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The effect of groundwater on macrophyte community structure in selected near-shore ecosystems

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Abstract

Results summarised here are in accordance with the second objective of the GROFLO project named " to elucidate differences in near-shore community structures and ecosystem functioning in relation to groundwater outflow". During the last six months (mid-November- mid-May) Zanzibar (Unguja island) received part of the El-nino influenced short rains (November-December) and long rains (March-May). It was at an optimal time to observe the influence of highest groundwater output and associated anthropogenic input on the near-shore community structures and ecosystem functioning. Algal blooms that are usually associated with input of additional nutrients were observed particularly in Chwaka where the highest algal blooms (2- 25 kg(FW) m^{-2} of Ulvaceae species, 2.5 kg(FW) m^{-2} *Gracilaria* species and 3 kg(FW) m^{-2} *Halimeda* species) were recorded in May 98. Above ground weight of *Thallasia hemprichii* closest to the groundwater bore-holes was also highest in Chwaka (0.25 kg(FW) m^{-2}). As a result of blooms dominated by green algae, species diversity was reduced. In Paje the number of filter feeding bivalves were highest in the area receiving groundwater.

Introduction

The eutrophication or nutrient enrichment, of coastal waters as a result of anthropogenic substances contained in groundwater outflowing into the intertidal ecosystems is now recognised as one of the major factors threatening the integrity of near-shore ecosystems. This is because the growth of human population and of industrial and agricultural production produces quantities of waste that is greater than that which the environment can easily absorb. Through leaching, nutrients and other pollutants from liquid wastes, sanitary landfills for solid wastes, sewage systems, animal wastes, fertilisers and pesticides from agricultural soils pollutants reach the subsurface. It appears that percolating ground water coming from the agricultural areas treated with fertilisers and from sewage effluents are responsible for most land derived nutrients entering coastal waters and are therefore, primarily responsible for eutrophication processes. The excessive growths of macro-algae in response to eutrophication may lead into detrimental ecological and environmental consequences such as decreasing species diversity of the relevant ecosystems, restrict water movement, lower aesthetic quality of beaches and thus affect tourism and cause a general reduction in the productivity of locally important fisheries.

There are a number of natural mechanisms by which nutrients are released into the marine environment e.g. the release of nutrients disturbed by storms, from rotting benthic seaweeds and as a result of upwelling systems, many reports relate to man's activities. These include release of nutrients from disturbed sediments (e.g. due to dredging activities), fish farms, river input, rainwater run-offs, percolating ground water coming from the agricultural areas treated with fertilisers and from sewage effluents. Probably the last two are responsible for most land derived nutrients entering coastal waters and are therefore, primarily responsible for eutrophication processes.

This study examines floristic composition of selected sites in Chwaka bay, Paje, Uroa and Fumba. Groundwater bore-holes have been located in Chwaka and Paje. Study sites in Chwaka bay are located along a channel emptying water from a mangrove forest. As irrigation rice farms are behind the bay, it is expected that the impact of farm fertiliser and pesticide applications will be felt in this bay. Agricultural activities around Paje appears to be minimal. Nevertheless, the village is an attractive tourist destination. The Menai bay in Fumba receives freshwater from groundwater bore-holes located in Dimani. Due to logistic problems, an area without an apparent groundwater bore-hole has been chosen as an additional control for Chwaka site with freshwater bore-holes. Uroa does not have an apparent freshwater bore-hole and was chosen as a control for Paje as villagers from both villages farm seaweed. The impact of seagrass communities to the productivity of the farmed seaweed is of interest here.

Methodology

As shown in the last annual report, sampling was guided by the physical dynamics (e.g. current direction). Sampling was done on permanent 500 m long transects established parallel the beach. For areas with groundwater bore-holes, such bore-holes were located at the middle of the transect so as to study the influence of groundwater and associated inputs on the macrophyte community along the channel. Standing stocks (biomass and species composition) have been analysed with the intention of identifying possible effects of groundwater input and associated anthropogenic substances.

Habitats

General characteristics of the study sites were as indicated In the last annual report.

Status of sites with permanent transects for these studies. Salinity and pH regimes (in bracket) for samples taken in May, 1998:

	Site A	Site B	Notes
Chwaka	12-13‰ (7.12-7.17)	35-36‰ (7.90-8.21)	Fresh water at site A; several groundwater bore-holes with mean outflow of about 60 l min^{-1} in May and one third of that in November
Paje	5-10‰ (6.98-7.52)	34-36‰ (8.10-8.22)	Fresh water at site A; several groundwater bore-holes with mean outflow of about 40 l min^{-1} in May and half of that in November
Fumba	34-35‰ (8.22-8.42)	35-36‰ (7.99-8.21)	A site with a clear source of fresh water not found.
Uroa	34-35‰ (8.15-8.26)		No freshwater bore-hole. There is also seaweed cultivation. Chose as a control site for Paje.

Effect of groundwater on the seagrass communities in Paje and Chwaka

Macrophyte abundance recorded in sites with freshwater bore-holes appeared to fluctuate with the amount of fresh water outflowing from the bore-holes. Blooms of Ulvaceae species (*Ulva reticulata, U. pulchra, U. pertusa, U. rigida, U. fasciata* and *Chaetomorpha crassa*) was highest in Chwaka during mid-May. The abundance of *Gracilaria salicornia* was also high during the long rains. Nevertheless, tips were whitish. The reason for the bleaching of tips was not established as optimal conditions for their growth is not yet established. In *E. denticulatum*, a condition known as ice-ice is a sign of physical stress. Factors influencing such a situation includes high light intensities, low salinity, high pH etc.

The reason for the enhanced macrophyte growth is yet to be established as the status of nutrients in the outflowing groundwater is not yet known as data analysis is still in progress. Whereas the seagrass species diversity remained the same, the number of brown and red algae was low, especially in Fumba. Samples for C:N:P ratio will soon be sent for analysis.

The reason for high density of filter feeding bivalves in an area receiving groundwater is not yet clear as the extent of nutrients in the water column is not yet clear. Samples for phytoplankton analysis have been taken.

Table 1. Status of macrophytes at site A in Paje. Freshwater bore-holes are 250 m away and freshwater streams into the channel. A distance marked 0 m is opposite the first major fresh water bore-hole. Other bore-holes are found south of the first one and their water flows down the stream flowing southward. Growth rate of E. denticulatum *was determined from farms located at respective points. A permanent transect to monitor macrophytes other than Eucheuma denticulatum has been located at the middle of the channel.*

(i) November, 1997:

Distance (m)	‰	pH	*T. hemprichii* above ground	*Pina* (bivalves)	Cyanobacteria mats	*E. denticulatum* growth rate (%)
Upstream						
500	35	8.25	5.1±0.4	0	Absent	7.2±0.6
300	34	8.30	0	0	Absent	No farm
200	35	8.24	3.2±1.1	0	Absent	No farm
100	35	8.24	10.23±2.0	0	Present	6.2±0.3
50	35	8.29	9.29±3.2	0	Present	5.8±1.1
0	34	8.20	23.77±3.1	5±2	Present	No farm
Down stream						
50	34	8.25	15.24±0.3	5±1	Present	5.5±1.5
100	33	8.22	15.9±2.7	5±2	Present	6.0±0.9
200	34	8.20	17.04±0.5	35±10	Absent	No farm
300	30	8.19	23.9±7.1	40±8	Absent	No farm
500	30	8.15	15.2±3.9	35±6	Absent	No farm
900	34	8.32	12.4±5.7	0	Absent	6.2±1.0

(ii) May, 1998:

Distance (m)	‰	pH	*T. hemprichii* above ground	*Pina* (bivalves)	Cyanobacteria mats	*E. denticulatum* growth rate (%)
Upstream						
500	35	8.20	4.3±2.5	0	Present	7.2±0.6
300	34	8.20	0	0	Present	No farm
200	35	8.20	6.2±5.1	5±1	Present	No farm
100	34	8.21	13.44±4.1	0	Present	5.2±1.1
50	34	8.22	16.49±2.3	5±1	Absent	5.3±1.3
0	29	8.12	31.56±5.1	12±2	Absent	No farm
Down stream						
50	34	8.22	21.23±1.1	5±1	Absent	5.4±0.5
100	33	8.21	15.8±4.2	6±2	Absent	5.3±1.1
200	30	8.18	30.34±3.9	55±5	Absent	No farm
300	28	8.16	34.3±2.3	65±8	Absent	No farm
500	27	8.11	34.9±5.1	55±10	Absent	No farm
900	31	8.21	18.5±6.3	6.4±2	Absent	6.8±0.7

Table 2. Macrophyte status at site A in Chwaka. Freshwater streams into a channel at 0 m and 120 m (upstream). The middle of the channel is dominated by Enhalus ecoroides *and species diversity is minimal due to the strength of the current and sedimentation. A site measuring 500 x 50 m has been marked along the strip besides the channel for purposes of monitoring macrophyte status. Transect was run 25 m parallel the freshwater source. Macrophyte abundance shown in kg(FW) m*$^{-2}$

(i) November, 1997:

Distance (m)	‰	pH	*T. hemprichii* above ground	*G. salicornia*	*Halimeda* species	Ulvaceae
Upstream						
250	35	8.22	0.06	0	0	0
200	36	8.20	0.12	0.2	0.3	0
150	35	8.19	0.08	0.5	0	0.8
Bore-hole	12	7.14	0	0.5	0	1.5
100	36	8.12	0.2	1.5	0	0.3
50	35	8.20	0.24	2.4	2.5	0.6
0	35	8.25	0.25	2.5	3.0	0.4
Bore-hole	20	7.35	0	0	0	2.0
Down stream						
50	35	8.20	0.04	0	0	0.2
100	35	8.21	0.06	0	0	0
150	35	8.20	0.03	0	0	0.01
200	35	8.23	0.10	0.01	0	0.08
250	35	8.20	0.08	0.02	0	0

(ii) May, 1998:

Distance (m)	‰	pH	*T. hemprichii* above ground	*G. salicornia*	*Halimeda* species	Ulvaceae
Upstream						
250	35	8.20	0.13	0.5	0	0.7
200	35	8.20	0.22	0.6	1.5	5
150	35	8.20	0.19	1.0	0	10
Bore-hole	13	7.15	0	2.0	0	3.1
100	35	8.21	0.2	1.5	0	0.3
50	35	8.12	0.24	2.4	2.5	0.6
0	35	8.22	0.25	2.5	3.0	0.4
Bore-hole	12.5	7.15	0	0	0	2.0
Down stream						
50	34	8.20	0.18	0	0	0.34
100	35	8.21	0.18	0	0	0
150	35	8.20	0.13	0	0	0.2
200	35	8.20	0.09	0.4	0	0
250	35	8.20	0.16	0.2	0	0

Table 3. Algal species found in Chwaka Bay (C), Paje (P) and Fumba (F) in May 1998

Family	Species	C	P	F
Chlorophyceae:	*Avrainvillea* Decaisne	√	√	√
	Boodlea Murray and De Toni	√		
	Caulerpa cupressoides (Vahl) C. Agardg	√	√	√
	C. sertularioides (S.G. Gmelin) Howe		√	
	C. taxifolia (Vahl) C. Agardg	√		√
	Chaetomorpha crassa (C. Agardh) Kützing	√		
	Codium edule P.C. Silva	√		√
	Enteromorpha ramulosa (J.E. Smith) Hooker.	√	√	√
	E. clathrata (Roth) J. Ag.	√	√	√
	Ulva reticulata Forskaal	√	√	√
	U. pulchra Jaasund	√	√	√
	U. pertusa Kjellman	√	√	√
	U. rigida C. Ag.	√	√	√
	U. fasciata Delile	√		√
	Chaetomorpha crassa (Ag.) Kütz	√	√	√
	Cladophora sp.	√		√
	Bornetella oligospora Solms-Laubach			√
	Boergesenia forbesii (Harvey) Feldmann			√
	Dictyosphaeria cavernosa (Forsk.) Bôrgesen	√		√
	Caulerpa racemosa (Forsk.) J. Ag.			√
	Halimeda tuna (Ellis & Sol.) Lamouroux		√	
	H. macroloba Decaisne	√		√
	H. opuntia (L.) Lamouroux	√		
	Valonia fastigiata Harvey ex J. Agardh.	√		√
Phaeophyceae:	*Dictyota* sp.			√
	Padina gymnospora (Kütz) Vickers	√		√
	T. crateriformis Taylor			√
	Sargassum spp.	√	√	√
Rhodophyceae:	*Amphiroa anceps* Lamouroux.			√
	Gracilaria corticata J. Agardh	√		
	Gracilaria salicornia (J. Ag.) Dawson	√		√
	Hypnea musciformis (Wulfen) Lamouroux			√
	Laurencia papillosa (Forsk.) Greville	√	√	√

Note: √ = present

Preliminary conclusions

Most nutrient data is still being worked out and therefore it is premature to draw out concrete conclusions regarding the influence of underground freshwater influence on the relevant ecosystems. Nevertheless the following could be said:

Based on the length of inter-nodes and shoots of the seagrass *Thalassodendron ciliatum*, so far is evident that this seagrass survive better in sites influenced by groundwater. Nevertheless, *T. ciliatum* has never been found in sites with low salinity. The seagrasses *Thallasia hemprichii* and *Halodule uninervis* appears to survive areas with salinity as low as 20 ‰.