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The distribution of epiphytic algae on three Kenyan seagrass species

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A survey of epiphytic algae attached on the leaves of the seagrasses *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson, *Thalassia hemprichii* (Ehrenberg) Ascherson and *Thalassodendron ciliatum* (Forsskål) den Hartog was conducted in intertidal seagrass beds located in Vipingo and Nyali along the Kenyan coast. The aim of the survey was to determine the differences in epiphytic loading on these seagrass species between areas that have different nutrient levels. The study revealed a significant difference in the levels of nitrates, ammonia and phosphates in the water column at the two sites with Vipingo having lower levels of all nutrients. The biomass of *T. hemprichii* and *T. ciliatum* and their associated epiphytic algae was higher in Nyali. However the biomass of the *C. rotundata* was lower in Nyali, though the epiphytic biomass remained the same when the two sites were compared. Rhodophytes dominated in both sites and there were more cyanophytes found on the seagrasses of Vipingo. The data presented in this paper shows that nutrient loading has an influence on the composition and biomass of epiphytic algae growing on these intertidal seagrasses. Vipingo, which had a lower level of nutrient loading, had higher numbers of cyanobacteria while in Nyali, where nutrient loading was higher, there were fewer species of epiphytes seen on the seagrasses.

Introduction

The stems and leaves of seagrasses are hosts to several organisms such as microalgae, macroalgae, bacteria and invertebrates. The epiphytic component of seagrass beds provides food for marine organisms and several epiphytic algae contribute in nitrogen fixation within seagrass areas (Borowitzka and Lethbridge 1989). The skeletal remains of encrusting coralline algae are important sources of calcium carbonate for sediments (Borowitzka and Lethbridge 1989). Apart from being contributors in seagrass ecosystems, epiphytes also benefit from living on seagrass leaves. Epiphytes attached to seagrass leaves benefit from exposure to light and nutrient availability (Harlin 1975) and can be used as indicators of environmental health as they grow rapidly and respond quickly to environmental changes (Frankovich and Fourqurean 1997).

Studies on the epiphytic component of Kenyan seagrass beds have been few hence the aim of this study was to document the species composition of epiphytic algae found on three seagrass species growing along the Kenyan coastline. This was done in two areas, each with a different nutrient status in an attempt to relate the species composition and biomass of epiphytic algae to nutrient availability in coastal ecosystems.

Materials and Methods

The study area

Nyali Beach (4°03'S, 39°43'E) is an important tourist center located 2km from Mombasa Island. There are numerous hotels along the beach as well as town settlements in this area. There are also several groundwater seepage points along the beach zone in the Nyali area. Vipingo (3°45'S, 39°50'E) is located 33km from Mombasa Island. The site in Vipingo has a few residential houses along the beach and one beach hotel (Figure 1).

Like the rest of the Kenyan coast, these sites are characterised by the northeast (NE) monsoon that occurs from October to March and the southeast (SE) monsoon from March to October. The NE monsoon is characterised by low rainfall between November and December whereas the SE monsoon has higher rainfall levels between March and June. Decreased temperatures, high cloud cover, high wind energy, and thereby a lower light penetration in the water also characterise the SE monsoon. During the NE monsoon these variables are reversed (McClanahan 1988).

Sample collection and analysis

The seagrasses surveyed were found in near shore intertidal seagrass beds adjacent to the beach in Vipingo and Nyali. The shoot density of each species was determined

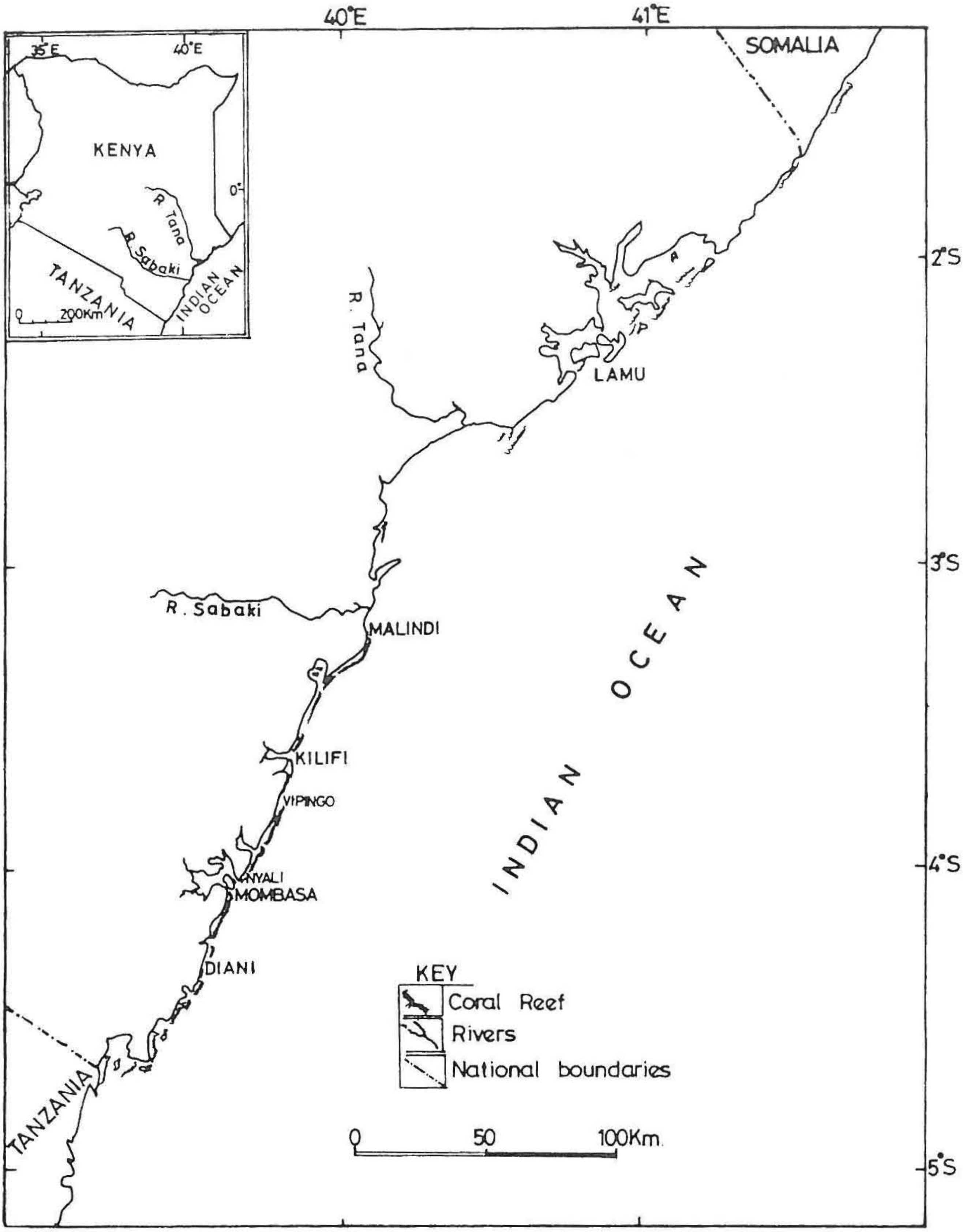

Figure 1: Map of the Kenya coast showing Nyali and Vipingo

using a 25cm x 25cm quadrate. Samples of the seagrasses *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson, *Thalassia hemprichii* (Ehrenberg) Ascherson and *Thalassodendron ciliatum* (Forsskål) den Hartog were collected from both sites during the SE monsoon (August 1999) and the NE monsoon (February 2000). Thirty shoots of each species were collected. The shoots were placed in plastic bags and transported to the laboratory where they were frozen. Later the percentage cover and the species composition of the epiphytic algae attached on each leaf of each seagrass shoot was determined using a binocular microscope. The microscopic analysis was undertaken separately for each leaf of each species with leaf 1 representing the oldest leaf and subsequent leaves being younger in age. The inner and outer faces of each leaf were analysed (Heijs 1985, 1987). The epiphytic algae identified using keys by Jaasund (1976). The cover and species composition of algae on the stems of *T. ciliatum* were also determined using a dissecting microscope.

Dry weight estimates of the seagrass leaves and epiphytes were made. The epiphytic algae were scraped from both sides of the seagrass leaves and oven dried on preweighed filter papers for 24 hours at 60°C. On drying the filter papers were reweighed and the weight of the epiphytes was determined by subtracting the weight of the filter paper from the weight of the filter with epiphytes. Each seagrass leaf was placed in aluminium foil and oven dried for 24 hours at 60°C. The dried leaves were weighed then acid washed with 5% HCl to remove any encrusting coralline algae. The leaves were then redried and weighed. The weight of the acid washed leaves was subtracted from the weight of the unwashed leaves. This weight of encrusting coralline algae was added to the weight of epiphytic algae.

The carbon and nitrogen contents of the leaves of the seagrass *T. ciliatum* was also evaluated. The leaves of 10 shoots from each site were cleaned of epiphytes and dried at 60°C overnight. The leaves of each shoot were ground separately using a mortar and pestle. The C and N levels were then determined using an elemental analyser. Water samples were collected from the two sites over a 24 hour period for both the SE and NE monsoon. During the 24 hour collection period five replicates were collected hourly. The nitrate, ammonia and phosphate content of the water samples was determined using methods described in Parsons *et al.* (1984). The data obtained in this study were analysed using two way ANOVA with replication.

Results

Species composition of epiphytic algae

At both sites, the highest number of epiphytes was found on the two oldest seagrass leaves (leaf 1 and 2) in all the species. The colonisation of most algae and in particular the encrusting coralline algae began at the leaf margins before moving into the centre of the leaves. Thus the leaf edges appeared to have a denser cover of algae compared to the centre of the leaves. There were also more epiphytes on the leaf tips compared to the base of the leaves. Colonisation of the leaves began with the encrusting coralline algae, and was then followed by the other epiphytic algae.

The younger leaves were often bare of macroscopic epiphytes and no macroalgae were found on the leaf sheaths. The young seagrass leaves and sheaths are usually colonised by microscopic epiphytes such as diatoms and bacteria before the establishment of larger species (Sterrenburg *et al.* 1995, Sullivan 1979). However, this study focused on macroscopic algae so no documentation of microscopic algae was made.

During the SE monsoon the number of species in Vipingo was higher than that in Nyali (Tables 1 and 2). In Vipingo the dominant species found on *C. rotundata* was *Ceramium flaccidum (*Kuetzing) Ardissone while in Nyali the encrusting algae dominated on the leaves of *C. rotundata*. In Vipingo, the leaves of the seagrass *T. hemprichii* and *T. ciliatum* were dominated by encrusting red algae (mostly *Hydrolithon farinosum* (Lamouroux) Penrose et Chamberlain). *Enteromorpha* sp. and *Ulva pertusa* Kjellman were found in both Nyali and Vipingo. The most notable feature was the distribution of Cyanophytes on most of the Vipingo seagrasses. *Calothrix* spp. and *Rivularia* sp. were the dominant cyanophytes. Phaeophytes were also found in both study sites but they were few in number compared to the other groups (Tables 1 and 2).

During the NE monsoon, the diversity of epiphytic algae decreased (Tables 3 and 4). However, the overall diversity of algae was higher in Vipingo. The cyanophyte *Rivularia* sp. was found only in seagrasses from Vipingo. In Nyali there was a general absence of cyanophytes. There was a decrease in the number of epiphytes on *C. rotundata* in Vipingo (Tables 3 and 4).

Epiphytic algae on the stems of Thalassodendron ciliatum

The diversity of algae on the stems of *T. ciliatum* was higher in Vipingo compared to Nyali during the SE monsoon (Table 5). This changed in the NE monsoon with more algae appearing on the stems of *T. ciliatum* in Nyali. Encrusting algae were dominant in both sites during the two seasons. *Ulva pertusa* Kjellman was abundant on the stems in Nyali. Phaeophytes were found only on *T. ciliatum* from Vipingo during the SE monsoon. The overall percentage cover of the stems increased in Vipingo during the NE monsoon whereas in Nyali the overall cover remained the same though more species appeared on the stems (Table 5).

Overall leaf and epiphytic biomass at the study sites

During the SE monsoon, the seagrass *T. ciliatum* at Nyali had a higher biomass of leaf and epiphytic algae compared to Vipingo (Figures 2 and 3). Nevertheless, in both sites the epiphytic load on the leaves of *T. ciliatum* comprised half of the leaf biomass. The seagrasses, *C. rotundata* and *T. hemprichii* had relatively low leaf and epiphytic biomass at both sites compared to *T. ciliatum*. During the NE monsoon, the leaf and epiphytic biomass of *T. hemprichii* increased in Nyali (Figures 4 and 5).

When the two sites were compared, the leaf biomass of *C. rotundata* was significantly different for both sites and sea-

Table 1: The species composition of epiphytic algae found on leaves of seagrass species from Vipingo (SE monsoon)

Algal species composition	*Cymodocea rotundata*			*Thalassia hemprichii*					*Thalassodendron ciliatum*							
	1	2	3	1	2	3	4	5	1	2	3	4	5	6	7	8
Rhodophyta																
Ceramium flaccidum (Kuetzing) Ardissone	*1	*1		*2	*2	*2	*2		*2	*	*3	*3	*2	*2		
Encrusting red algae 1	*2	*2		*1	*1	*1	*1		*1	*1	*1	*1	*1	*1	*1	
Encrusting red algae 2	*	*														
Dark red algae									*	*	*	*				
Gracillaria sp.	*															
Hypnea cornuta (Lamour.) J. Ag.									*	*						
Unid red algae 1	*	*							*	*						
Unid red algae 2										*						
Phaeophyta																
Giffordia sp.									*	*	*					
Chlorophyta																
Enteromorpha sp.	*3	*3		*	*3				*	*3	*2	*2				
Cladophora mauritania Kutzing	*								*	*	*	*				
Ulva pertusa Kjellman	*															
Cyanophyta																
Blue green algae									*3	*2	*	*	*3			
Calothrix sp1	*					*										
Calothrix sp2	*	*														
Oscillatoria sp.	*			*												
Rivularia sp.	*	*		*3					*							

Notes: Blue green algae is a mixture of *Calothrix* spp. and *Oscillatoria* spp.; n = 30 for each species; leaves are arranged from the oldest to the youngest; 1–3 = the most abundant species in terms of dominance on the leaf based on percentage cover estimates; * = present

Table 2: The species composition of epiphytic algae found on leaves of seagrass species from Nyali (SE monsoon)

Algal species composition	*Cymodocea rotundata*				*Thalassia hemprichii*							*Thalassodendron ciliatum*								
	1	2	3	4	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9
Rhodophyta																				
Ceramium flaccidum (Kuetzing) Ardissone	*1	*2	*2		*2	*2	*2	*2				*2	*2	*2	*2	*2	*2	*2		
Centroceras clavulatum (C. Agardh) Montagne												*								
Encrusting algae 1	*2	*1	*1									*1	*1	*1	*1	*1	*1	*1	*1	
Encrusting algae 2					*1	*1	*1	*1	*1											
Hypnea cornuta (Lamour.) J. Ag.														*						
Unid red algae 1					*															
Phaeophyta																				
Hincksia rallsiae (Vickers) Silva		*3																		
Sphacelaria rigidula Kuetzing	*				*															
Chlorophyta																				
Enteromorpha sp.					*3		*3					*3	*	*3		*3				
Ulva pertusa Kjellman						*3						*	*3							
Cyanophyta																				
Blue green algae		*																		

Notes: Blue green algae is a mixture of *Calothrix* spp. and *Oscillatoria* spp.; n = 30 for each species; leaves are arranged from the oldest to the youngest; 1–3 = the most abundant species in terms of dominance on the leaf based on percentage cover estimates; * = present

sons ($F = 28.49, 22.48$ respectively; $p \leq 0.05$). The biomass of epiphytes on *C. rotundata* showed a significant seasonal variation ($F = 0.26$; $p \leq 0.05$) but did not show a difference between the sites. In the case of *T. hemprichii*, the leaf biomass varied significantly with sites and between seasons ($F = 52.29, 47.07$ respectively; $p \leq 0.05$). The epiphytes found on the leaves of *T. hemprichii* also varied significantly between sites and seasons ($F = 25.46, 6.32$ respectively; $p \leq 0.05$). *T. ciliatum* also showed a significant difference in the leaf biomass between the sites and seasons ($F = 7.93, 222.8$ respectively; $p \leq 0.05$). The cover of epiphytic algae was also found to be significantly different when the sites and seasons were compared ($F = 22.89, 75.82$; $p \leq 0.05$).

Table 3: The species composition of epiphytic algae found on leaves of seagrass species from Vipingo (NE monsoon)

Algal species composition	*Cymodocea rotundata*			*Thalassia hemprichii*					*Thalassodendron ciliatum*							
	1	2	3	1	2	3	4	5	1	2	3	4	5	6	7	8
Rhodophyta																
Ceramium flaccidum (Kuetzing) Ardissone	*2	*3		*2	*2	*2			*	*3	*2	*				
Encrusting algae 1	*	*2		*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	
Gracilaria sp.				*												
Hypnea cornuta (Lamour.) J. Ag	*								*	*						
Phaeophyta																
Giffordia sp.	*3								*							
Chlorophyta																
Cladophora Mauritania Kutzing										*						
Enteromorpha sp.	*	*3		*3					*3	*	*3	*3	*2			
Ulva pertusa Kjellman	*															
Cyanophyta																
Rivularia sp.	*1	*1		*3					*2	*2	*	*2				

Notes: n = 30 for each species; 1–3 = the most abundant species in terms of dominance on the leaf based on percentage cover estimates; * = present

Table 4: The species composition of epiphytic algae found on leaves of seagrass species from Nyali (NE monsoon)

Algal species composition	*Cymodocea rotundata*				*Thalassia hemprichii*							*Thalassodendron ciliatum*								
	1	2	3	4	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9
Rhodophyta																				
Ceramium flaccidum (Kuetzing) Ardissone	*1	*2				*2						*	*	*	*	*3	*3			
Encrusting algae 1	*2	*1	*1		*1	*1	*1	*1	*1			*1	*1	*1	*1	*1	*1	*1	*1	*1
Unid red algae 1	*												*			*				
Chlorophyta																				
Chaetomorpha crassa (Ag.) Kutz													*	*						
Cladophora sp.													*	*						
Enteromorpha sp.	*2				*3	*3						*2	*2	*2	*2	*2	*2			
Ulva pertusa Kjellman	*3				*2	*3						*3	*3	*3	*3	*				

Notes: n = 30 for each species; 1–3 = the most abundant species in terms of dominance on the leaf based on percentage cover estimates; * = present

Table 5: The algal species found on the stems of *Thalassodendron ciliatum*

Species	Vipingo (SE monsoon)	Vipingo (NE monsoon)	Nyali (SE monsoon)	Nyali (NE monsoon)
Rhodophyta				
Amphiroa sp.		*2		
Encrusting algae	*1	*1	*1	*1
Gracilaria corticata J. Agardh				*
Hypnea cornuta (Lamour.) J. Ag.	*2			
Wurdemania sp.				*3
Phaeophyta				
Giffordia sp.	*3			
Hincksia rallsiae (Vickers) Silva	*			
Sphacelaria rigidula Kuetzing	*			
Cholorophyta				
Chaetomorpha crassa (Ag.) Kutz				*
Cladophora sp.		*		
Enteromorpha sp.		*3		
Ulva pertusa Kjellman	*	*	*2	*2
Total Cover (%)	37.1 ± 16.43	46.5 ± 14.39	40.2 ± 24.17	40.97 ± 24.08

Notes: n = 30 for each species; 1–3 = the most abundant species in terms of dominance on the leaf based on percentage cover estimates; * = present

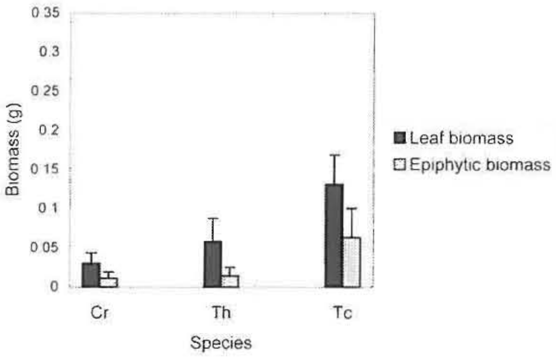

Figure 2: Overall leaf and epiphytic biomass in Vipingo (SE Monsoon)

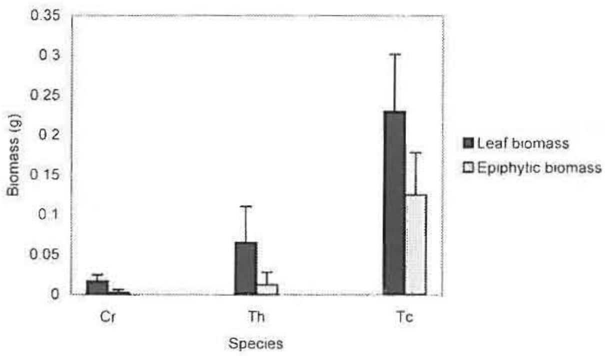

Figure 3: Overall leaf and epiphytic biomass in Nyali (SE Monsoon)

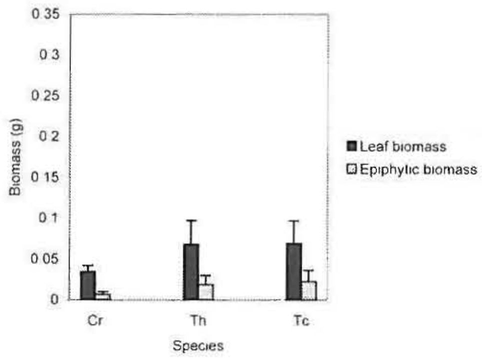

Figure 4: Overall leaf and epiphytic biomass in Vipingo (NE Monsoon)

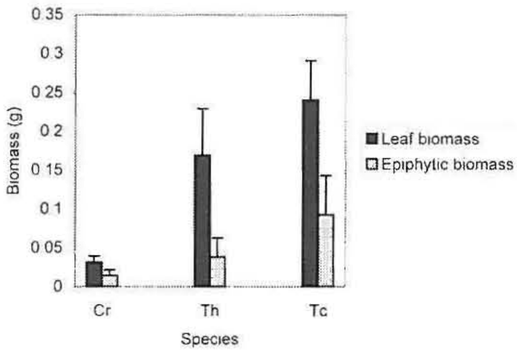

Figure 5: Overall leaf and epiphytic biomass in Nyali (NE Monsoon)

Table 6: Shoot densities of seagrasses in Vipingo and Nyali (n = 10 for all sites)

	SE Monsoon (August 1999)	
Seagrass	Vipingo	Nyali
C. rotundata	30.8 ± 10.1	25.8 ± 9.17
T. hemprichii	20.9 ± 7.0	23.9 ± 7.1
T. ciliatum	15.2 ± 7.12	20.9 ± 5.7
	NE Monsoon (February 2000)	
	Vipingo	Nyali
C. rotundata	91.1 ± 12.7	50.5 ± 14.2
T. hemprichii	57.9 ± 13.5	48.6 ± 20.3
T. ciliatum	28.6 ± 11.4	35.9 ± 15.5

Shoot densities in Vipingo and Nyali

The overall shoot densities of *T. hemprichii* and *T. ciliatum* were higher in Nyali compared to Vipingo (Table 6) however this difference was not significant. Shoot densities of *C. rotundata* was significantly different when the sites and seasons were compared (F = 131.67, 37.89; $p \leq 0.05$). The densities of *C. rotundata* were lower in Nyali (Table 6) and the leaves of this species from Nyali disintegrated easily.

Carbon and nitrogen levels in the leaves of T. ciliatum

The data of the carbon and nitrogen levels in the leaves of *T. ciliatum* was not significant (Table 7) indicating the leaves from Nyali and Vipingo were similar.

Table 7: Carbon and Nitrogen analysis of *T. ciliatum* leaves (n = 10 in each site)

	Vipingo (SE monsoon)	Nyali (SE monsoon)	Vipingo (NE monsoon)	Nyali (NE monsoon)
Carbon (%)	38.53 ± 4.13	34.01 ± 2.58	36.57 ± 2.20	39.99 ± 0.85
Nitrogen (%)	1.67 ± 0.36	2.06 ± 0.15	1.62 ± 0.08	1.92 ± 0.17
C:N ratio	23.66	16.5	22.67	20.98

Table 8: Summary of the abiotic variables in the study sites during the different seasons (n = 120 for each variable)

SE Monsoon (August 1999)		
Nutrients	Vipingo	Nyali
Nitrates (µM)	1.84 ± 2.32	19.96 ± 12.06
Ammonia (µM)	0.56 ± 1.00	6.64 ± 5.97
Phosphates(µM)	0.24 ± 0.09	0.23 ± 0.11
Salinity (‰)	34.8 ± 2.7	34.9 ± 1.2
PH	8.36 ± 0.24	8.38 ± 0.18
Water Temp.(°C)	25.5 ± 5.8	26.7 ± 1.8
NE Monsoon (February 2000)		
Nutrients	Vipingo	Nyali
Nitrate (µM)	10.50 ± 11.76	8.58 ± 9.01
Ammonia (µM)	3.52 ± 3.68	6.68 ± 4.41
Phosphates (µM)	0.06 ± 0.11	0.54 ± 0.99
Salinity (‰)	33.5 ± 0.7	34.5 ± 1.2
PH	7.53 ± 0.48	8.17 ± 0.17
Water Temp.(°C)	26.4 ± 2.4	27.6 ± 3.0

Abiotic variables in Vipingo and Nyali

Table 8 shows the nutrient levels found in the two sites. There was a significant difference in the levels of nitrates and ammonia between the two sites (F = 15.27, 29.61 respectively; $p \leq 0.05$). The levels of phosphates were also significantly different when the two sites were compared (F = 5.66; $p \leq 0,05$). However, the seasonal difference was not significant. Other abiotic variables were similar between the two sites.

Discussion

The analysis of epiphytic species on the leaves of the different seagrasses in Vipingo and Nyali revealed the dominance of rhodophytes. This was also documented for the epiphytes found on seagrasses and macroalgae during the survey by Moorjani (1977). However, as this study was not conducted monthly the seasonal variation in the species of epiphytic algae could not be compared to the seasonality patterns documented by Moorjani (1977).

Nevertheless, the high abundance of epiphytes in the SE monsoon can be related to the tidal patterns (Isaac and Isaac 1968). High diversity of epiphytic flora has been reported during the SE monsoon when low spring tides occur during the night (Isaac and Isaac 1968). At night desiccation stress is less severe and the temperatures are relatively low. During the NE monsoon, the lowest spring tides are during the day where the high air temperatures cause plant stress and reduce the diversity of benthic algae (Isaac and Isaac 1968).

The oldest leaves (leaf number 1 and 2) were found to support the most diverse epiphytic community and this has been reported in other studies (Borowitzka and Lethbridge 1989, Heijs 1985, 1987, Jacobs *et al.* 1983). The colonisation patterns seen in these seagrass species have also been documented in these studies. The finding that epiphytes comprise half of the biomass of the leaves of *T.* ciliatum indicates the importance of this seagrass to the marine ecosystems of this region. The contribution of the stem in this species further adds to the total area available for colonisation by epiphytes. Epiphytic algae show a preference for the stems of *T. ciliatum* due to the rough surface that makes the stems suitable for the attachment by algal spores (Semesi 1988).

In a previous study of the Nyali area, the nitrate levels were found to be between 5 and 200µM, levels of ammonia were less than 16µM and the levels of phosphates were around 2µM (Mwahsote *et al.* 1999). In this study, nutrient levels recorded in Nyali did not reach this level but they were high enough to reflect an input of nutrients via the groundwater streams. Nutrient studies in Vipingo have been in coral areas within the lagoon and the levels recorded were 1.8µM for nitrates and 1.0µM for phosphates (McClananhan 1997). The SE monsoon values were within this range but the levels of nitrates increased during the NE monsoon.

The data obtained from the carbon and nitrogen analysis of the leaves where there was no difference between the sites when the data was compared could be attributed to the methodology adopted in the treatment of the leaves by acid washing to remove epiphytic algae. Acid washing has been documented to result in leaching which affects the content of carbon, nitrogen and phosphate in the leaves (Nieuwenhuize *et al.* 1994).

Nevertheless, the existence of a higher nutrient loading into the Nyali area is reflected in the persistence of *Ulva pertusa* on the stems of *T. ciliatum*. Excessive growth of green seaweeds (algae) in response to sewage effluence is a common phenomenon (Lobban and Harrison 1994) and this is reflected in the presence of *U. pertusa*.

C. rotundata seems to be sensitive to the nutrient loading as indicated by its low biomass and shoot densities in Nyali, which indicates that *T. hemprichii* and *T.ciliatum* are more tolerant to groundwater inputs.

Conclusions

There is a significant difference in the species composition of epiphytic algae between the two sites with a more diverse community seen on the Vipingo seagrasses. Lower nutrient levels seem to enhance the presence of Cyanophyta as can be seen in Vipingo where nutrient levels were lower than Nyali. There is also evidence of a strong seasonality effect, which caused a shift in the species composition of epiphytes in the two seasons. The effects of nutrient loading can be seen clearly in the lower number of epiphytes seen in Nyali, in the abundance of the Chlorophyte *U. pertusa* on the stems of *T. ciliatum* and the reduced vigour of *C. rotundata*.

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