Seagrasses and Algae of North-Eastern Madagascar

Source: A Rapid Marine Biodiversity Assessment of the Coral Reefs of Northeast Madagascar: 44

Published By: Conservation International

URL: https://doi.org/10.1896/054.061.0106

Chapter 4

Seagrasses and algae of north-eastern Madagascar

Giuseppe Di Carlo & Monica Tombolahy

SUMMARY

The north-eastern coast of Madagascar presents extensive and highly diverse algal and seagrass assemblages. As this part of the coastline is almost completely undeveloped, these habitats are in a pristine state, only limited by environmental conditions, such as wave action, sediment runoff and nutrient concentrations. Ten species of seagrass were common, comparable to the species diversity found elsewhere in the Western Indian Ocean: *Thalassodendron ciliatum, Thalassia hemprichii, Syringodium isoetifolium, Cymodocea rotundata C. serrulata, Halodule uninervis, H. wrightii, Halophila ovalis, H. stipulacea and Zostera capensis.* Larger species (e.g. *T. ciliatum* and *T. hemprichii*) were mainly found on stable substrates, mostly in coastal lagoons or on the shallow, inner edge of coral reef flats. In areas where sediment conditions were particularly dynamic and hydrodynamic forces play a major role, smaller, fast growing species (e.g. *H. uninervis*) were dominant, with considerable spatial and temporal variation. In the few urban areas present along this coastline, seagrass distribution was limited by pollution and eutrophication resulting from sewage outfalls and farming activities.

To capture the diversity and abundance of algae and seagrass beds in the study area, four habitat categories are described here: coastal, including both exposed areas and lagoons; reef flats; riverine systems and deep/open water. The list of species, frequency of occurrence and shoot density (the latter for *T. hemprichii* and *T. ciliatum*) are reported for each habitat, including key ecological processes such as sediment type, physical disturbance, light limitation and human-induced threats. The understanding of differences in the habitats, their key ecological functions and potential threats described here provide recommendations for adaptively managing algal beds and seagrass meadows and their ecosystem services.

INTRODUCTION

Seagrasses are flowering plants that have adapted to exist fully submersed in the sea. Although they are distributed globally, along temperature and tropical coastline of the world, they display highest diversity of species in the tropical Indo-Pacific region with 24 species present (Short et al., 2008). Seagrasses form extensive meadows that support biologically diverse ecosystems and play key ecological functions in the coastal marine environment (Orth et al., 2006). Seagrasses are typically found in shallow coastal areas, connecting estuarine, mangrove and coral reef habitats, hence the ecological services they provide are considered to have a high global value (Costanza et al., 1997). In deeper water (i.e. on the outer edge of coral reefs), seagrasses tend to be light limited with only some species being found. Seagrasses colonize coastal and riverine lagoons and often act as a buffer zone for nutrient recycling, improving water quality, altering water flow and stabilizing sediments, with consequent beneficial effects for nearby coral habitats and minimizing beach erosion and floods. In addition, seagrass beds provide habitats for a wide variety of plants and animals, including food for micro (i.e. sea urchins) and macrograzers (sea turtles and dugongs) as well as nursery and feeding grounds for a range of animals and commercially important fish species.

Algae are commonly found on rocky shores, among mangrove roots, seagrass beds, coral reefs, on mud flats and coastal lagoons. All three major algal groups, the Rhodophyta or red algae, Chlorophyta or green algae, and Pheophyta or brown algae, are common in these habitats. They play a crucial role in maintaining ecological balance of the aquatic environment. Algae are primary producers which provide important food sources for a diversity of marine wildlife. As a result of photosynthesis, algae also release oxygen into the water column, benefiting many fish, mollusks, crabs and other marine species. Therefore, algae, together with seagrasses form the base of the marine food web that supports the life of herbivores and primary consumers. Within coral habitats, algae,such as the green alga *Halimeda* and red coralline algae (i.e. *Amphiroa*), contribute to reef formation and development through the secretion of a calcium carbonate skeleton. In Madagascar, 20 species of algae including eight species of red algae, 10 species of brown and green algae are commercially exploited (www.meeft.gov.mg). The most commercially exploited are the red algae *Eucheuma*, *Gelidium* and *Gracilaria.*

The north-eastern coast of Madagascar presents several diverse assemblages of algae and seagrass habitats, ranging from patchy seagrass beds to meadows extending over several kilometers. Those meadows harbour an incredibly high diversity of associated macroalgae and epiphytes as well as a diversity of benthic invertebrates (i.e. sea cucumber and sea urchins) hence they represent areas of high biodiversity importance. In addition, primary production and habitat construction in seagrass beds make them important nursery areas for shrimp, lobster, and several species of fish (i.e. siganids and scarids) that later live in coral reef habitats. Seagrasses are also important for the maintenance of sea turtles (*Chelonia mydas*), and historically they supported dugong populations (*Dugong dugong*). Seagrasses and algae are a major component of the rich and productive coastal and marine ecosystem of East Africa (ref).

Here we report on the algae and seagrass assemblages found along the northeastern coastline of Madagascar, including community composition, distribution and species diversity. In addition, we attempt to capture the key features of these assemblages, community composition, including ecological and physical processes and threats to these ecosystems.

METHODS

Five locations were sampled between the town of Diego Suarez and Vohemar, namely Ambodivahibe Bay, Loky Bay, Vohemar, Andravina Bay and Nosy Ankao (Table 4.4). The habitats found within these locations were classified into four basic types:

Riverine seagrass/algae habitats were found in shallow, intertidal areas, in the proximity of large freshwater inputs, where sediments were mostly muddy sand to mud.

Coastal habitats were identified as intertidal to subtidal lagoons located between the shoreline and the reef flats, with a mixture of consolidated (sand) and unconsolidated (coral rubble) substrates and with a max depth of 2-3m.

Reef flats generally covered the entire extent of the reef, with a mixture of sand and coral rubble and with seagrass and algae growing in the proximity of coral. Reef flats are exposed at low tide, hence seagrasses are mostly found in intertidal pools.

Deep/open water seagrass and algae habitats were found at the outer edge of the reef below a depth of 8 m, with *Halophila* spp being the only seagrass species found in these habitats.

Algae and seagrass habitats, community composition and abundance were assessed using a rapid, visual assessment technique known as the Braun-Blanquet method (Braun-Blanquet, 1972). This method is quick, requiring only minutes at each sampling site, but at the same time is considered robust and highly repeatable, thereby minimizing among observer differences. At each of the five locations sampled, a number of stations were chosen to represent the habitat differences and spatial variability of the area. At each station, three replicate 50m-long transects were established at random GPS points. For each transect, a meter tape was extended along the bottom and secured with metal rods. Ten quadrats ($0.25m^2$) were then placed along the line at predetermined random positions, re-calculated for each transect. Each quadrat was examined using SCUBA, listing all algae

Table 4.1. The Braun-Blanquet abundance score. Each algae and seagrass species was scored in each quadrat according to this scale.

Cover Class	Description
0	Species absent
0.1	Species found in solitary shoots, < 5% cover
0.5	Species found in few shoots, < 5% cover
1	Species found in many shoots, < 5% cover
2	Species found in 5% - 25% cover
3	Species found in 25% - 50% cover
4	Species found in 50% - 75% cover
5	Species found in 75% - 100% cover

and seagrass species present and scoring their percent cover based on the fraction of the total area of the quadrat that was obscured by a particular species (Table 4.1). Additionally, shoots of large, climax seagrass species were counted to establish their density. Other features (ie flowers, seeds, etc), new species or anomalies were noted as well as sediment type and evidence of grazing and canopy height.

At each site, key processes and threats were noted such as fishing activities, high sediment deposition, presence of river systems, pollution and/or sewage outfalls, etc. Where taxonomic doubts existed (i.e. for *Halodule wrightii*), species were photographed for further identification in the laboratory.

RESULTS AND DISCUSSION

Algae

Ninety one species of algae were recorded in the surveys, in the three major taxonomic groups Rhodophyta or red algae, Chlorophyta or green algae, and Pheophyta or brown algae.The largest group was the red algae with 44 species in 12 families, followed by 32 species of green algae in 10 families and brown algae were least represented with 11 species in 2 families (Dictyotacea and Sargassacea) (fig.4.1). All groups were common in all the four habitat types.

The dominant green algae families were Valoniacae, Udoteacae and Caulerpacae (Table 4.2), while within the red algae the dominant families were Rhodomelacae and Hypneacae. The calcareous red algae Coralinacae and Galaxauracae were in abundance in Andravina and Vohemar.

Some algal species are only found seasonally at the locations sampled, or in different phases of their life cycle. For example, some green algae species in Andravina and Loky bay were encountered at low abundance in their growing phase (e.g. *Acetabularia pavula*, *Microdyction aghardianum),* and similarly for the red algae such as *Gelidiela acerosa*, *Laurencia* sp.

Algae species that are indicative of ecological imbalance were recorded at several locations, in particular *Tydemania expeditionis* and *Microdyctionsp* in Ambodivahibe. *Caulerpa racemosa* and *C. brachypus* were abundant in Nosy Ankao due to the seaweed farm present at this location. At Nosy Ankao and Ambodivahibe blue green algae (i.e. Cyanophycees, *Lyngbia* sp.) were recorded covering a large proportion of corals and sponges.

Different alga species were found across the five locations, reflecting local ecological conditions. Calcareous

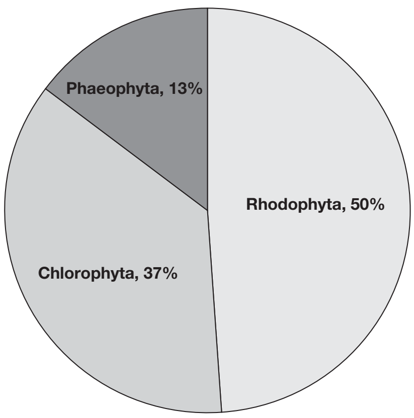

Figure 4.1. Distribution in percentage of algal groups across the five locations.

Table 4.2. Number of species of algae in each Family, by survey location (AMBDV = Ambodivahibe Bay)

	AMBDV	LOKY	ANKAO	ANDRAVINA	VOHEMAR
CHLOROPHYTA					
Ulvacae	1	1	1	1	2
Cladophoracae	0	0	0	0	2
Siphonocladacae	1	0	0	1	2
Anadyomenacae	1	0	1	1	0
Valoniacae	4	0	2	0	5
Caulerpacae	3	6	5	6	1
Udoteacae	6	6	5	4	3
Caudiacae	0	1	1	1	0
Dasycladacae	1	0	1	0	1
Polyphisacae	1	0	0	0	0
TOTAL	**18**	**14**	**16**	**14**	**16**
RHODOPHYTA					
Rhodomelacae	5	0	1	4	11
Delesseriacae	1	1	1	0	0
Champiacae	0	0	1	1	2
Soleriacae	0	0	0	0	3
Schizymeniacae	1	0	0	0	1
Hypneacae	4	2	1	1	4
Corallinacae	0	2	2	5	5
Peyssonneliacae	0	2	1	2	0
Halymeniacae	1	0	2	1	2
Gracillariacae	1	0	0	1	3
Gelidiacae	1	1	0	0	1
Galaxauracae	0	3	0	5	0
TOTAL	**14**	**11**	**9**	**20**	**32**
PHEOPHYTA					
Dictyotacae	4	3	4	5	2
Sargassacae	0	3	0	0	0
Subtotal	**4**	**6**	**4**	**5**	**2**
TOTAL	**36**	**31**	**29**	**39**	**50**

sediment-forming algae (e.g. *Halimeda macroloba*) are tolerant of low light levels and were commonly found at depths greater than 25 m (Weinberg, 1976). A*vrainvillea erecta* and some red algae such as *Hypnea* sp. and *H. cuneata* were common in shallow and intertidal seagrass beds affected by terrigenous runoff and sedimentation, where high levels of anoxia on the muddy substratum occur.

Seaweed populations on intertidal rocky shores tend to be more productive and extensive than those on sandy beaches or mud flats (Branch et al., 1994). Some areas presented abundant species in each habitat. In particular,

Table 4.3. Summary of algal community in the four main habitats (riverine, coastal, reef flat and deep reefs), and the locations in which these were found. LKB (Loky Bay), VOHM (Vohemar), ANDR (Andravina Bay), AMBD (Ambodivahibe Bay). In each habitat, algal species are listed by their prime habitat, with blanks in the substrate column indicating the same substrate as the species above.

Habitat	% species	Key algae species	Substrate	Location occurrence
Riverine	*7*	*Avrainvillea erecta* *Hypnea sp1* *Hypnea cornuata*	mud	LKB, VOHM, ANDR
Coastal	*36*	*Cladophora* sp.	coral rubble/hard bottoms	AMBD, LKB
		Chaetomorpha indica *Caulerpa sertularoides* *Enteromorpha compressa* *Neomeris vanbosseae* *Dictyopteris versluysii*	sand/coral rubble	
		Champia sp. *Chondrophycus papillosus* *Gracilaria salicornia* *Acanthophora spicifera* *Hypnea cornuata* *Tolypiocladia glomerulata* *Dictyota dichotoma* *Padina gymnospora* *Padina boryana* *Avrainvillea erecta*	sand/coral rubble	
Reef flat	*30*	*Cladophora* sp. *Dictyosphaeria cavernosa* *Ulva lactuca* *Enteromorpha compressa* *Sarconema filiforme* *Digenia simplex* *Acanthophora spicifera* *Gracilaria salicornia* *Gracilaria acruata* *Jania adhaerens*	coral rubble/hard bottoms	VOHM
		Halimeda opuntia	sand	
		Boergensenia forbesii	sand/coral rubble	
		Ventricaria ventricosa	sand/muddy sand	
Deep/open water	*27*	*Neurymenia fraxinifolia* *Peyssonnelia capensis* *Peyssonnelia simulans*	coral	VOHM, ANDR
		Udotea indica *Caulerpa serrulata*	sand	
		Halimeda opuntia *Amancia rhodanta* *Galaxaura fasciculata* *Galaxaura elongata*	sand/coral	
		Galaxaura sp2. *Coralina* sp. *Halimenia durvillei*	sand/coral	

in Ambodivahibe Bay, we noted thriving red algae *Acanthophora spicifera* and the brown algae *Dictyota dichotoma*. The first species could likely be an invasive species that became abundant as environmental factors are favorable (e.g human-induced organic matter increase).

In areas frequently exposed to disturbances, opportunistic species, such as *Ulva lactuca* and *Enteromorpha compressa* were found. A few rare species were found at high abundance at individual sites, sometimes indicative of disturbance or invasion, such as *Caulerpa* and *Halimeda* spp. An unknown species of blue-green algae was found at most sites, but was particularly abundant at Nosy Ankao. This finding, together with the presence of *Caulerpa* at this site, suggests enrichment in nutrients from the seaweed farm (Kraufvelin et al. 2010). Species of *Udotea* were common, and always found small patches in the sand patches between reefs, mostly at Ankao, Loky bay, and Andravina.

Coastal habitats had the highest number of algal species (36%, Table 4.3), dominated by green algae, in some cases by species indicative of eutrophic input (e.g. *Enteromorpha compressa* and *Ulva lactuca*). These were followed in importance by brown algae, such as *Padina gymnospora* and *P. boryana* (more abundant in the Loky Bay). Within seagrass beds, particularly in Ambodivahibe bay, Andravina bay and Loky Bay, *Dictyota dichotoma* was abundant. On reef flats, where aerial exposure is common at low tide (especially at Vohemar) the red algae *Gracilaria salicornia* and *Dygenia simplex* were abundant. In shallow pools on the reef flats that retain water during low tide, tolerant species such as *Gracilaria acruata, Acanthophora spicifera* and *Boergensenia forbesii* were common. Finally, deeper areas (below 2 m) were occupied by a diversity of larger red algae.

Seagrasses

Ten seagrass species were common, with the highest number of species (7) in riverine habitats, followed by the shallow platform of reef flats and coastal areas (6 species each, both exposed and sheltered) and lowest in deep habitats (2 species) (Table 4.4). Although seagrass beds were not mapped, our observations suggest that seagrasses form extensive meadows along this coastline covering in some areas (i.e. Loky Bay and Vohemar) tens of kilometers of coastline, generally on shallow sheltered coastal lagoons. Annual beds formed mostly by smaller, fast-growing species (i.e. *Halodule uninervis*, *Halophila ovalis*) were often found in exposed and transient environments, such as shallow sand banks and reef flats (Table 4.5). Those meadows are largely affected by sediment movement during storms and cyclones.

Along this coastline, seagrasses typically form mixed species assemblages though with dominance by one species, controlled principally by depth (subtidal vs intertidal) and sediment conditions (Table 4.5). In the intertidal, *Zostera capensis*, *H. uninervis* and *Cymodocea rotundata* were common. *Z. capensis* was most commonly present in exposed areas, while *H. uninervis* and *C. rotundata* colonise tidal pools on mudflats (e.g. in Vohemar, Table 4.4). In the subtidal, *T. hemprichii* and *S. isoetifolium* formed extensive meadows on sand or muddy sand (e.g. in Vohemar, Ambodivahibe Bay), largely influenced by sediment composition. All species were associated with mud, sand, muddy sand, and coarse sand substrates, while only *T. hemprichii*, *S. isoetifolium* and *Thalassodendron ciliatum* colonised rubble substrate where the sediment layer was minimal (Ambodivahibe Bay and Vohemar). At mid depths on the edges of reefs (8-12 m), or among coral patches on sand, *Halophila ovalis* formed extensive patches often mixed with *H. stipulacea*. No seagrasses were found below 12 m on the deeper reefs.

Figures 4.2 and 4.3 show the relative abundance and shoot density parameters, respectively, for seagrass species at the five locations. Comparing the five locations sampled, Loky Bay had the highest diversity of species (9 species) followed by Nosy Ankao (8 species) (Fig. 4.2). This was due to their diversity of habitats, from reef flats to riverine systems. In Loky Bay, *T. ciliatum* was commonly found on coral rubble with the highest cover and shoot density (mean 260±95 and 212.5±89 shoot m^{-2} for coastal lagoon and reef flat respectively, Fig. 4.3). On sand and muddy sand, seagrasses formed mixed communities of *T. hemprichii*, *C. rotundata* and *H. uninervis*. In this area, *T. hemprichii* shoot density was the lowest recorded, ranging from 14.2±40.1 in the coastal lagoons to 31.2±60.4 shoot m^{-2} on the reef flat and zero in riverine habitats. *C. serrulata* and *Z. capensis* occurred in shallow, sheltered lagoons adjacent to river deltas or freshwater runoffs.

Table 4.4. Seagrass species recorded at each habitat, with site occurrence. LKB (Loky Bay), VOHM (Vohemar), ANDR (Andravina Bay), AMBD (Ambodivahibe Bay).

Habitat	*T. hemprichii*	*T. ciliatum*	*C. serrulata*	*C. rotundata*	*H. ovalis*	*H. stipulacea*	*Z. capensis*	*H. uninervis*	*H. wrightii*	*S. isoetifolium*	Site occurrence
Riverine			*x*	*x*	*x*	*x*	*x*	*x*	*x*		LKB, VOHM, ANDR
Coastal	x	x	*x*		*x*	*x*				x	AMBD, LKB, LKB
Reef flat	x	x		*x*	*x*	*x*				x	VOHM, LKB
Deep					*x*	*x*					LKB ANDR

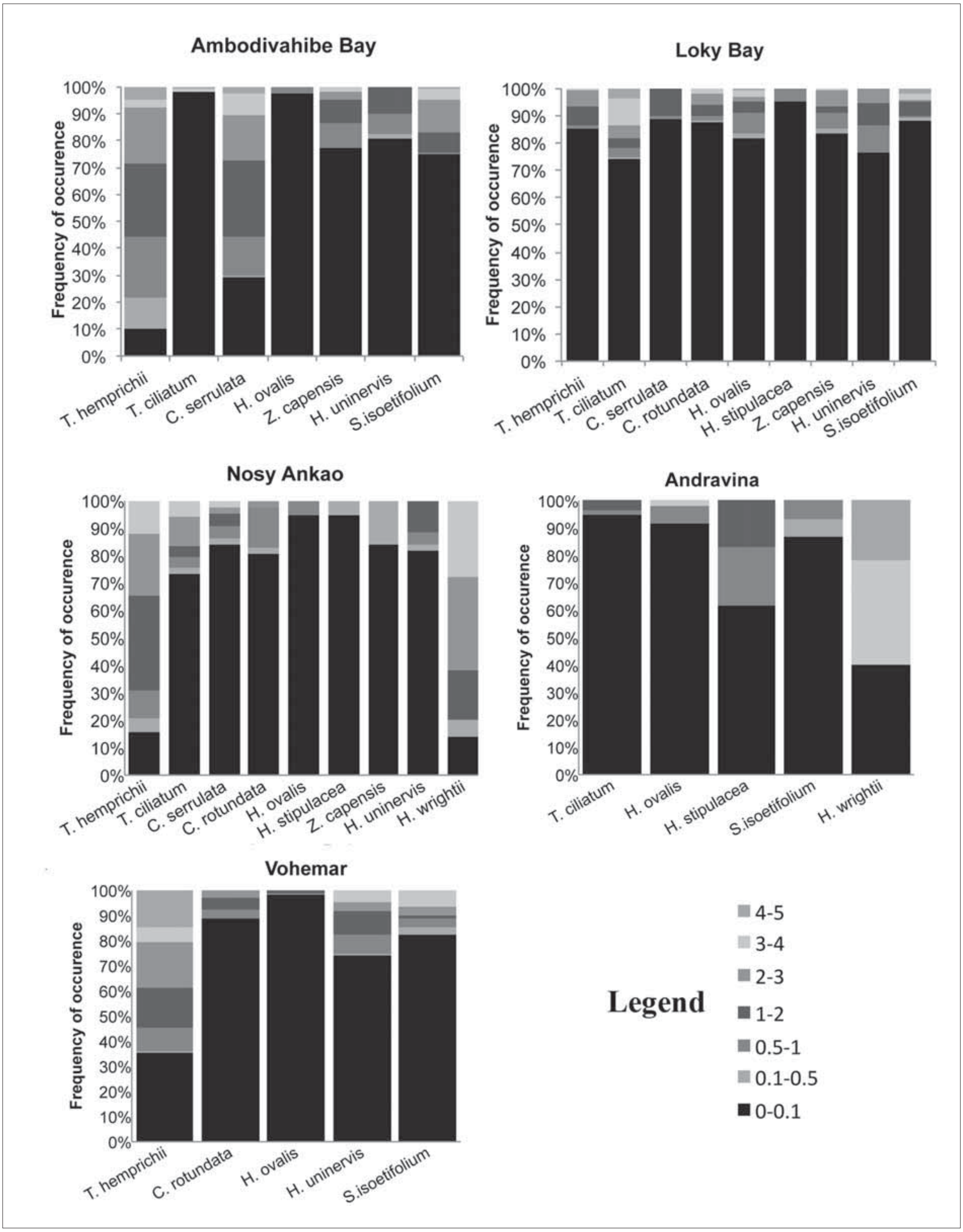

Figure 4.2. Frequency of occurrence according to the Braun-Blanquet assessment of seagrass percent cover at the five locations in northeast Madagascar: Ambodivahibe Bay, Loky Bay, Vohemar, Andravina Bay and Nosy Ankao. The legend for Braun-Blanquet scores is shown in the upper figure (and see Table 1). Greater dominance by a single species is shown by a larger proportion of the higher density classes (ie. shorter length of the dark black, low-density class).

Table 4.5. Summary of the seagrass community in the three main habitats (riverine, coastal, reef flat) in which seagrasses were found.

Habitat	Limiting factors	Seagrass species	Substrate
Riverine	Terrigenous runoff	*Cymodocea serrulata*	mud
	salinity	*Cymodocea rotundata*	mud
	sediment anoxia	*Halophila ovalis*	mud
	bioturbation	*Halophila stipulacea*	mud
		Zostera capensis	mud
		Halodule uninervis	mud
		Halodule wrightii	mud
Coastal	physical disturbance	*Thalassia hemprichii*	sand/muddy sand
	bioturbation	*Thalassodendron ciliatum*	coral rubble/hard bottoms
		Syringodium isoetifolium	sand/coral rubble
		Cymodocea rotundata	sand/muddy sand
		Halophila ovalis	sand/muddy sand
		Halophila stipulacea	sand/muddy sand
Reef flat	physical disturbance	*Thalassia hemprichii*	sand/muddy sand
		Thalassodendron ciliatum	coral rubble/hard bottoms
		Syringodium isoetifolium	sand/coral rubble
		Cymodocea rotundata	sand
		Halophila ovalis	sand
		Halophila ovalis	sand
		Halophila stipulacea	sand

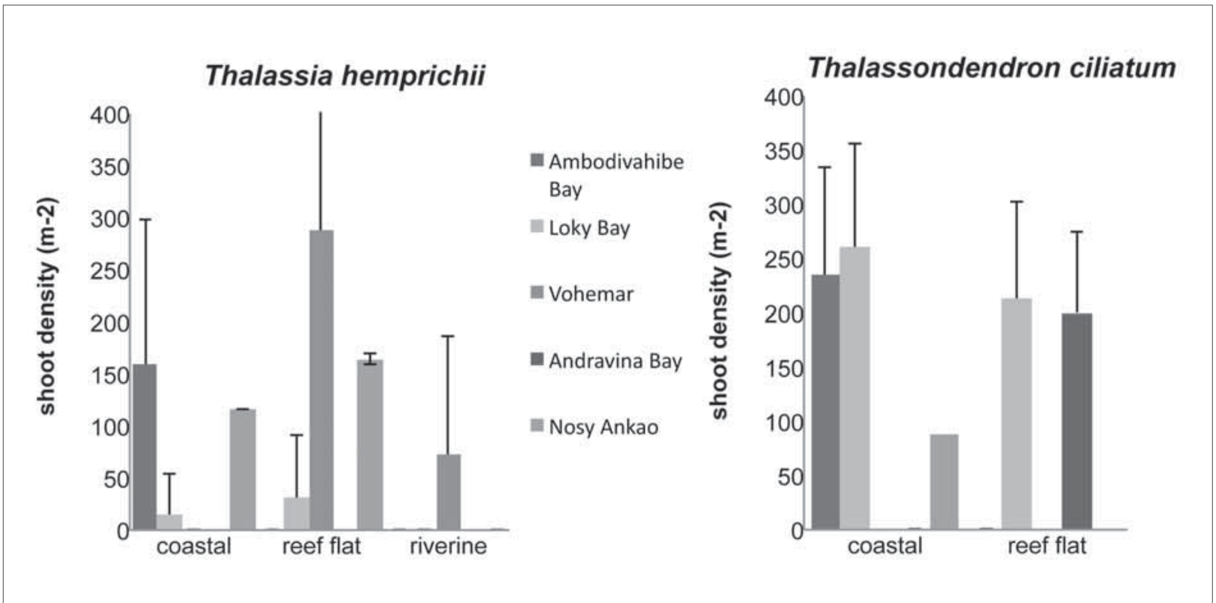

Figure 4.3. *Thalassia hemprichii* and *Thalassondendron ciliatum* (m ± stdev) in locations and habitat of occurrence. For *T. hemprichii* on reef flats in Vohemar, the stdev goes off the scale, sd = 340.

In Nosy Ankao, *T. hemprichii* dominated sand banks, followed by *C. rotundata* and *T. ciliatum* (average shoot density 87.5±62 shoot m^{-2}) that were found on the inner reef flat on coral rubble. In this area, *T. hemprichii* shoot density ranged from 116.4±65.3 in the coastal lagoons to 164.5±118.9 shoot m^{-2} on the reef flat. *C. serrulata* was also present in this area close to a freshwater runoff.

In Ambodivahibe Bay seven species of seagrass were found, where *T. hemprichii* and *C. rotundata* were largely present on the sand flat between the mangrove fringe and the reef flat. On the southern side of the bay, seagrasses formed mixed intertidal and subtidal communities where *T. hemprichii* (mean shoot density 158.7±140 shoot m^{-2}), *C. rotundata* and *S. isoetifolium* were most abundant. Near freshwater runoff also on the southern end of the bay, *Z. capensis* was commonly distributed on the intertidal. *T. ciliatum* was sparsely distributed on coral rubble on the inner part of the reef flat, with an average shoot density of 235±100 shoot m^{-2}.

In Vohemar and Andravina Bay five species of seagrass were found. In Vohemar, the extensive reef flat and associated sand bars were mostly dominated by mixed assemblages of *T. hemprichii*, *C. rotundata,H. univervis* and *S. isoetifolium.* In areas of the flat that are more exposed to sediment disturbance, *H. ovalis* is commonly found. On the Northwest side of the shore, towards the river delta, *T. hemprichii* and *H. uninervis* were the only species present. In this area, *T. hemprichii* showed the highest shoot density of all sites, with densities of 386.9±337.8 on the reef flat and 72.9±113.4 shoot m^{-2}.

In Andravina Bay, the southern side of the bay is exposed to the wind fetch, where *T. ciliatum* is found on hard substrate on the inner edge of the reef and sparse *S. isoetifolium* can be found on sand patches. In this area, *T. ciliatum* shoot density averaged 200±75 shoot m^{-2}. In the shallow, quiescent lagoon, near the river mouth, *Halophila*sp and *H. wrightii* were the only species present.

CONCLUSIONS AND RECOMMENDATIONS

Seagrass beds are in pristine condition along this coastline, except in proximity of sewage outfalls or larger human settlements. In these areas (i.e. Vohemar), the high organic matter content in the sediment and water turbidity increase epiphyte growth.

Ten species of seagrass werefound along the coast of northeastern Madagascar: *Thalassodendron ciliatum, Thalassia hemprichii, Syringodium isoetifolium, Cymodocea rotundata* and *C. serrulata, Halodule uninervis* and *H. wrightii, Halophila ovalis* and *H. stipulacea, Zostera capensis.* In deeper water (i.e. below 10 m) (i.e. on the outer edge of coral reefs) in light limited conditions, only *Halophila* species were found.

Ninety one species of algae were recorded in the surveys, dominated by the red algae (45 spp), followed by the green then brown algae.

As coastal development and population growth increases in the areas surveyed, seagrasses and algae will face growing pressures such as mechanical removal for infrastructure development (hotels, marinas, etc), increasing sediment runoff due to deforestation, and propeller and anchor damage as power engines become more readily available. The impacts of climate change will also likely affect seagrass ecosystems, through increase in sea surface temperature (expected to rise up to 0.6 °C in the Region) and sea level rise (predicted up to 50cm by 2100) and changes in storms/cyclone patterns, frequency and intensity.

To maintain the functions and ecosystem services of algal and seagrass ecosystems the following recommendations should be implemented:

1. Establish monitoring programs to assess changes in algae and seagrass beds over time; This would be particularly important in areas where Conservation Areas may be established (e.g. Ambodivahibe Bay) and in proximity to villags and urban areas (e.g. Vohemar).

2. Create marine protected areas (MPA) that will reduce or avoid altogether future impacts on coastal ecosystems, including mangroves, seagrasses and coral reefs;

3. Enforce existing and establish new requirements and zoning codes for sustainable coastal development that minimizes impacts on shallow coastal ecosystems;

4. Establish marine protected areas that limit or ban destructive fishing practices that uproot and remove seagrass to rebuild healthy marine ecosystems, fish larvae and populations;

5. Promote sustainable aquaculture practices (eg. low density and chemical-free) that minimize waste and runoff that cause algal blooms reducing light availability;

6. Encourage waste management solutions to address improper disposal and critically reduce eutrophication, organic matter pollution and plastic pollution into the coastal zone;

7. Restore mangroves and forests to prevent siltation and runoff that inhibits seagrass growth and can cause seagrass burial;

8. Enhance awareness campaigns on the importance of coastal ecosystems, particularly mangroves and seagrasses to ensure they are specifically addressed in coastal management plans and community engagement in coastal protection is enhanced;

9. Hold training sessions for coastal managers to improve monitoring skills and develop effective conservation measures;

10. Conduct outreach programs for communities, governments, and tourists to help them get involved in the conservation of ecosystems and the services they provide.

Given their importance for in the marine environment and their ecosystem services, the full assessment of algae assemblages is critical to define marine conservation sites and establish new marine protected areas (MPA). Algal distribution can be used as an ecological indicator and their presence entails important nutritional elements that are beneficial to fish communities and other marine organisms. Therefore, including algal surveys in ecological monitoring of MPAs provides information on site productivity and ecosystem health. As the marine algae of Madagascar are little known, it is important to conduct an exhaustive inventory to widen management interventions and adopt more detailed management plans.

REFERENCES

Branch, G.M. and C.A. Moreno. 1994. Intertidal and subtidal grazers. In: Sigfried W.R. (ed.). Rocky shores: exploitation in Chile and South Africa. Springer-Verlag, Berlin. Germany. Pp 75–100.

Braun-Blanquet, J. 1972. Plant sociology: the study of plan communities. Hafner, New York.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Kraufvelin, P., A. Lindholm, M. F. Pedersen, L.A. Kirkerud, and E. Bonsdorff. 2010. Biomass, diversity and production of rocky shore macroalgae at two nutrient enrichment and wave action levels. Marine Biology 157(1): 29-47.

Orth, R.J., T.J.B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott and S.L. William. 2006. A global crisis for seagrass ecosystems. BioScience 56(12): 987-996.

Short ,F.T., T.J.B. Carruthers, W.C. Dennison and M. Waycott. 2007. Global seagrass distribution and diversity: A bioregional model. Experimental Marine Biology and Ecology 350: 3-20.

Weinberg, S. 1976. Submarine daylight and ecology, Mar. Biol.37, 291–304.