean in general over the past decade and the majority specified that they observed a decrease in the amount of products landed from gleaning and fishing. The observed decreases that participants discussed may have a positive effect on the volume of gleaners in seagrass beds if households respond to decreased fish landings by increasing their gleaning activity.

The relationship between species diversity and proximity to a human settlement was not found to be negatively correlated as was expected. The median Shannon Weaver Diversity Index was highest for Mangily B (high human use) and was lowest for Mangily A (low human use). Despite having the highest median value for percent cover of seagrass vegetation, Mangily A exhibited the lowest species diversity index and was dominated by *T. ciliatum*. Because numerous factors, including pioneer and climax growth strategies, irradiance requirements and nutrient requirements, affect the ability of certain seagrass species to compete with others, it is possible that differences in the volume of gleaners at each site have affected interspecific competition of seagrass. Interspecific competition is also related to species' capacities to tolerate disturbance. *T. ciliatum* and *T. hemprichii* are recognized as the two most common species for the Western Indian Ocean region, thus they were found to be most dominant for this study. It is possible that adaptations of these species will allow them to fill ecological niches made available by disturbance.

The ecological significance of the loss of seagrass vegetation has been documented for excessive nutrient enrichment in the Western Indian Ocean region, however the implications for mechanical damage due to human collection of invertebrates have not been studied (Gullström et al. 2002). The possible consequences for the comparatively lower median percent cover of seagrass at Ifaty B and Mangily range widely, but some proximate results may be speculated. The first implication may be increased coastal erosion over time. In the bay of Ranobe, sedimentation rates have increased due to logging of mangrove forests and terrestrial forests, causing increased turbidity in the coastal lagoon ecosystem (Reef Doctor). Rapid loss of seagrass communities, which tends towards a positive feedback, may lead to more sedimentation in the Bay of Ranobe (Gullström et al. 2002). Corals in the Bay, which are highly susceptible to the negative impacts of sedimentation, may suffer further due to loss of seagrass. Through further study, the loss of seagrass communities due to mechanical damage in the intertidal zone may be used as an indication of threat to other marine ecosystems.

There is no current formalized management system for seagrass ecosystems in the Western Indian Ocean and most efforts towards marine protected areas have focused on coral reefs and mangroves (Gullström et al. 2002, IUCN 2008). This poses a threat to the status of seagrass communities and reef systems which have interdependent ecology (de la Torres-Castro *et al*. 2008; IUCN 2008). The notion of ecological connectivity among these habitats is imperative to developing a comprehensive management strategy for the WIO. While further long term research is necessary to gauge the actual ecosystem health of seagrass meadows in the Bay of Ranobe, the results of this study indicate that degradation of seagrass meadows is occurring in areas near to coastal settlements and that this degradation is manifesting in the loss of overall seagrass cover in the intertidal zone. In the Bay of Ranobe has an existing Marine Protected Area system which is managed by the FIMIHARA organization. FIMIHARA is comprised of important stakeholders in marine conservation such as pirogués, hotel owners, fishers and rural politicians. The organization monitors visitation to coral reefs such as the Rose Garden Marine Protected Area by ensuring that fishers do not enter the protected zone and by taking a fee for touristic visitation. The capacity of this organization might be expanded to manage seagrass meadows abutting villages in the bay by enforcing staggered closed and open seasons to allow for regeneration of shoots and leaves in degraded areas. To inform these management decisions, further study should be conducted on the rates of regeneration of the nine species present in the bay and more extensive surveys of the overall density of the seagrass beds in the bay should be derived from remote sensing data which has been useful in determining species cover and extent of seagrass beds and concurrently occurring mangrove forests (Howari *et al.* 2009). Other methods of visual estimation of seagrass cover, such as the Blaun-Blanquet method for rapid visual assessment, should be compared to the percent cover estimation method for accuracy such that future *in situ* surveys of seagrass health in the Bay of Ranobe might gather the most representative data.

Conclusion

The reasons to protect and manage seagrass communities are numerous but the priorities for management remain unclear. Given a greater amount of time for study, the questions surrounding the implications of mechanical damage on seagrass roots and faunal communities could be studied to inform projections for future loss of seagrass vegetation in the WIO. As mentioned, research into the effects of seagrass interspecific competition as a result of mechanical damage may help to provide baseline and trend data for future modeling of seagrass systems and anthropogenic perturbation. As has been mentioned, the role that seagrasses play in maintaining the marine trophic web has been studied and found to significantly affect fisheries (de la Torre-Castro *et al.* 2008), thus *in situ* study or computer modeling studies of the trophic web would additionally be useful to inform decisions about seagrass management and future threats to important fisheries. Data from these studies must be conveyed to local peoples in ways that are understandable and meaningful to them in order for management to be long lasting and supported by a community base. Throughout Madagascar, the notion of community-based management has been attempted for terrestrial and some aquatic ecosystems but these programs have been criticized for their often nominal community organization. For community management of seagrass to be effective, it is likely that the Vezo themselves must be both informed and consulted in developing management and restoration strategies in the future. While it may seem clear that livelihoods in the Vezo villages must be diversified to reduce dependence on the coastal lagoon system, the Vezo are defined by their connection to working with the sea and drawing on its resources for survival. Approaching increased gleaning as a notable change in an important cultural tradition in response to environmental change may help to afford the necessary cultural sensitivity to future seagrass management.

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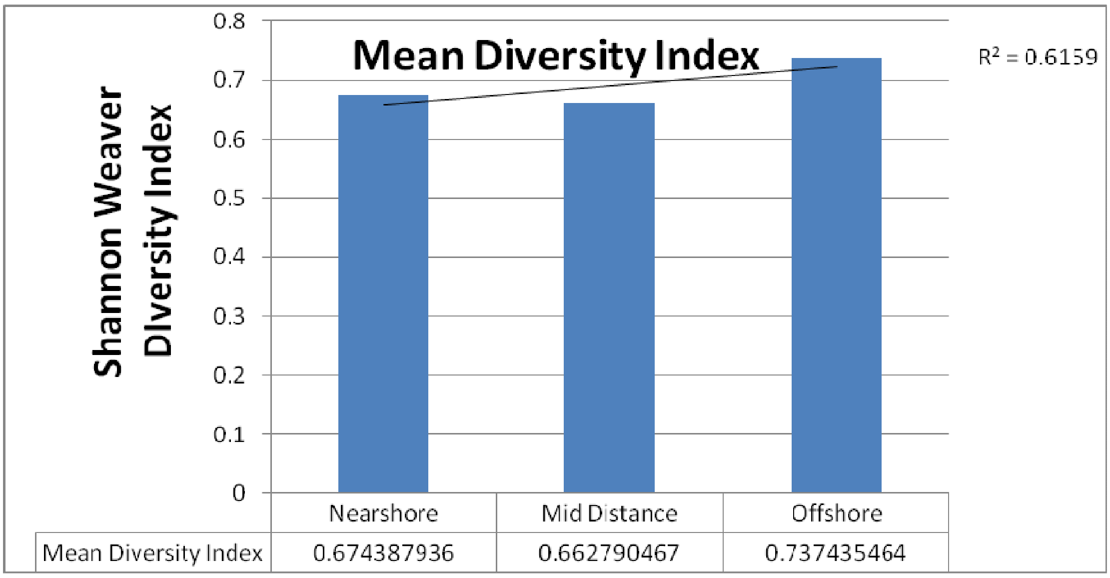
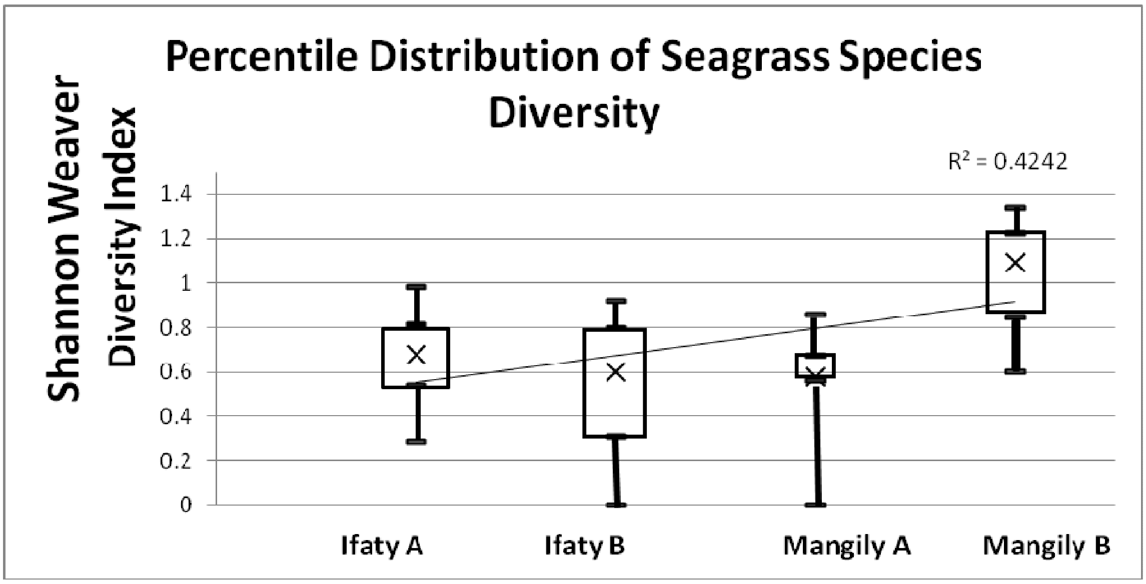


Comparison of mean differences in diversity index all transects for three distances from shore.



Percentile distribution of diversity indices for all quadrats for four study sites

Appendix B

Percent Cover of Seagrass					
		IFATY A	IFATY B	MANGILY A	MANGILY B
TRANSECT	Quadrat	% COVER	%COVER	% COVER	% COVER
T1	1	70	10	0	85
T1	2	60	5	90	80
T1	3	30	5	0	20
T1	4	50	0	80	90
T1	5	45	0	65	75
T1	6	80	75	60	65
T1	7	75	0	85	55
T1	8	45	0	45	55
T1	9	50	0	35	60
T1	10	50	0	40	50
T1	11	50	0	55	10
T1	12	45	50	50	15
T2	1	25	60	0	45
T2	2	30	60	0	60
T2	3	35	25	90	65
T2	4	45	40	70	65
T2	5	50	25	40	50
T2	6	50	30	25	55
T2	7	50	25	35	85
T2	8	55	10	40	50
T2	9	55	20	100	20
T2	10	55	30	100	50
T2	11	60	25	95	50
T2	12	60	35	100	70
T3	1	30	50	90	60
T3	2	50	50	95	65
T3	3	55	50	95	75
T3	4	35	60	95	30
T3	5	60	45	85	75
T3	6	25	30	100	55
T3	7	50	70	95	50
T3	8	55	50	80	95
T3	9	55	45	60	45
T3	10	45	45	70	40
T3	11	50	40	70	30
T3	12	65	40	95	40
MEAN		49.86111	30.69444	64.72222	55.13889
	Percentiles	IFATY A	IFATY B	MANGILY A	MANGILY B
	95%	71.25%	62.50%	100.00%	86.25%
	75%	55.00%	50.00%	95.00%	66.25%
	50%	50.00%	30.00%	70.00%	55.00%
	25%	45.00%	8.75%	40.00%	45.00%

	5%	28.75%	0.00%	0.00%	18.75%

Appendix C

Shannon Weaver Diversity Indices					
TRANSECT	Quadrat	IFATY A	IFATY B	MANGILY A	MANGILY B
T2	1	0.8891602	0.913338	0	1.026339
T2	2	0.80709061	0.827033	0	1.219833
T2	3	0.66608952	0.621461	0.718657	1.002393
T2	4	0.36554817	0.576832	0.734875	1.152179
T2	5	0.30649537	0.584141	0.799395	0.943348
T2	6	0.24967246	0.49636	0.514827	1.021958
T2	7	0.55214609	0.584141	0.576832	1.09117
T2	8	0.34657359	0.230259	0.714011	1.333074
T2	9	0.38004512	0.434355	0.500402	1.048506
T2	10	0.284568	0.552146	0.325083	1.094056
T2	11	0.29957323	0.610304	0.3684	1.361608
T2	12	0.284568	0.745085	0.395302	1.264707
T1	1	0.72770813	0.334231	0	1.245894
T1	2	1.09511968	0.174807	0.696248	1.327436
T1	3	0.66461312	0.693147	0	0.851719
T1	4	0.8614001	0	0.733033	1.12743
T1	5	0.74123696	0	0.71309	1.093256
T1	6	0.9680344	0.510267	1.054339	1.395458
T1	7	0.98078927	0	1.034977	1.257154
T1	8	0.59769625	0	0.668461	1.036576
T1	9	0.50911508	0	0.576832	1.145607
T1	10	0.65200574	0	0.576832	1.289922
T1	11	0.9865007	0	0.576832	0.529832
T1	12	0.90602881	0.795546	0.576832	0.664613
T3	1	0.72238368	0.795546	0.576832	0.950392
T3	2	0.69314718	0.943348	0.576832	0.839078
T3	3	0.82517055	1.003491	0.576832	1.185325
T3	4	0.73487549	0.827033	0.576832	1.222592
T3	5	0.61299075	0.795546	0.576832	1.134424
T3	6	0.69314718	0.664613	0.576832	1.161676
T3	7	0.69314718	0.874155	0.576832	0.747483
T3	8	0.6576207	0.795546	0.576832	0.537649
T3	9	0.6576207	0.756242	0.576832	0.741237
T3	10	0.71865693	0.741237	0.576832	0.660765
T3	11	0.85568867	0.799395	0.576832	0.621461
T3	12	0.56001779	0.59145	0.576832	0.660765
MEAN		0.65406237	0.535307	0.549368	1.027414
	Percentiles	IFATY A	IFATY B	MANGILY A	MANGILY B
	95%	0.98221713	0.920841	0.85829	1.340208
	75%	0.8116106	0.795546	0.675408	1.220523

	50%	0.67961835	0.600877	0.576832	1.092213
	25%	0.54138834	0.308238	0.561331	0.848559
	5%	0.284568	0	0	0.600508

Appendix D

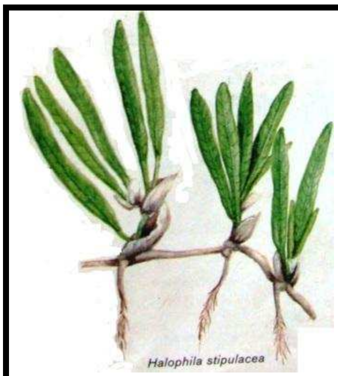
Household and Vocational Data

Ifaty	Age	Range	# Children	Mean	#Gleaners/household	# Pirogues
	21	20-39	1		2	3
	23	class 1	2		10	2
	24		1		2	1
	24		0		9	1
	29		2		4	0
	30		2		6	1
	33		5		6	2
	35		5		3	4
	35		7		3	2
	37		4	2.9	3	4
	48	40-59	9		2	3
	49	class 2	4		5	1
	50		6		6	4
	50		8		3	3
	54		6	6.6	5	4
	63	60-90	8		3	1
	65	class 3	11		3	2
	65		8		4	1
	68		1		2	2
	70		6	6.666667	2	1
	Mean		4.8		4.15	2.1
	Total		96		83	42

Appendix E

Household and Vocational Data						
		Age Range	# Children	Mean	#of Gleaners/Household	# of Pirogues
Mangily	27	20-39	3		2	1
	28	class1	2		0	1
	32		3		0	1
	33		4		1	1
	38		3		14	3
	39		8	3.83333333	0	2
	42	40-59	2		2	4
	42	class2	7		1	0
	45		9		4	4
	47		7		3	3
	48		4		1	1
	57		5		0	1
	59		7	5.85714286	5	3
	65	60-90	7		0	4
	65	class 3	5		0	3
	66		9		0	0
	68		6		3	4
	69		8	7	0	1
Total			99		36	37
Mean			5.5		2	2.05555556

Appendix F

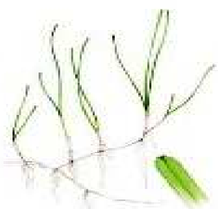


Halophila stipulacea

Thalassia hemprichii

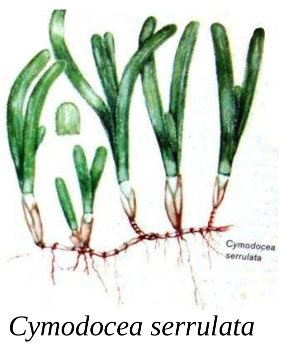
Thalassadendron ciliatum

Halodule uninervis



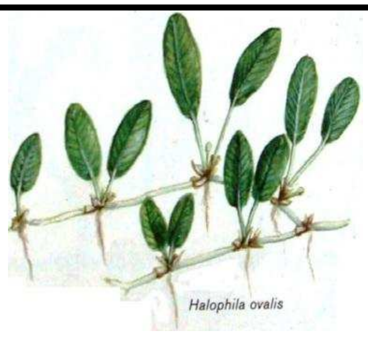
Halodule wrightii

Syringodium isotifolium



Cymodocea serrulata

Cymodocea rotundata



Halophila ovalis

Appendix F

SeagrassNet = Seagrass Monitoring Network

***Seagrass*Net Field Sampling Form (one sheet per station)** — **Indo-Western Pacific Region IX**

Location:	Transect code & no.:	Researchers:	Sampling date and time: e.g. 20 Jan 2004 1400 hrs.
State/Country:	Station (circle one): **A.** Nearshore, **B.** Middle, **C.** Offshore	Comments:	

PARAMETERS	Example	1	2	3	4	5	6	7	8	9	10	11	12
		Cross-transect 0-25 m						Cross-transect 26-50 m					
Quadrat Measures at pre-selected random distances	Quadrat 2	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat	Quadrat
Photograph (1 per quadrat)	√												
Voucher Specimen (1 of each species/Station)	√												
All Species Cover Total %	60												
Species =Hu % Cover	40												
Species = % Cover													
Species = % Cover													
Species = % Cover													
Species =Ea % Cover | Density (Ea density per 25x25 cm quadrat)	20 | 32	|	|	|	|	|	|	|	|	|	|	|	|
Canopy Height (cm) Grazing Evidence? (y/n)	20 y												
Flower/Fruit Count by species	4 Hu 6 Cr												
Leaf Biomass Core Size (m^2)	√ 0.0035												

Pre-selected Random Distances for 0-25m / Pre-selected Random Distances for 26-50m

	1	2	3	4	5	6	7	8	9	10	11	12
A. Nearshore	2	7	8	16	18	25	26	33	38	40	44	46
B. Middle	9	10	15	17	22	25	28	31	35	37	39	45
C. Offshore	5	7	10	18	19	22	26	34	35	38	43	44

Cross-transect Measures

				Left (0m)		Center (25m)		Right (50m)	
GPS: Latitude	Dist. to edge (m)	° ' "	8.6						
Longitude	Dist. to last (m)	° ' "	11.2						
Water Depth (m) at time (hrs)			2.35 @ 1524	at		at		at	
Surface sediment observation / sample			fine-sand / yes						

Station Measures — **Region IX species**

Light -- Hobo (day in - day out)	6Jan - 20Jan	-	Cr - *Cymodocea rotundata*	Hw - *Halodule wrightii*	Hq - *Halophila ovata*	Th - *Thalassia hemprichii*
Water temp. logger (day out)	20Jan		Cs - *Cymodocea serrulata*	Hb - *Halophila beccarii*	Hn - *Halophila spinulosa*	Tc-*Thalassodendron ciliatum*
Salinity (ppt)	25.8		Ea - *Enhalus acoroides*	Hd - *Halophila decipiens*	Hs - *Halophila stipulacea*	Zp - *Zostera capensis*
Tidal Stage (high or low / spring or neap)	high spring		Hp - *Halodule pinifolia*	Hm - *Halophila minor*	Rm - *Ruppia maritima*	Zc - *Zostera capricorni*
			Hu - *Halodule uninervis*	Ho - *Halophila ovalis*	Si -*Syringodium isoetifolium*	Un - Unknown

SeagrassNet survey data sheet for the West Indian Ocean region; used for field surveys (SeagrassNet 2006)

Seagrass Percentage Cover

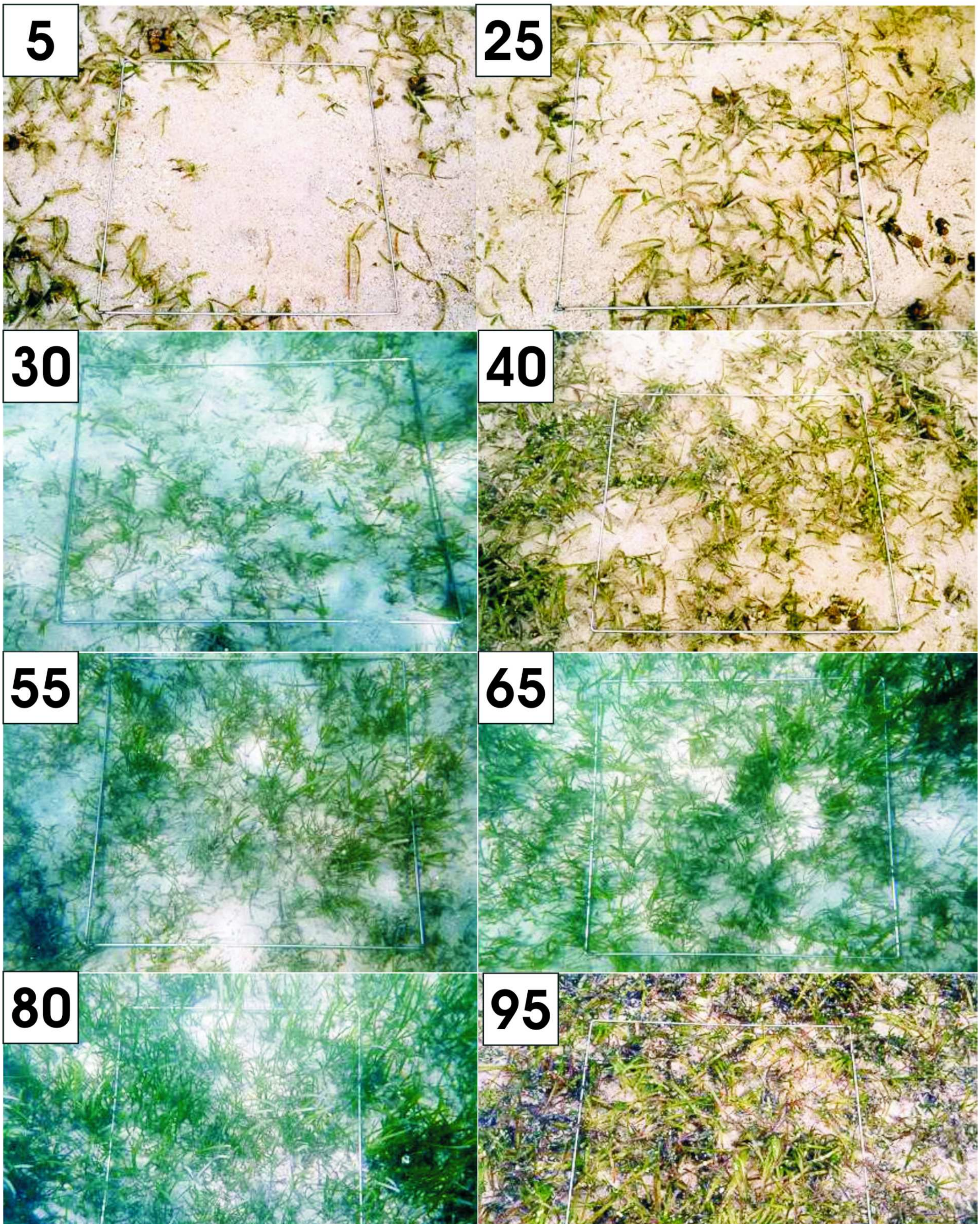
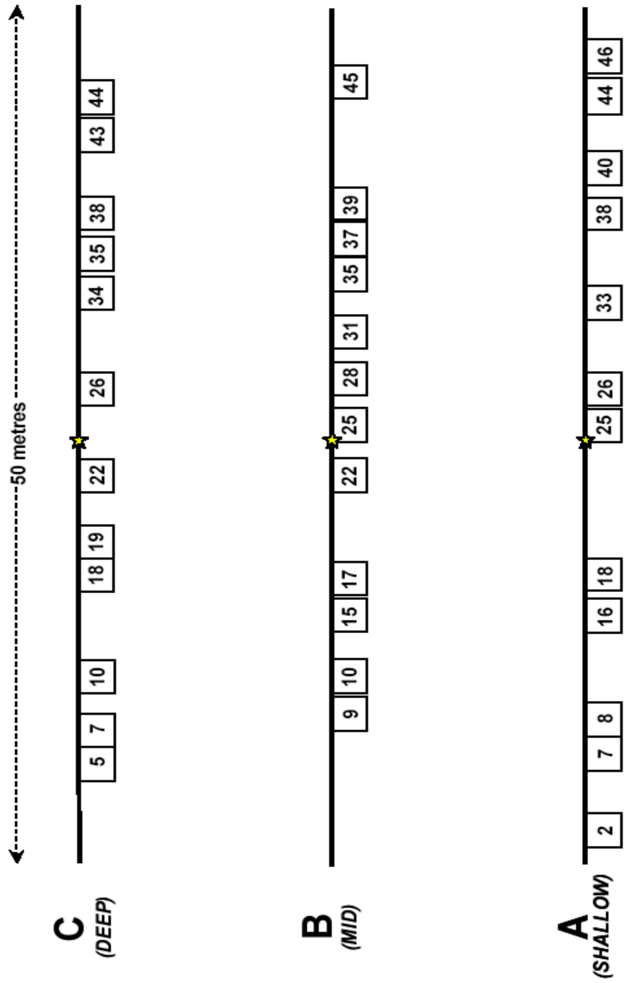
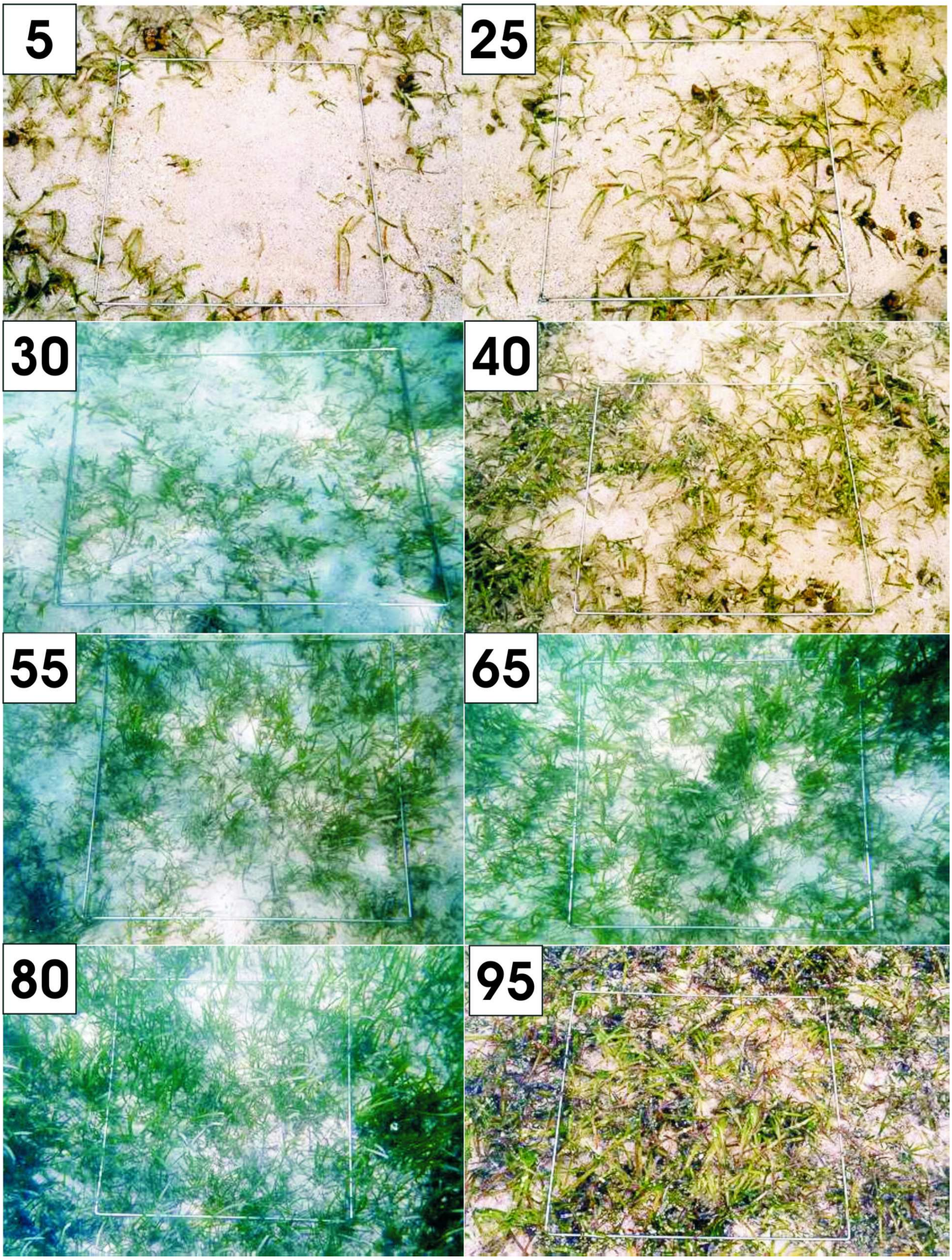


Figure 6. Location (distance) of quadrats along each cross-transect.



Locations of quadrats along cross transects, for this study A=nearshore, B= mid distance, C= offshore (SeagrassNet 2006)

Seagrass Percentage Cover



Appendix G

Social Survey Questions for Ifaty and Mangily

Sample Size: 20 Participants per village

Target Group: Oldest female resident of a compound of homes

1. Eno ty anaranao : What is your name?
2. Firy taona ianao : How old are you?
3. Eno datyhataratanaanao : what is the date of your birth?
4. Miteraky iea eha : where were you born?
5. Manambady va ianao : are you married?
6. Vezo eha : are you Vezo?
7. Miterakie firy eha : How many children have you given birth to ?
    a. Firy velo : how many are alive?
    b. Firy maty : how many are dead?
8. Firy tao anakany anao : how old are your children?
9. Anakany anao mandayah ecole : do your children go to school?
10. Inona no asananao : what do you do?
11. Misy lakana eha : do you own a boat?
12. Firy lakana : how many?
13. Firy miasa : how many are working?
14. Firy olo mipetraka anatany tokantany anao : how many people live in your compound?
    a. Longo sa namana sa olo hofan-trano : family, friends, or people renting?
15. Eno asan'ny olo mipetraka miaraka amin` anao : what do the people in your compound do?
16. anatany vola riky firy andro mehina raha bakao ranjekie eha : how many days in the month do you consume seafood?
17. anatny vola riky firy andro mehina hena : how many days in the month do you consume meat?
18. Mihakie va eha : do you glean?
19. Mahazo eno : what do you glean?
20. Firy olo anatany tokantany anao mihakie: how many people in your compound glean?
21. Mihakie asan'ny ampela sa leylahy sa zaza :is gleaning a woman's, mans or children's work?
22. Anaky anao mihakie va : do your children glean?

23. Mahazo eno : what do they glean?
24. Matsiaro tamny toa lasa, ranjekie mitovie aminizao sa miova : think back to last year, have you noticed any changes to the ocean?
    a. Miovo eno : what changes?
25. Matsiaro tamny folo tao lasa, ranjekie mitovie aminizao sa miova : think back ten years ago, have you noticed any changes to the ocean?
    a. Miovo eno : what changes?