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Seagrass Biomass and Productivity in Seaweed and Non-Seaweed Farming Areas in the East Coast of Zanzibar, Tanzania

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Abstract—Seagrass beds are often subjected to stress resulting from natural and human activities. In this study, the shoot density, biomass and growth characteristics of *Thalassia hemprichii* and *Enhalus acoroides* were measured to assess the impact of seaweed farming activities on seagrass meadows at Marumbi, Chwaka Bay and Jambiani in the East Coast of Zanzibar. There was significantly higher *T. hemprichii* shoot density in non-seaweed areas compared to seaweed farmed areas. However, there were no significant differences in *E. acoroides* shoot density between seaweed and non-seaweed areas and between the two sites. Also, there was significantly higher total biomass of *T. hemprichii* in non-seaweed areas compared to seaweed areas. However, there were no significant differences in the total biomass of *E. acoroides* between seaweed and non-seaweed areas and among the sites. The growth and photosynthetic (ETR and Fv/Fm ratios) characteristics of both *T. hemprichii* and *E. acoroides* varied inconsistently between seaweed and non seaweed areas suggesting that there is no effect on seaweed farming to the growth rate of the seagrasses. Thus, the reduced seagrass shoot density and biomass in seaweed farms compared to non-seaweed areas observed in this particular study is most likely to be due to physical disturbances in the farms such as bioturbation or deliberate removal of seagrasses by farmers.

INTRODUCTION

Worldwide, seagrass beds are subjected to stress resulting from natural and human activities (Short & Wyllie-Echeverria, 1996). In particular, seaweed farming has been hypothesised to affect seagrass beds through shading and competition for nutrients in the water (Collén *et al.*, 1995), mechanical abrasions by algal fronds, trampling and removal of shoots by farmers (de la Torre Castro and Rönnbäck, 2004) as well as excretion of hydrogen peroxide and halogenated compounds by algae (Mtolera *et al.*, 1995, 1996).

Commercial cultivation of seaweed in the Western Indian Ocean was first introduced to the Tanzanian Islands of Unguja and Pemba (Zanzibar) in 1989 (Oliveira *et al.*, 2005). Since then, seaweed farming has become one of the major economic activities, boosting the economy and living standard of many people (mainly women) (Petterson-Löfquist, 1995). In 2000 for example, Tanzanian export reached 36,000 tonnes, of which approximately 5,000 - 6,000 tonnes were produced in Zanzibar (Oliveira *et al.*, 2005).

Except at Chwaka Bay where farms were established in areas with seagrasses, where farmers regard the presence of seagrass as a good indicator

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of suitable environment, (de la Torre Castro and Rönnbäck, 2004), extensive farms in the east coast of Zanzibar were established in sandy lagoons with moderate currents and bare sand. As cultivation space becomes limited in areas where bare sand is preferred, farmers move to new cultivation stations in the neighbouring seagrass beds and start clearing the substrate to produce the preferable cultivation conditions. The main reason for this practice is that the yield of seaweed is low in the presence of seagrasses due to destruction by sea urchins that are normally found in seagrass meadows (according to farmers consulted). In contrary however, Mtolera (2003) suggested that seagrasses contribute to seaweed growth by supplying sediment-bound nutrients.

It has long been shown that there is lower seagrass cover and other macro flora in seaweed farms compared to areas without seaweeds farms (e.g. Semesi 2002; Eklöf *et al.*, 2005). Low seagrass cover within seaweed farming areas, might be due to the fact that farms are established in sand lagoon, but also may be attributed to disturbances caused by farming activities, including frequent human trampling as evidenced by the paths created from the beach to farming stations, and clearance of seagrasses to create farm areas. In shallow areas seagrass may be damaged by vessel anchors and chain sweeps, by vessel hulls and by eroded sediment from vessel propulsion.

Seaweed farming has been shown to impact components of the ecosystems in which such farms are placed. For example, Eklöf *et al.* (2005) showed that seagrass biomass, shoot density and cover is lower in seagrass beds with seaweed farms compared to similar beds without seaweed farms. In the present study we investigated the impact of seaweed farming on growth characteristics and photosynthesis of two seagrass species at Chwaka Bay, Marumbi and Jambiani in the East Coast of Zanzibar.

MATERIALS AND METHODS

The study sites

Sampling for this study was conducted during November to December 2004. Three sampling sites were established along the East Coast of Zanzibar, i.e. Marumbi, Chwaka Bay and Jambiani (Fig. 1). The tidal regime in these areas has a semi-diurnal periodicity and the tidal range is about 3.9 m. Seaweed farming activities are practiced since 1990's in all three sites, and the farms are located in the inter-tidal zone.

Sampling stations were established in seagrasses meadows with good coverage of seagrasses, which were found in mid intertidal areas where seaweed farming are practiced (seaweed area) and away (~100 - 150 m) from the seaweed farms in similar areas but without seaweed farms (non-seaweed areas). Within these stations, quadrats were thrown randomly. In seaweed areas the quadrats were thrown both within the farm plots and in-between the farm plots.

Shoot density and biomass

Shoot density was determined by counting individual shoots within 0.25 x 0.25 m quadrats. A total of 8 randomly placed quadrates were counted for each seagrass species. Thereafter, the seagrass were harvested for biomass estimation by digging with a shovel making sure that the whole plant biomass was recovered as described by Duarte and Kirkman (2001). In order to remove epiphytes, samples were rinsed with freshwater and then treated with dilute (1%) HCl. Dry weight was determined by drying the plants (entire sample) in an oven at 60°C until constant weight was attained, whereas ash free dry weight was determined by combusting the dried sub-sample in a muffle furnace at 550°C for 2 h (Ott, 1990).

Growth characteristics

Growth of individual leaves was measured using the leaf-marking technique as described by Dennison (1990), whereby individual leaves of seagrass were punched using a small borer. The hole was made just above the basal meristem region of each shoot. A minimum of 22 shoots was punched for each species and then left to grow for three days when all the leaves were re-punched at the reference point, harvested and stored in a cool box and transferred to the laboratory. In laboratory, new growth increments of the leaves i.e. the length

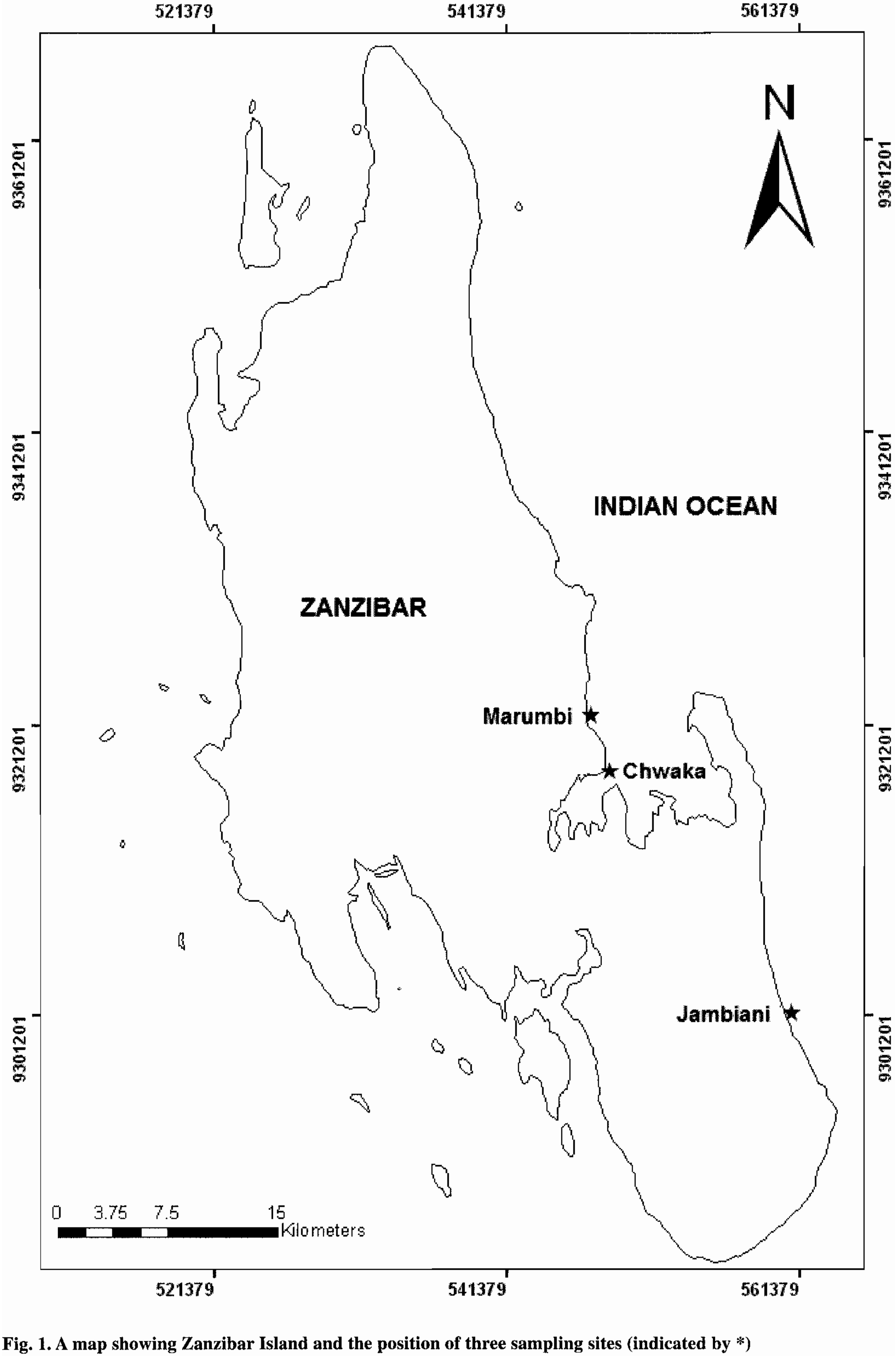

Fig. 1. A map showing Zanzibar Island and the position of three sampling sites (indicated by *)

between the initial hole and the hole punched at harvest were measured, cut out and dry weight was determined as described above. The remaining aboveground leaf material of the marked shoots were also dried and weighed separately.

The ratio of leaf material produced before marking to that produced after marking was divided by the time interval to give the relative production rate expressed as g g^{-1} day^{-1}. The aerial production rate was calculated by multiplying the leaf production per shoot by the shoot density and was expressed as g m^{-2} day^{-1} (Short & Duarte, 2001). Leaf growth was determined by summing the increased length per shoot per day (mm $shoot^{-1}$ day^{-1}). Leaf turnover time was estimated as the inverse of the relative leaf production rate. The canopy height of *T. hemprichii* and *E. acoroides* was measured using a ruler and neglecting 20% of the longest shoots, as prescribed by Duarte and Kirkman (2001). A minimum of seven replicates in randomly thrown quadrates was taken at each site for each seagrass species.

Productivity - PAM Measurements

Chlorophyll fluorescence was measured using a diving Pulse Amplitude Modulated (PAM) flourometer (Walz, Germany). The measurements were performed under water at 0 - 0.5 m depth, either in open water or in tidal pools formed at low tide and in full daylight between 9:00 am and 2:00 pm. The light intensity changed with the cloud cover thus providing a range of natural light intensities for the experiment. The tip of the instrument's optical fibre was placed approximately 2 mm from, and perpendicular to the adaxial surface of leaves using dark-leaf clips. The effective quantum yield of electron transport through photosystem II (Y) was determined by the saturating-light method as (Fm'-F)/Fm', where F is the fluorescence at a given photon irradiance (when part of the reaction centre are closed) and Fm' is the corresponding maximal fluorescence measured during a short (0.8 second) period for photosynthesis saturating light (when all reaction centre are closed). The Fv/Fm (where Fv is the variable fluorescence measured as maximal (Fm) less minimal (Fo) fluorescence in dark adapted leaves) were also determined after acclimating leaves to darkness for 10 minutes using dark-leaf clips. In order to estimate photosynthetic electron transport rates (ETR) through photosystem II, Y was multiplied by the measured incident photon irradiance, by 0.5 (assuming that half of the photons absorbed were absorbed by photosystem II) and by absorption factors (AF) of the leaf. Further details of chlorophyll fluorescence measurements in seagrass research are found in Beer *et al.* (2001).

Statistical analysis

Differences between stations (seaweed and non-seaweed areas) and the three sites for the aforementioned variables were statistically tested using two-way analysis of variance (ANOVA) with post hoc Tukey's HSD Test in STATISTICA (6.0). Prior to the analysis, the data were subjected to normality and homogeneity of variance tests. Where assumptions for parametric test were not met, data were transformed ($\log_{10}$) or the non-parametric Kruskal-Wallis Median test was used with Dunn's multiple comparison tests.

RESULTS

The mean values of number of leaves per shoot, canopy height, shoot density and biomass of *Thalassia hemprichii* and *Enhalus acoroides* are shown in Table 1. The number of leaves per shoot for *T. hemprichii* ranged from a mean value of 3.31 ± 0.66 to 3.85 ± 0.78 recorded in non-seaweed areas at Chwaka Bay and in non-seaweed areas at Jambiani, respectively. For *E. acoroides*, number of leaves per shoot ranged from a mean value of 3.28 ± 0.46 in non-seaweed areas at Marumbi to 4.15 ± 0.84 in seaweed areas at Chwaka. There was no significant difference in the number of leaves per shoot between seaweed and non-seaweed areas for *T. hemprichii* while a significant ($KW = 33.47$; $p < 0.0001$) higher number of leaves per shoot was observed for *E. acoroides* in seaweed areas compared to non-seaweed areas at Marumbi ($p < 0.01$) and Chwaka ($p < 0.001$). The mean canopy height of *T. hemprichii* ranged from 8.57 ± 2.05 cm in seaweed areas at Jambiani to 15.7 ± 2.84 cm also in seaweed areas at Chwaka. For *E. acoroides*, canopy height ranged from an

Table 1. The mean biomass, canopy height and shoot density (± standard deviation, n given in brackets) of *T. hemprichii* (TH) and *E. acoroides* (EA). SW = Seaweed site, NSW = Non seaweed site, AG=Above Ground, BG= Below Ground; DW = Dry weight, AFDW = ash free dry weight

Characteristics		Seagrass	Marumbi		Chwaka Bay		Jambiani	
		Spp.	SW	NSW	SW	NSW	SW	NSW
Number of leaves shoot^{-1}		TH (39)	3.72 ± 0.92	3.51 ± 0.60	3.54 ± 0.68	3.31 ± 0.66	3.74 ± 0.75	3.85 ± 0.78
		EA (39)	3.72 ± 0.56	3.28 ± 0.46	4.15 ± 0.84	3.46 ± 0.51		
Canopy height (cm)		TH (7)	8.71 ± 1.89	11.6 ± 2.44	15.8 ± 2.84	13.6 ± 3.64	8.57 ± 2.05	9.38 ± 2.95
		EA (8)	26.2 ± 4.09	34.9 ± 9.29	47.0 ± 3.41	46.9 ± 14.6		
Shoot density (no shoots m^{-2})		TH (8)	542 ± 98.4	384 ± 164	326 ± 116	380 ± 83.3	582 ± 181	1090 ± 361
		EA (8)	148 ± 60.8	134 ± 50.6	138 ± 64.5	128 ± 33.9		
AG (g dw m^{-2})	DW	TH (5)	465 ±183	301 ± 42.1	108 ± 23.8	175 ± 19.0	90.4 ± 16.1	609 ± 71.5
		EA (8)	144 ± 63.0	143 ± 57.5	177 ± 85.5	199 ± 54.5		
	AFDW	TH (5)	279 ± 125	134 ± 75.3	60.9 ± 15.1	107 ± 9.60	57.7 ± 10.9	426 ± 44.0
		EA (8)	93.5 ± 41.1	94.9 ± 38.3	117 ± 56.6	209 ± 57.2		
BG (g dw m^{-2})	DW	TH(5)	904 ± 129	442 ± 66.9	179 ± 57.9	220 ± 3.43	185 ± 32.9	2455 ± 726
		EA (8)	810 ± 356	512 ± 207	563 ± 272	415 ± 114		
	AFDW	TH (5)	688 ± 108	202 ± 96.1	124 ± 43.8	165 ± 21.3	127 ± 19.3	1614 ± 603
		EA (8)	656 ± 288	401 ± 162	475 ± 218	325 ± 89.0		
Total biomass	DW	TH (5)	1369 ± 266	742 ± 81	286 ± 81.5	393 ± 18.7	276 ± 48.7	3063 ± 715
		EA (8)	953 ± 419	655 ± 264	740 ± 358	614 ± 98.9		
	AFDW	TH (5)	967 ± 183	336 ± 120	185 ± 58.7	272 ± 12.0	185 ± 29.9	2040 ± 586
		EA (8)	750 ± 329	496 ± 200	592 ± 271	534 ± 146		

average of 26.2 ± 4.10 cm in seaweed areas at Marumbi to 47.0 ± 3.41 in seaweed areas at Chwaka. There were no significant differences in canopy height between seaweed farmed and non-seaweed farmed areas at all site. However, a significant difference in canopy height was observed for *T. hemprichii* (KW = 20.69; p = 0.0009) and *E. acoroides* (F = 26.61; p = 0.0001) among sites (i.e. Marumbi, Chwaka and Jambiani).

The shoot density of *T. hemprichii* ranged from a mean value of 326 ± 116.9 shoots m^{-2} recorded in seaweed areas at Chwaka to an average value of 1090 ± 360.9 shoots m^{-2} in non-seaweed areas at Jambiani. For *E. acoroides* the shoot density ranged from a mean value of 128 ± 33.9 to 148 ± 60.8 shoots m^{-2} as recorded in non-seaweed areas at Chwaka and in seaweed areas at Marumbi, respectively. There was significantly higher *T. hemprichii* shoot density in non-seaweed areas compared to seaweed farmed areas (F = 7.87, p = 0.01). Also, the shoot density for *T. hemprichii* was significantly higher (F = 22.39; p < 0.0001) at Jambiani compared to Marumbi and Chwaka. However, there were no significant differences in *E. acoroides* shoot density between seaweed and non-seaweed areas and between the two sites.

The mean value of above ground biomass of *T. hemprichii* ranged from an average value of 90.37 ± 16.08 g dw m^{-2} in the seaweed farmed areas to 608.69 ± 71.46 g dw m^{-2} in non-seaweed areas both recorded at Jambiani. Above ground ash free dry weight ranged from an average value of 57.72± 10.93 g dw m^{-2} recorded in seaweed farmed areas at Jambiani to 426 ± 44.03 g dw m^{-2} recorded outside the farm areas at Jambiani. Similarly, the mean below ground biomass was lowest (178.5 ± 57.9 g dw m^{-2}) in seaweed farm areas at Chwaka Bay and highest (2455 ± 725.6 g dw m^{-2}) in non-farmed areas at Jambiani. For below ground ash free dry weight a lowest average value of 123.9 ± 43.78 g dw m^{-2} was recorded in seaweed farmed areas at Chwaka and the highest value of 1614 ± 602.9 g dw m^{-2} in non-seaweed areas at Jambiani. Similarly, lowest total dry weight (above ground plus below ground) was recorded in seaweed farmed areas (276.2 ± 48.65 g dw m^{-2}) at Jambiani and the highest mean value of 3063 ± 714.5 g dw m^{-2} was recorded in non-seaweed areas at Jambiani.

Also, total below ground ash free dry weight was lowest (184.6 ± 29.88 g dw m^{-2}) in seaweed farmed areas at Jambiani and highest (2040 ± 585.7 g dw m^{-2}) in non-farmed areas at Jambiani.

There was significantly higher total biomass of *T. hemprichii* in non-seaweed areas compared to seaweed areas ($F = 15.80$; $p = 0.002$). Also, there were significant differences in the total biomass of *T. hemprichii* among the three sites ($F = 35.88$; $p < 0.0001$). The significantly higher total biomass was observed at Jambiani compared to Marumbi ($p = 0.004$) and Chwaka ($p = 0.0002$). In addition Marumbi area had significantly higher total biomass compared to Chwaka ($p = 0.001$). However, there were no significant differences in total biomass of *E. acoroides* between seaweed and non-seaweed areas and among the sites. Likewise, there was significantly higher total ash-free dry weight of *T. hemprichii* in non-seaweed areas compared to seaweed areas ($F = 20.85$; $p < 0.0006$). Also, there were significant differences in the total ash free dry weight of *T. hemprichii* among the three sites ($F = 31.00$; $p < 0.0001$). However, there were no significant differences in total ash-free dry weight of *E. acoroides* between seaweed and non-seaweed farmed areas and among the stations.

The growth characteristics of both seagrasses species varied slightly from site to site (Table 2). The mean total leaf growth rate of *T. hemprichii* varied from 13.0 ± 3.01 to 18.39 ± 4.75 mm $shoot^{-1}$ day^{-1} in seaweed areas at Jambiani and non-seaweed areas at Chwaka respectively. However, there were no significant different in total leaf growth of *T. hemprichii* between seaweed and non-seaweed areas. A significant difference in total leaf growth of *T. hemprichii* was found among sites ($F = 10.50$; $p = 0.0001$). The differences were observed between Marumbi and Chwaka ($p = 0.0002$) and between Chwaka and Jambiani ($p = 0.002$). The mean total leaf growth rate of *E. acoroides* varied from 18.2 ± 5.51 mm $shoot^{-1}$ day^{-1} to 24.8 ± 9.37 mm $shoot^{-1}$ day^{-1} in seaweed area at Marumbi and non-seaweed at Chwaka, respectively. There was significant ($F = 7.26$; $p = 0.0098$) higher growth rate in non-seaweed than seaweed areas.

Leaf production of *T. hemprichii* ranged from 0.004 ± 0.001 g dw $shoot^{-1}$ day^{-1} as recorded in seaweed areas at Jambiani to 0.006 ± 0.005 g dw

Table 2. Growth characteristics of *T. hemprichii* (TH) and *E. acoroides* (EA) at Chwaka Bay, Marumbi and Jambiani (Mean ± standard deviation; n in brackets) SW= Seaweed site, NSW= Non seaweed site

Characteristics	Seagrass Spp	Marumbi (n =22)		Chwaka Bay (n = 33)		Jambiani (n = 42)	
		SW	NSW	SW	NSW	SW	NSW
Total leaf growth (mm $shoot^{-1}$ day^{-1})	TH	13.8 ± 3.55	13.4 ± 4.69	18.4 ± 4.75	17.1 ± 5.15	13.0 ± 3.01	15.8 ± 5.99
	EA	18.2 ± 5.12	19.4 ± 7.08	18.1 ± 5.95	24.8 ± 9.37		
Leaf production (g dw $shoot^{-1}$ day^{-1})	TH	0.004 ± 0.002	0.004 ± 0.002	0.005 ± 0.001	0.01 ± 0.01	0.004 ± 0.001	0.005 ± 0.002
	EA	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.02		
Relative growth rate (g g^{-1} dw day^{-1})	TH	0.10 ± 0.07	0.09 ± 0.08	0.07 ± 0.03	0.07 ± 0.03	0.08 ± 0.05	0.13 ± 0.14
	EA	0.03 ± 0.01	0.02 ± 0.004	0.03 ± 0.03	0.02 ± 0.01		
Aerial production (g dw m^{-2} day^{-1})	TH	2.18 ± 0.77	1.97 ± 0.89	1.74 ± 0.45	1.86 ± 0.64	2.37 ± 0.51	5.92 ± 2.33
	EA	2.64 ± 0.93	2.05 ± 0.91	2.087 ± 0.823	2.767 ± 1.159		
Leaf turnover time (days)	TH	16.1 ± 13.6	16.2 ± 8.13	16.4 ± 5.57	17.2 ± 6.60	15.54 ± 5.576	11.54 ± 5.876
	EA	38.9 ± 9.05	43.3 ± 11.2	48.7 ± 18.8	51.1 ± 24.9		

shoot^{-1} day^{-1} recorded in non-seaweed areas at Chwaka. For *E. acoroides*, leaf production ranged from 0.015 ± 0.007 g dw shoot^{-1} day^{-1} as recorded in non-seaweed areas at Marumbi to 0.021 ± 0.018 g dw shoot^{-1} day^{-1} recorded in non-seaweed areas at Chwaka. There were significant differences in *T. hemprichii* leaf production rate among sites (KW = 19.65; p = 0.002). However, there was no significant difference in leaf production between seaweed and non-seaweed areas. Also, there were no significance differences in leaf production of *E. acoroides* between seaweed and non-seaweed areas and among sites.

An aerial production rate of *T. hemprichii* ranged from an average of 1.74 ± 0.45 g dw m^{-2} day^{-1} in seaweed area at Chwaka to 5.92 ± 2.33 g dw m^{-2} day^{-1} in non-seaweed area at Jambiani. There were significant differences in aerial production rate of *T. hemprichii* between seaweed and non-seaweed areas (F = 30.95; $p < 0.0001$) and among sites (F = 42.2; $p < 0.0001$). The aerial production of *E. acoroides* ranged from 2.05 ± 0.91 to 2.77 ± 1.16 g dw m^{-2} day^{-1} and there were no significant differences between seaweed and non-seaweed areas and among the two sites. In all cases, *T. hemprichii* and *E. acoroides*, leaf one (L1), which is the oldest leaf, showed consistently no growth while the maximum growth rate was found to occur in leaf 3 and/or leaf 4 (L3 and/or L4) (Fig. 2A & B).

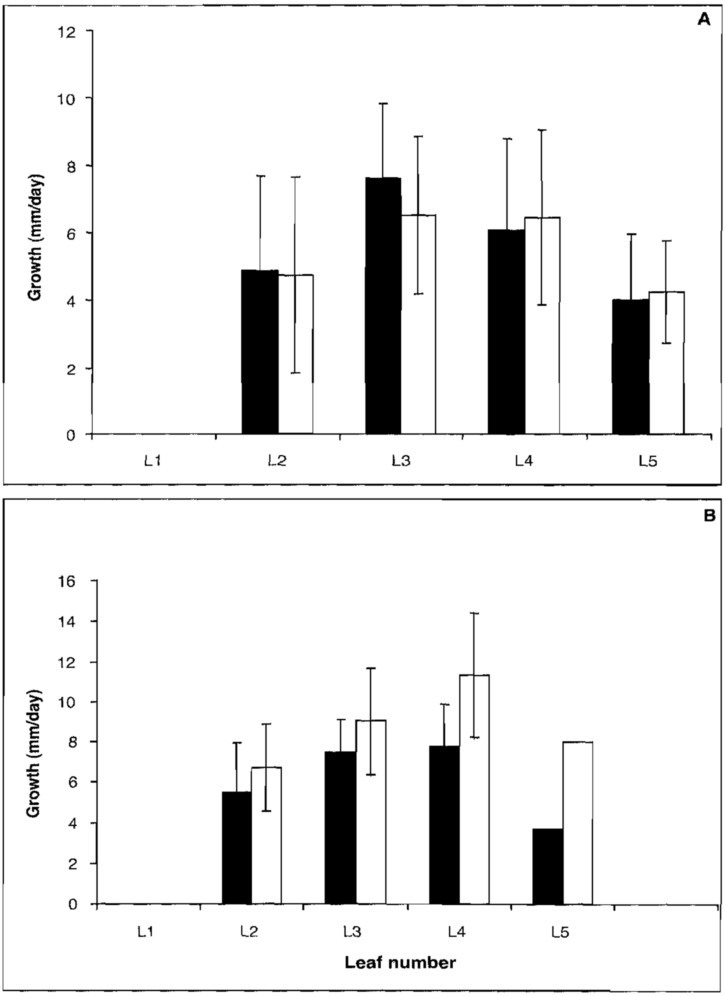

Fig. 2. Mean (all sites) growth rate of individual leaves (L) in seaweed areas (black bars) and non-seaweed areas (white bars). A; *T. hemprichii* and B; *E. acoroides*

Photosynthetic characteristics

Results of in situ photosynthesis measurements carried out in seaweed and non-seaweed areas at Marumbi, Chwaka Bay and Jambiani are summarized in Fig. 3. There was significantly higher ($F = 8.49$; $p = 0.004$) photosynthetic electron transport rate (ETRs) of *T. hemprichii* in non-seaweed areas compared to seaweed areas. In contrast, ETR for *E. acoroides* was significantly higher in seaweed areas than in non-seaweed areas ($F = 74.38$; $p < 0.0001$). The maximal quantum

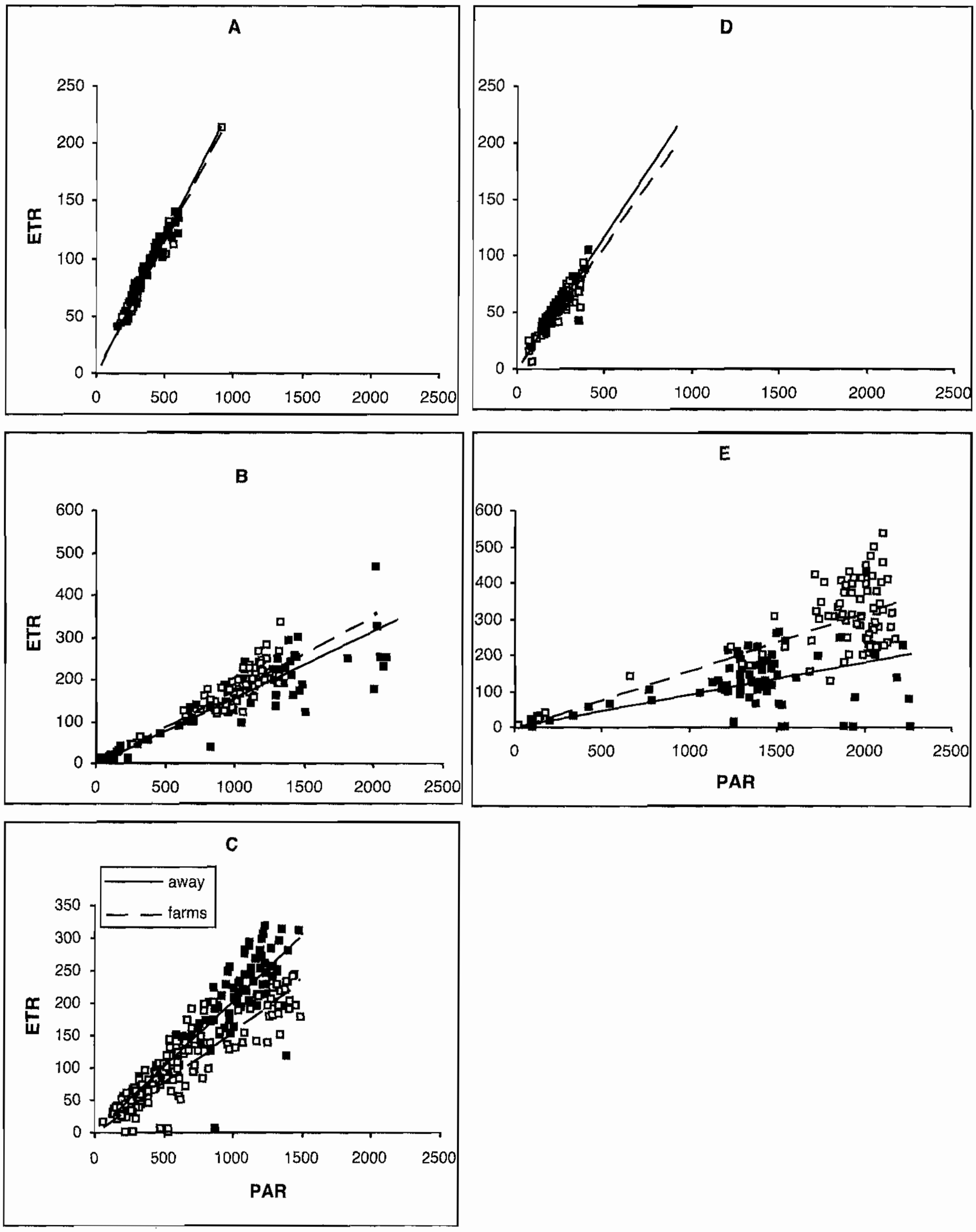

Fig. 3. The electron quantum transport rate (ETR, 'point measurements) for *T. hemprichii* at Marumbi (A), Chwaka Bay (B), Jambiani (C) and *E. acoroides* at Marumbi (D) and Chwaka Bay (E) in seaweed farms (□) and about 100 m away from the seaweed farms (■)

yields of electron transport (Fv/Fm) at different sites are shown in Figure 4. There was no significant difference in the maximal quantum yield of electron transport (Fv/Fm) between seaweed and non-seaweed areas for both *T. hemprichii* and *E. acoroides*, although significant differences were observed among sites for *T. hemprichii* (F = 10.77; p = 0.0008) and E. acoroides (F = 43.88; p < 0.0001).

The total biomass obtained in the present study for *T. hemprichii* and *E. acoroides* seems to be higher compared to published data from other tropical regions (Duarte & Chiscano, 1999 and the references therein). However, the biomass for *T. hemprichii* was within the range of reported values in the Western Indian Ocean region (Martins & Bandeira, 2001, Uku & Björk, 2005) and in Indonesia (Erftemeijer *et al.*, 1993). Also, the biomass of *E. acoroides* fall within the range of 292-308 g dw m^{-2} reported by Erftemeijer *et al.* (1993). The aboveground biomass was always lower than the belowground biomass for both species (*T. hemprichii* and *E. acoroides*). This may be a response evolved to minimize exposure and desiccation at low tide and to increase stability when exposed to waves at high tide. Excessive grazing by herbivores such as sea urchin may also contribute to the reduction of above ground biomass, although they have been reported to stimulate production in some instances (Cebrián *et al.*, 1997). Grazing losses of below ground material are negligible for most seagrass species and are less prone to losses derived from disturbances. On the other hand, the health of seagrass communities obviously relies heavily upon the amount of sunlight that penetrates the water column to reach submerged blades. Light

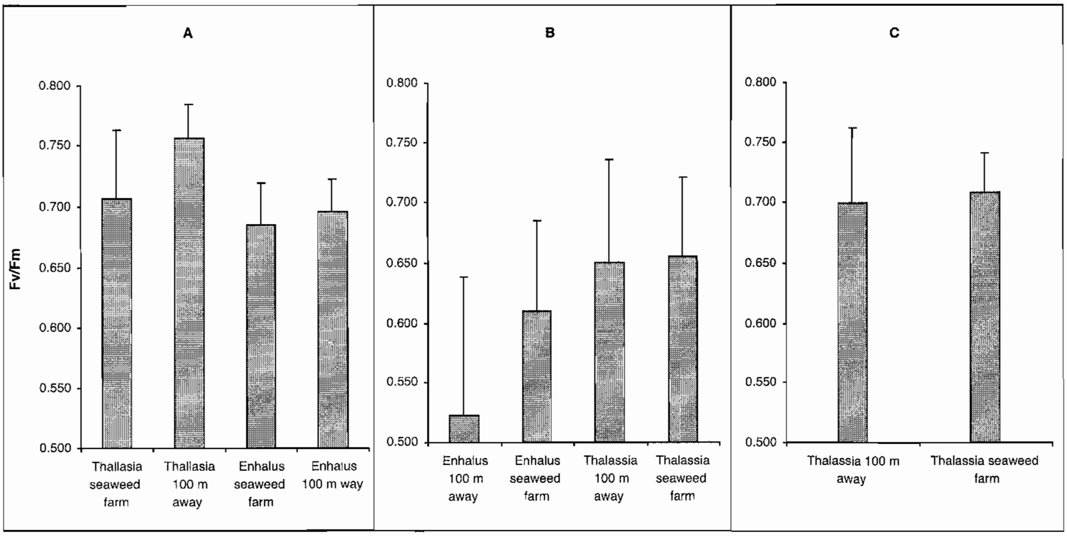

Fig. 4. Maximal electron quantum yields (Fv/Fm, 'Dark Adapted') of leaves in the seaweed farms and about 100 m away from the farms at Chwaka Bay (B) and Jambiani (C). The Fv/Fm data are average of 10 measurements ± s.d.

DISCUSSION

The values on shoot density, leaf number and canopy height obtained in the present study were within the range of other studies in the tropics and in Western Indian Ocean Region (e.g. den Hartog, 1970; Lanyon 1986; Erftemeijer *et al*, 1993; Lin and Shao, 1998; Agawin *et al.*, 2001, Rollon *et al.*, 2001; de la Torre-Castro and Rönnbäck, 2004 and Uku & Björk, 2005). At Chwaka Bay, which was dominated by *E. acoroides*, lower shoot density of *T. hemprichii* was recorded as compared to other sites which may indicate that there is high level of competitive interactions among the seagrass species present in multi-species seagrass meadows. However, the values of mean shoot density of *E. acoroides* at Chwaka Bay and Marumbi were comparable to previous studies in the area (de la Torre-Castro and Rönnbäck, 2004).

availability imposes an ultimate limit to the biomass and production of seagrasses, particularly towards the light-imposed depth limit of the populations (Duarte, 1991).

The observed higher total biomass of *T. hemprichii* in non-seaweed area than in seaweed areas correspond well with previous results that show lower biomass is seagrass meadows under seaweed farms (Eklöf *et al.*, 2005). The anthropogenic pressures resulting from seaweed farming activities could account for the differences in biomass between the two areas. Disturbances reduce the cover of seagrasses and can therefore, limit both biomass and production. Generally, if only leaves and above-ground vegetation are impacted, seagrasses are able to recover from damage within a few weeks; however, when damage is done to roots and rhizomes, the ability of the plant to grow is severely impacted, and the plant may never be able to recover (Zieman *et al.*, 1984; Fonseca *et al.*, 1988).

The growth characteristics data of both *T. hemprichii* and *E. acoroides* observed in this study are comparable to those reported by other researchers elsewhere (e.g. Erftemeijer *et al.*, 1993; Uku & Björk, 2005). The observed range of leaf production rates of our study could somewhat encompass other rates reported for *T. hemprichii* and *E. acoroides* using the leaf marking technique (Hemminga *et al.*, 1995; Brouns, 1985). Erftemeijer *et al.* (1993) reported relative growth rate in southern Sulewasi Indonesia, which ranged from 0.022 - 0.056 (g $g^{-1}day^{-1}$) for *T. hemprichii* and 0.012-0.037 (g $g^{-1}day^{-1}$) for *E. acoroides.*

Although there were some differences in growth characteristics between sites and between seagrass meadows in seaweed and non-seaweed areas (Table 2), the differences were not systematic. For example, aerial production rate of *T. hemprichii* was found to be lower in seaweed area at Jambiani but not other stations, while aerial production rate of *E. acoroides* was high. Thus, in general, we could not clearly observe any significant differences in growth characteristics of seagrass under seaweed and away from the farms. Similarly, the observed inconsistency in differences between seaweed and non-seaweed areas for most of the ETR values and Fv/Fm ratios of both *T. hemprichii* and *E. acoroides* suggest that seaweed farming has no effect on the photosynthetic characteristics of the seagrass species under study. On the other hand, the consistently observed significant differences in ETR and Fv/Fm ratio among sites is most likely due to the fact that the measurements were taken on different dates with different light regimes. Plants are known to respond to changes in irradiance by regulating their absorption cross-section of Photosystem II (PSII) and by means of state transition (e.g. Kroon, 1994). It is however interesting to note that neither *T. hemprichii* nor *E. acoroides* showed signs of light saturation in their ETRs even when light levels went up to 1,500 and 2,000 µmol photons $m^{-2}s^{-1}$, respectively, suggesting that the two species are well adapted to high light intensities.

In general seaweed farming seems not to have a direct impact on growth characteristics of the seagrass species under study. Thus, the observed reduced seagrass abundance or biomass in seaweed farms is most likely to be due to physical disturbances in the farms such as bioturbation or deliberate removal of seagrasses by farmers. This may have an impact on the ecological goods and services generated by seagrass beds such as fish aggregation, traditional medicine, fertilizers, aesthetic, instrumental and spiritual values that have been previously observed to be derived from seagrasses by local communities in the area (de la Torre-Castro and Rönnbäck 2004). However, more data is required to corroborate the current results and to test other hypotheses such as the effects of excretion of halogenated compounds and hydrogen peroxide production by Eucheuma on seagrass growth.

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