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Undergrowth species diversity of Sundarban mangrove forest (Bangladesh) in relation to salinity

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Abstract

Undergrowth species diversity was investigated by random quadrat method. Ordination and Shannon-Wiener diversity index were produced by the CANOCO program and Cluster analysis was done by the SAS (Statistical Analylitical System, sixth version) program. 48 undergrowth species were recorded in the Sundarban mangrove forest belonging to the dominant families such as Fabaceae (*Cynometra ramiflora, Dalbergia spinosa, Derris trifoliata*), Poaceae (*Myriostachya wightiana, Porteresia coarctata),* Palmae (*Nypa fruticans, Phoenix paludosa*), Acanthaceae *(Acanthus ilicifolius*), Pteridaceae (*Acrostichum aureum*), Myrsinaceae (*Aegiceras corniculatum*), Rhizophoraceae (*Rhizophora mucronata, Bruguiera gymnorrhiza*). On the basis of frequency distribution of undergrowth vegetation data sets six undergrowth species were found to be dominant and widely adapted to the various salinity conditions in different zones of Sundarban mangrove forest, which were frequently occurring in most of the sites and quadrats such as *Acanthus ilicifolius, Acrostichum aureum, Derris trifoliata, Vitis trifoliata, Sarcolobus globosus* and *Phoenix paludosa*. The ordination of undergrowth species was assessed between environmental variables (salinity and pH) and undergrowth species. The ordination of undergrowth species revealed that some species are more saline tolerant, closely associated and widely distributed in the Sundarban mangrove forest like *Derris trifoliata*, *Acanthus ilicifolius*, *Nypa fruticans, Sarcolobus globosus, Dalbergia spinosa*, *Flueggia virosa, Pandanus foetidus* and *Phoenix paludosa.* It is interesting to note that salinity is a vital factor for the development of undergrowth species. It can also be concluded that the rich diversity of undergrowths of healthy individuals might be indicative of the healthy mangrove forest of the low saline zone area and poor diversity of undergrowths, as well as their stunted growth might be indicative of the ill mangrove forest of high saline zone area.

Keywords: Undergrowth flora, salinity, pH, ordination, Sundarban.

1. Introduction

Mangroves are generally found along the coastlines of tropical and sub tropical regions, usually between 25° N and 25° S latitude, throughout the world. As an exception to these, mangroves are found as far south as New Zealand and as far

as north as Japan (CHOUDHURY, 1997). Mangroves once covered ¾ of the world's tropical coastlines, often in conjunction with the coral reefs. Asia contains most of the world's mangroves with 46 %, followed by America with 35 % and Africa with 17 % (MAP, 1990). Particular environmental factors such as temperature, warm sea current, rainfall, salinity stress, wave action, sedimentation, fresh water flow etc. determine the occurrence and development of mangroves in the local area. WALSH (1874) stated generally tropical countries had mangroves in the past and the world mangroves divided into two main areas, i) the Indo-Pacific regions and ii) Western Africa and American regions. He also suggested five basic requirements for extensive mangrove development such as 1) tropical temperature, 2) fine grained alluvium, 3) low wave and tidal action, 4) salt water and 5) large tidal range.

The Sundarban is the single largest continuous mangrove forest in the world and has been recognized as an international important Ramsar Wetland Site and declared as a World Heritage Site (WHS) by the UNESCO in 1997. The Sundarbans delta stretches across coastal India and Bangladesh, over the northern part of the Bay of Bengal. It is located in the estuary of the river Ganges spanning an area of about a million ha. south west of Bangladesh and the south eastern portion of the State of West Bengal in India. The Sundarban forests tract including the Indian part covers an area 10,000 km^2 of which 66 % are land, the remainder is water (HUSSAIN & ACHARYA, 1994). About 62 % of the Sundarbans forest is in Bangladesh and the rest in India.

Floristic composition

There are varying definitions of what constitute a mangrove. According to two reputable scientific studies, mangroves include approximately 16-24 families and 54-75 species (TOMLINSON, 1986; FIELD, 1995) respectively. The greatest diversity of mangrove species exists in Southeast Asia. For example, there are only twelve mangrove species in the New World and only four species of mangroves exist along the coasts of the southern USA (ALFREDO, 1997). Floral diversity of Sundarban mangrove forests is very rich compared to other mangroves in the world. HENING (1892) recorded 69 species under 34 families in the whole of Sundarban (Bangladesh and India) territory. KARIM (1994b) reported 123 plant species belonging to 22 families representing 30 genera in SMF in Bangladesh. HOSSAIN (2003) reported 44 undergrowth species of Sundarban mangrove forest. As a matter of fact, SMF has not yet been thoroughly explored floristically, except for a few sporadic trips made by the above-mentioned scientists and teams of Bangladesh National Herbarium, IUCN, UNDP, ODA and FAO.

The Sundarban forest is dominated mostly by three major tree species, viz. *Heritiera fomes, Excoecaria agallocha* and *Ceriops decandra*. The species of the Rhizophoraceae exist in more saline areas in the south and west, but they are also found in the north and east, although relatively infrequently. *Bruguiera*

gymnorhiza occurs throughout the SMF and is not affected by the various degrees of salinity. The common undergrowth species of the study areas are *Acrostichum aureum*, *Acanthus ilicifolius*, *Phoenix paludosa*, *Pandanus foetidus*, *Porteresia coarctata*, *Dalbergia spinosa*, *Derris trifoliata* and *Hibiscus tiliaceus.*

The present paper is concentrates on the undergrowth species composition and diversity, dominant categories and zonation patterns of SMF, those are responding in various levels of salinity.

2. Materials and Methods

2.1 Sundarban

The Sundarban was declared as a Reserve Forest (SRF) in 1879, since then it has been directly administered and managed by the Forest Department. Sundarban mangrove forests lying between the longitudes 89°00' and 89°55' east and latitudes 21°30' and 22°30' north covering an area of 5.770 km^2, of which 4.016 km^2 are covered by the forests and the remaining 1.756 km^2 are in the form of rivers, canals and creeks, varying from a few meters to several miles (HUSSAIN & ACHARYA 1994). The SRF is an important natural resource provider of a large number of products such as timber, pulpwood, fuelwood, fish, thatching materials, honey, bee wax and shells. In addition, it also supports a very rich and diverse flora and fauna. The only natural habitat of the endangered flagship species, the Royal Bengal Tiger lies in Sundarban.

Sundarban biodiversity is noticeably rich in terms of plant and animal diversity. The number of species found in the Indian mangal swamps is nearly as many as those reported for Malaysia and Indonesia (CHAPMAN, 1976). PATIL (1962) reported that half of the total number of mangrove species found in the world occur in the Indian Sundarbans (present in Bangladesh and Indian Sundarbans).

2.2 Study sites

The study area included 29 key sites from the SMF in order to represent the various existing identifiable ecological habitats of the mangrove landscape (Fig. 1). Plant specimens recorded represented a wide section of the previously recognized three zones, (CURTIS, 1933; KARIM, 1994; SIDDIQI, 2001) namely oligohaline, mesohaline and poloyhaline zones.

2.3 Methods of plant collection and identification

Plant samples were collected by standard quadrat method (BRAUN-BLANQUET, 1964; RAUNKIAER, 1934). The quadrat size (5m x 5m) was determined on the basis of a species area curve (BRAUN-BLANQUET, 1964). During the study period (2002 to 2004) two times was visited in each sites. The quantitative data on undergrowth species, collected from at least ten randomly taken quadrats on its representative part of 29 sites. All undergrowth species were identified at the

Bangladesh National Herbarium (BNH). The major floristic works consulted were HOOKER (1872-1897), PRAIN (1903, 1903a), BOR (1960) and HUQ (1988) and the Flora of Bangladesh (Nos. 1-55).

2.4. Methods of Ordination

The undergrowth species were analyzed by the ordination method. The collected vegetation data were transformed in a frequency table and analyzed with the ordination method by the application of CANOCO software program (BRAAK & SMILAUER, 2002). Shannon-Wiener diversity index (KENT & COOKER, 1992) and N_2 diversity (according to HILL, 1973) were produced by the CANOCO program. The Cluster analysis was done by the SAS (Statistical Analylitical System, sixth version) program.

2.5 Water salinity and pH

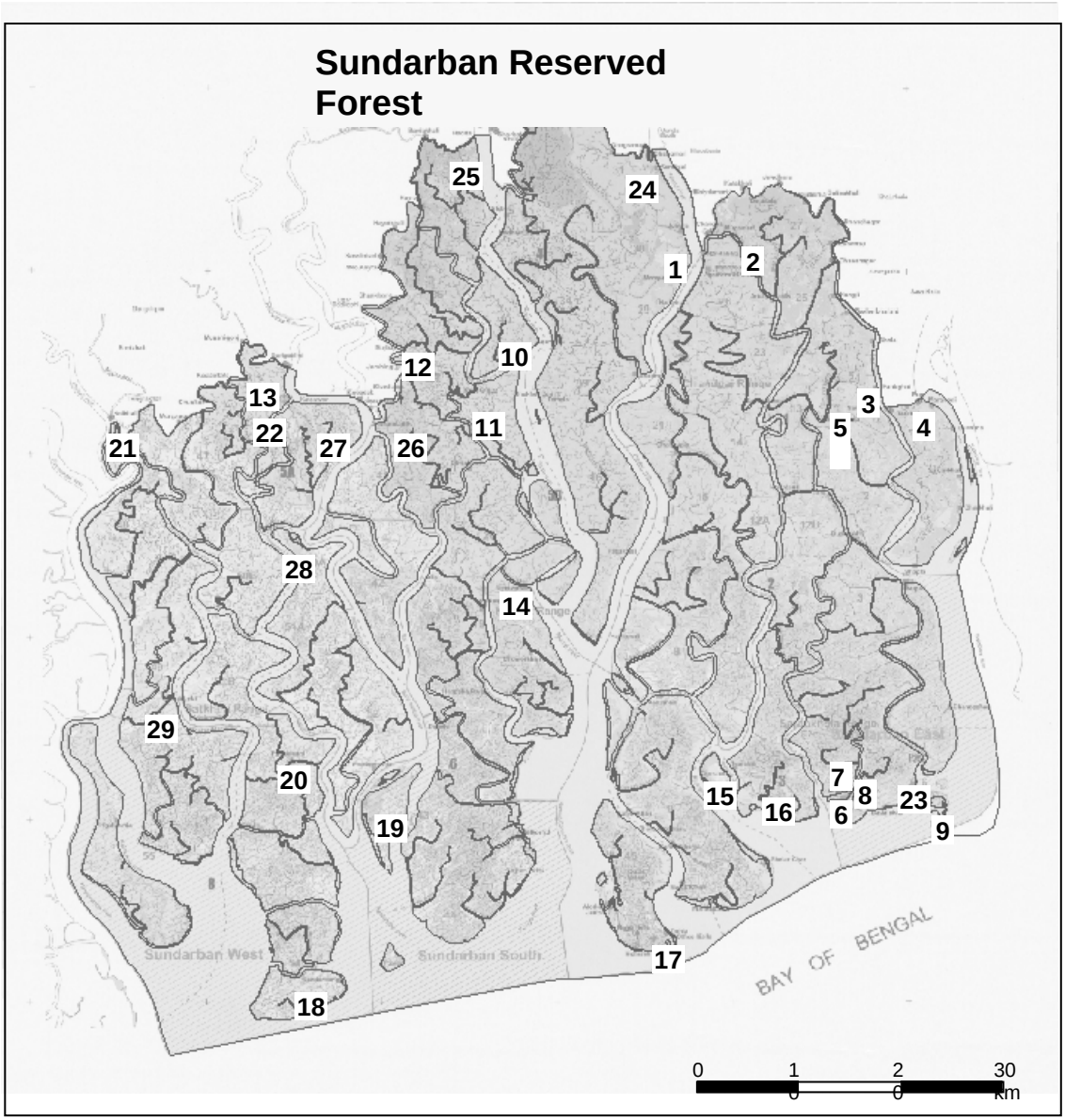
Water pH and salinity of water were estimated by pH meter and conductivity meter respectively.

3. Results

3.1 Diversity of undergrowth species

Total frequency values of individual undergrowth species in each site was correlated with salinity and pH values of all selected sites of SMF (Table 2). Diversity indices for the undergrowth species revealed that there is a positive correlation among higher diversity indices, spatial locations and existing environmental parameters, such as fresh water flow, salinity gradient and sedimentation load from the east to the west direction or vice versa (HOSSAIN, 2003). These general trends indicate that the Sundarbans biodiversity is much richer in the oligohaline or low saline zones in comparison to that of the polyhaline or hyperhaline zones i. e. biodiversity vary salinity gradient-wise. In another sense, the plant diversity, especially the undergrowth diversity in terms of species richness of ecosystem in most of the sites decreases strikingly, as one gradually moves from fresh water zones i. e. Eastern and North-Eastern and South-Eastern Sundarbans to more saline zones i. e. Western and South-Western Sundarbans. This is also explicit in the values of diversity indices of the visited sites (Table 1 and 2).

Forest vegetation type is a major factor for the development of undergrowths. There are many forest vegetation types located in Sundarban ecosystem. Healthy and diverse undergrowth were recorded in various forest vegetation types such as *Heritiera*, *Heritiera-Xylocarpus, Heritiera-Excoecaria*, *Sonneratia-Excoecaria*, *Excoecaria-Sonneratia,* and *Ceriops-Excoecaria* associations.



Vegetation sites

1 Jongra Beel
2 Mirgamari
3 Sharonkhola Panir Ghat
4 Sharonkhola South Dhabrivarani
5 Sharonkhola Tera-becka Khal
6 Kotka Range Office
7 Kotka North Jamtala
8 Kotka South of Jamtala
9 Dimer Char
10 Dhanshiddir Char
11 KNM Office
12 Kewrabunia
13 Danokhali (Beside the Kalagachi)
14 Patakata
15 Tiar Char
16 Pakhir Char
17 Dubla Char
18 Mandarbari
19 Kalir Char
20 Puspakathi
21 Koikhali
22 Kolagachia
23 Kochikhali Forest
24 Karamjal
25 Hoddo
26 Andharmanik
27 Kobadak
28 Dobeki
29 Notabeki

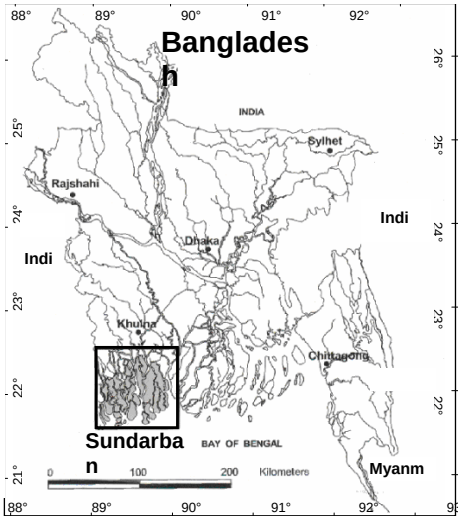


Fig. 1: Map of Sundarban Mangrove Forest including Vegetation Sites

Table 1: Site description, Shanon Diversity Index and salinity values of Sundarban mangrove forest.

Sl	Sites	Forest type	pH	Salinity	SDI	N2 div.
Nos.				ppt.		
1	Jongra Beel	*Heritiera-Xlyocarpus-Bruguiera*	6,8	4,6	2,59	12,35
2.	Mirgamaria	*Heritiera-Bruguiera-Xylocarpus-Avicennia*	8,5	5	2,53	10,97
3	Sharonkhola Panirghat	*Excoecaria-Heritiera*	7,6	0	2	6,37
4	Shorankhola : South of Dhabribarani	*Excoecaria-Heritiera*	7,7	0	2,33	8,68
5	Sharonkhola Terabecka Khal	*Heritiera-Excoecaria*	7,5	0	2,15	6,95
6	Kotka Range Office	*Heritiera-Excoecaria-Sonneratia*	7,7	1,3	2,42	8,75
7	Kotka North Jamtala	*Sonneratia-Heritiera-Excoecaria*	7,6	1	2,19	7,07
8	Kotka South Jamtala	*Sonneratia-Heritiera-Excoecaria*	7,7	1,5	2,74	13,55
9	Deemyer char	*Sonneratia-Excoecaria-Heritiera*	7,9	3	3,09	19,51
10	Dhanshiddher Char	*Heritiera-Xylocarpus-Bruguiera*	7,6	17	1,9	5,53
11	KNM collection Centre	*Heritiera-Excoecaria*	7,5	16,5	1,41	3,68
12	Kewrabunia Char	*Sonneratia-Heritiera-Excoecaria*	7,5	16,5	7,98	5,64
13	Kalagachia Danokhal	*Excoecaria-Ceriops-Xylocarpus*	6,9	20,5	2	5,41
14	Patakata	*Heritiera-Excoecaria-Ceriops*	7,8	10	1,84	6,01
15	Tiarchar	*Sonneratia-Excoecaria-Ceriops*	7,6	15	1,97	6,33
16	Pakhirchar	*Sonneratia*	7,8	7	2,3	8,56
17	Dublar Char	*Excoecaria-Sonneratia*	7,5	20,5	2,51	11,63
18	Mandarbaria	*Excoecaria-Ceriops*	6,8	20	2,1	7,47
19	Kalir Char (north)	*Ceriops-Excoecaria-Sonneratia*	5,9	20,2	1,63	3,92
20	Puspha Kathi	*Ceriops-Excoecaria*	5,1	22	1,95	6,2
21	Koikhali	*Bruguiera-Heritiera-Xylocarpus*	6,8	20,5	1,74	5,45
22.	Kalogachia	*Excoecaria-Heritiera-Xylocarpus-Avicennia*	7	14,5	1,57	4,33
23	Kochikhali	*Heritiera-Sonneratia-Excoecaria*	7,8	4,5	3,11	18,89
24	Karamjal	*Heritiera-Sonneratia-Ceriops-Nypa*	7,9	4,4	2,86	15,33
25	Hoddo	*Bruguiera-Heritiera-Sonneratia*	7,6	16	2,46	10,79
26	Andharmanik	*Ceriops-Excoecaria-Avecennia-Xylocarpus*	7,7	18	2,36	9,65
27	Kobadak	*Sonneratia-Xylocarpus-Excoecaria*	7,5	21	1,65	4,78
28	Dobeki	*Sonneratia-Ecoecaria-Avecennia*	7,5	22	2,51	11,63
29	Notabeki	*Ceriops-Excoecaria-Xylocarpus*	7,4	23	1,41	3,68

Note: SDI= Shanon Diversity Index and N_2 Diversity (According to Hill's) applying to the CANOCO software program, 2003.

In almost all forest types, except *Sonneratia* dominated forests and Char lands (sand bar), the plant diversity is comparatively poor in the interior or deep and rich at the margins or edges. Mixed forest of *Heritiera-Excoecaria-Ceriops-Sonneratia* in the moderately fresh water or mesohaline zones supported a good number of undergrowth species, but *Hibiscus tiliaceus*, *Pandanus foetidus*, and *Cynometra ramiflora* are unique to mostly *Heritiera fomes*, and occasionally *Heritiera-Excoecaria* dominated forests (HOSSAIN, 2003). Noticeably very poor diversity of undergrowths in western saline zones might be due to high salinity (Table 1 and 2). Adverse nature of habitat composed of compact sandy loam and wet soil not accumulating the tidal or rainwater and canopy shade formed by the bushes of densely grown *Ceriops decandra* (Goran) occupying most of the areas, in association with *Xylocarpus mekongensis (Poshur)* and *Avicennia officinalis* (Bain) and sometimes by *Excoecaria agallocha* (Gewa) only.

Table 2: Frequency values of undergrowth species in different sites of Sundarban mangrove forest.

	Sites (1-29)																											
Scientific name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
Acanthus ilicifolius	5	5	2	4	2	4	2	4	4	1	2	1	8	6	5	5	1	6	6	7		8	5	4	3	4	3	2	1
Acrostichum aureum	4			2	2	2	1	4	2		8	1	5					6	1	5	3		6	3	3	3	4	4	3
Aegiceras corniculatum								2				1	2			3	1					4	1	1					
Brownlowia tersa							1	1													3		3	1					
Caesalpinia crista								1										1		1									
Clematis arborea									2							1	1												
Clerodendron innermae						1		2								1	1						3	1					
Carallia bracheata																1	1												
Crotalaria saltiana						1		2	3									1											
Crinum asiaticum									1																				
Cuscuta reflexa									1																				
Cynometra ramiflora	5	6	4	5	8		4	2					1	8									2	1	2	2			
Cyperus exaltatus		3		2													2		1				3	2					
Cyperus japanicus						1										3							2						
Cyperus malaccensis	2	1				1			1	1			1				1						1						
Cyperus tagetiformis	1	1	1			1				1							1						2						
Dalbergia candelensis						1										3							2						
Dalbergia spinosa	6								3						4		2	6											
Derris trifoliata	2	6	6	8	2	8	6	5	5	4	2	7	10	8	6	4	1	6	3	1	7	7	5	3	2	4	1	2	
Dioscorea spec.									1																				
Entada pursaetha		1					2					1											1	1	1	1			
Fimbristylis acuminata	1		1				1	1							1	2		1	1				2		1				
Flagelaria indica	4	2																											
Flueggia virosa			1			4																							
Hemarthria compressus						1			4	1									1	1									
Hibiscus tiliaceous	5	5	4		4			2	4						1	1	1						1	1					
Impereta cylindrica						1			1	1													3						
Ipomoea pes-caprae									1														2						
Mikania cordata				1	3				3						1														
Myristachya wightiana									3	1	2	2	1						1	1			1	2	2	3			
Nypa fruticans						4			3			6	1	6		2				4	4	1	2	1	2				
Panicum repens				1		1																	1		1				
Pandanus foetidus	4	4	2	2	4	2	6	2				1	1	4									1	2		2			
Paspalum vaginatum									2																				
Phoenix paludosa	4			6			1	2	1				1	6	3	1		5		6	5	1	2	1		1	4	4	5
Phragmites karka		1	2	1	1				1						1														
Pongamia pinnata		1					1		1					1			2						1	1					5
Porterasia coarctata								1	2			2	1										2	2	3	2		1	1
Rhizophora mucronata	2	1		2	1	2	1	1															1	3	1	2	2	1	
Saccharum spontananeum									1														1	1	1				
Salacia chinensis		1																					1						
Sapium indicum				2	1	1				2																			
Sarcolobus globosus				1	1		1	1	1		2	2					1	7		5	4	5	1	1	1	1	1	1	
Scirpus articulatus									1																				
Solanum xanthocarpum																		2											
Stenoclaena palustris	7	4		7				3	3				1												1				
Tamarix indica	5	6						1							5	1							1	1		1		1	
Typha elaphantica				1		1																	1						
Vitis trifolia	2	2	2	5	5	1	2	2	3	3	2			4	1	1	1		2	5	9		3	1	1	2	1	1	
Note: Fequency values:	1=10%, 2=20%, 3=30%, 4=40%, 5=50%,6=60%,7=70%,8=80%, 9=90%, 10=100%																												

Table 3: Most frequent undergrowth species of SMF

Scientific name	Local name	Family	Zones
Acanthus ilicifolius	Hargoza	Acanthaceae	All zones
Acrostrichum aureum	Tiger fern	Pteridaceae	All zones
Cynometra ramiflora	Shingra	Fabaceae	Oligohaline zone
Derris trifoliata	Kalialata	Fabaceae	All zones
Hibiscus tiliaceus	Bhola	Malvaceae	Oligohaline zone
Nypa fruticans	Golpata	Palmae	All zones
Pandanus foetidus	Keya	Pandanaceae	Oligohaline zone
Phoenix paludosa	Hental	Palmae	All zones
Vitis trifoliata	Angorlata	Vitaceae	All zones
Porteresia coarctata	Dhanshi	Gramineae	Oligohaline zone
Rhizophora mucronata	Garjan	Rhizophoraceae	Oligohaline zone
Sacrobolus globosus	Bawalilata	Asclepiadaceae	All zones

The absence of undergrowths at slightly depressed and clayey areas between the canopies of few mangrove trees species, such as *Heritiera fomes* (Sundri) or *Excoecaria agallocha* (Gewa), as observed in a few sites of fresh water or less saline water zones (e. g. Jongra Beel, Mirgamari, Kotka and Kochikhali sites), might also be due to the repeated and stronger flow of tidal water, not allowing the settling and germination of seeds or propagules of undergrowth species in these areas. Forests and the associated undergrowths of higher saline sites were much more degraded than lower saline sites. The diversity of undergrowth species may be richer in relatively younger mangrove forest, as at Deemyer Char, than in the older ones.

On the other hand, the lower values of Shannon Diversity Index, N_2 diversity values (calculated by the CANOCO program according to HILL, 1973) and poor growth performances and biomass formation by the undergrowths, like *Phoenix paludosa* (Hental) and *Nypa fruticans* (Golpata) in mesohaline or polyhaline zones, might be correlated with ill health status of the mangrove ecosystem (HOSSAIN, 2003). The diversity value of Shannon Diversity Indices for the undergrowths occurring throughout higher saline zones of Sundarban forest ecosystem indicated that its health status is not better or rather sick in these areas. Field surveys and the available ecological data revealed that there are distinct forest associations and these can be visually identified in the field, mainly by their dominance as determined by species abundance or presence/absence criteria. Further, these associations are predominately influenced or controlled by the existing geomorphological and hydrological characteristics. Because, in the *Heritiera-Excoecaria* dominated forests recognized in the nonhaline and oligohaline zones, *Phoenix paludosa* (Hental) formed scattered small clumps both at the margins and interior of the forests. *Nypa fruticans* (Golpata) formed both scattered small clumps and long strips of healthy individuals mostly at the edges of forests (HOSSAIN, 2003). These were followed by small to medium-sized populations of healthy individuals of

Hibiscus tiliaceus (Bhola) growing in scattered fashion. The most abundant and densely populated communities of healthy individuals growing throughout most of the forest areas were found belonging to *Pandanus foetidus* (Keya) and *Acanthus ilicifolius* (Hargoza). Two other species, e. g. *Flagellaria indica* (Abetee) and *Cynometra ramiflora* (Shingra) were found to grow as scattered individuals. Similarly, in the *Heritiera-Xylocarpus-Bruguiera* or *Heritiera-Bruguiera-Avicennia* dominated forests of nonhaline and oligohaline zones, the undergrowths were represented by the same above-mentioned species, but uniquely characterized by having a pteridophytic climber, *Stenochlaena palustris* (Dhekia Lata) with its profuse growth and abundant individuals. On the contrary to the nonhaline and oligohaline zones, *Heritiera-Excoecaria* dominated forests of mesohaline zones were represented by small or large population of Hental, small-scattered clumps or isolated individuals of *Nypa fruticans, Acanthus ilicifolius* and *Cynometra ramiflora* comparatively less healthy, ill-developed and dwarf individuals. Striking fact is the absence of *Hibiscus tiliaceous* and *Pandanous foetidous*, the keystone mangroves of nonhaline and oligohaline zones, in the *Ceriops-Excoecaria* or rarely *Heritiera-Excoecaria* dominated forests of mesohaline and polyhaline zones (Table 2 & Table 3). *Cynometra ramiflora* (Shingra) was also absent in the mesohaline zones except in Hodda and in polyhaline zones of Sundarbans. The phenomenon of increase in the 'Diversity Status' from the West Zone of Sundarbans towards the East Zone is also remarkable (HOSSAIN, 2003).

3.2 Undergrowth species

The vegetation data sets are presented in the Table 2, which describes the frequency of undegrowth species in all sites. The present vegetation data sets provided information on undergrowth species association, distribution, zonation pattern & vegetation type and dominance category. On the basis of the frequency table, 48 undergrowth species were recorded belonging to dominant families such as Fabaceae (*Cynometra ramiflora, Dalbergia spinosa, Derris trifoliata*), Poaceae (*Myriostachya wightiana, Porteresia coarctata)*, Palmae (*Nypa fruticans, Phoenix paludosa*), Acanthaceae *(Acanthus ilicifolius*), Acrostichiaceae (*Acrostichum aureum*), Myrsinaceae (*Aegiceras corniculatum*) and Rhizophoraceae (*Rhizophora mucronata, Bruguiera gymorrhiza*) (Table 2). Some undergrowth species were recorded from most of the sites and it is revealed that species are closely associated with each other and are not affect by various degrees of salinity like *Acanthus ilicifolius, Acrostichum aureum, Derris trifoliata, Vitis trifolia, Sarcolobus globosus, Phoenix paludosa, Pandanus foetidus, Cynometra ramiflora, Hibiscus tiliaceus, Cyperus tagetiformis, Myriostachya wightiana, Porteresia coarctata, Rhizophora mucronata and Nypa fruticans* (Table 2 and 3). Six undergrowth species are most dominant and widely adapted to the varying salinity conditions in different zones of SMF, which are occurring in most of the sites and quadrats

such as *Acanthus ilicifolius, Acrostichum aureum, Derris trifoliata, Vitis trifolia, Sarcolobus globosus* and *Phoenix paludosa*.

4. Discussion

4.1 Zonation patterns of undergrowth vegetation

The natural mangroves are growing only where environmental conditions are favourable. The more important factors controlling mangrove distribution in any region of the world are as follows: sea level, salinity and drainage are mostly important (MAC NAE, 1968), WALTER & STEINER (1936) considered the degree of flooding, soil nature and salinity are to be most important and BALTZER (1969) believed the level of tides and hence, probably salinity as highly significant.

The zonation is a regular series of vegetational bands parallel to the coastline. Mangrove zonation patterens are established initially as new propagules colonize the available substrate at the seaward edge of the mangrove, and later as species replacement occurs at higher tidal elevation in a predictable sequence (LUGO, 1980). A number of researchers working in the field and undertook laboratory experiments in order to determine the influencing factors of mangrove zonation. These factors includes: salinity (CLARKE & HANNON, 1970; NAIDOO, 1985 and SIDDIQI et al., 1989), light (SMITH, 1987b), nutrient availability (BOTO & WELLINGTON, 1984; MACKEE, 1995a) and biotic interactions, such as intraspecific competition (Ball, 1980) and predation (SMITH, 1987a & b; MACKEE, 1995b; MCGUINNESS, 1997; DAHDOUH-GUEBAS et al., 1998).

BOWMAN (1917) mentioned salinity is an important factor regulating growth, height, survival and zonation of the mangroves (CHOWDHURY & ACHARYA, 1994). MATTHIJS (1999) reported that, soil sulphide concentration and salinity may contribute to the structure of mangroves through the distribution of dominant species at Gazi Bay (Kenya). UKPONG (1997) found that the level of variation in salinity, nutrient availability and soil texture are the major factors influencing the distribution of mangrove vegetation and zonation in Nigeria.

CLARKE & HANNON (1970) reported salinity to have the major effect on the mangrove zonation patterns and is correlated with tree height gradients. WATSON (1928) added, that the frequency of tidal flooding, salinity and soil type were the important determinants of mangrove zonation. KARIM (1988) viewed the variation of dominant plants based on salinity and elevation of the ground in relation to tidal flooding. The Sundarban has been divided into three ecological zones, based on salinity and distribution of species composition such as i) less saline/fresh water zone, ii) moderately salt water/moderately saline zone and iii) salt water zone/strong by saline zone. A number of plant species have preference for tolerance to various levels of salinity for survival and optimal growth.

A large numbers of undergrowth species were recorded in the Sundarban. The surveyed vegetation data sets supported that mangrove species are growing in a particular suitable environment. Influencing factors are soil and water salinity, tidal flooding, sedimentation load and nutrient availability etc. Table 2 indicated that most of the undergrowths species were found in the oligohaline and the mesohaline zones, because of lower salinity levels.

4.2 Ordination of undergrowths Species

The ordination of undergrowth species was assessed between environmental variables (salinity and pH) and undergrowth vegetation using the CANOCO program for the data sets of Table 1 and Table 2.

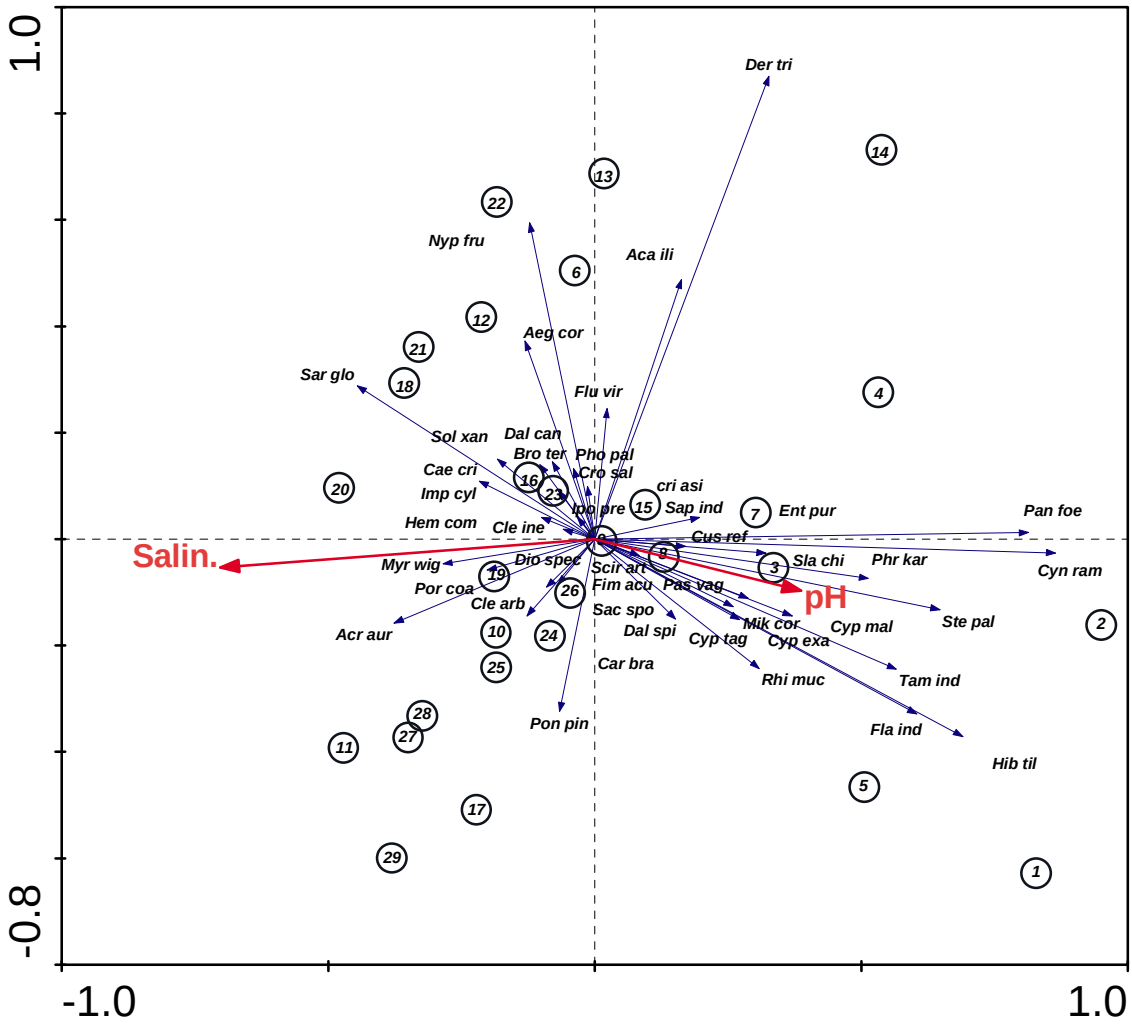


Fig. 2: Ordination of undergrowth species and their affect on salinity and pH values of Sundarban mangrove forest.
Note: Sites (1-29) is described in Table 1. Ordidation of species names: 3 character genus; 3 character species (see Table 2)

Table 2 recorded total frequency values of each species in individual site and Table 1 depicted the site description, vegetation type, salinity and pH. The figure 2 indicated that some undergrowth species are closely correlated salinity

and pH levels, such as *Sapium indicum*, *Entada purseatha*, *Crinum asiaticum*, *Crotalaria saltiana*, *Caesalpinia crista*, *Imperata cylindrica*, *Ipomoea pes-caprae*, *Scirpus articulatus*, *Fimbristylis acuminata*, *Dioscorea* spec., *Clematis arborea*. *Porteresia coarctata*, *Myriostachya wightiana*, *Salacia chinensis*, *Saccharum spontaneum*, *Cuscuta reflexa* etc.

The environmental variables such as pH is positively and salinity is negatively correlated (Fig. 2). The highest values of salinity and pH containing sites were 29, 27, 28, 24, 25, 26, 11 and 1, 5, 2 respectively. These sites (14, 4, 22, 13, 6, 12, 21, 18, and 20) were not related to salinity and pH. On the basis of PCA analysis the highest salinity containing sites were found to have some plants like *Pongamina pinnata*, *Acrostrichum aureum*, *Porterasia coarctata* and the highest pH dominating site was occupied by the plants like *Hibiscus tiliaceus*, *Flacourtia indica*, *Tamarix indica*, *Rhizophora mucronata*, *Cyperus tagetiformis*, *Cyperus exaltatus* and *Cyperus malaccenensis*. Some species were not affected by either salinity or pH like *Derris trifoliata*, *Acanthus ilicifolius*, *Nypa fruticans*, *Sarcolobus globosus*, *Dalbergia candelensis*, *Flueggia virosa* , *Pandanus foetidus*, *Phoenix paludosa*. It is noticed that these species are more tolerant and widely distributed in the Sundarban mangrove forests. The Fig. 2 also supports the most frequent undergrowth species of Sundarban which are described in the Table 3.

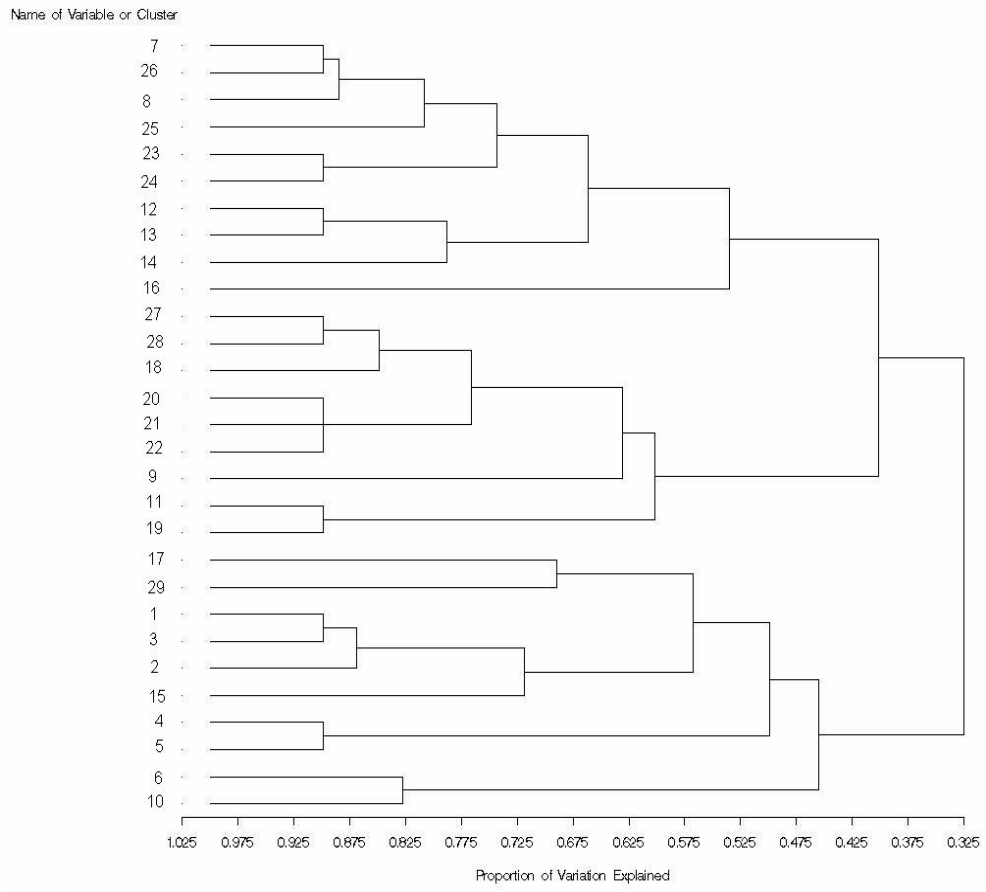


Fig. 3: Cluster analysis of undergrowth vegetation sites.

4.3 Cluster of sites

The Cluster analysis was done on the basis of present and absent data sets of under growth vegetation. The site cluster is showing the distance between the sites of the study area. As a considered of broad cluster group sites 7 (26, 8, 25, 23, 24, 12, 13, 14 and 16) are closest to the second cluster site 27 (28, 18, 20, 21, 22 etc). The second cluster also closet to the third cluster sites are 17 (29, 1, 3, 2, 15, 4, 5, 6, 10) (Fig. 3). It is noticed that first cluster group sites are belonging to the moderate saline zone and second cluster are in the strong saline zone area. The third cluster group sites are mostly in the less saline zone area.

5. Conclusions

The undergrowth species are growing in a suitable environment and related to salinity. Influencing factors are soil and water salinity, tidal flooding, sedimentation load and nutrient availability etc. It is indicated that most of the undergrowths species were found growing in the oligohaline to mesohaline zones, because of lower salinity levels. Naturally undergrowth species can not tolerate frequent tidal flooding and strong salinity except some species like *Acanthus ilicifolius*, *Porteresia coarctata*. It is interesting to note that the salinity is playing key role for the growing of the undergrowth species. Therefore, the values of salinity are really influencing the undergrowth vegetation as positively or negatively as well as high or poor diversity. It can also be concluded that the rich diversity of undergrowths of healthy individuals might be indicative of the healthy mangrove forest of the low saline zone and poor diversity of undergrowths, as well as their stunted growth might be indicative of the ill mangrove forest of the high saline zone.

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