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Salinity Gradient and Phytosociology in Bhitarakanika North Mangrove Forest

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Abstract: Mangroves are the highly productive wetland ecosystems, strategically located in the interface between land and sea, which serve as an ecotone. They are salt tolerant trees and shrubs that grow in tropical, sub-tropical, tidal coast and extending along estuaries and creeks throughout the world. This is forming a mangrove ecosystem which is highly productive or extending extreme tolerant to different salinity gradients. Specifically, these grow in mud flat areas that are frequently submerged with salt water due to tidal activities of gulfs, seas and oceans. It supports a special kind of food chain called detritus food chain, where mangrove plays a role of a producer. The mangroves are frail ecosystem and mostly depend upon fresh water influx and tidal inflow from the sea to grow. In Bhitarkanika north zone, the water salinity changes diurnally from fresh to saline, so, the community have adapted to the wide salinity gradients over the years resulting in varied and diversified vegetation. Salinity created due to fresh water and saline water inundation due to regular tides of the sea, causes brackish condition in the ecosystem. Since the ecosystem is very fragile and dynamic, it is vulnerable to salinity changes, thereby causing in diversity pattern of the species and establishment of phytosociology. It is observed that, salinity ranges from high to low according to distance from the creek. The saline zone is seen in maximum in bay region followed by estuarine region and then mangrove region. It is observed that *Exocarea agallocha* is the keystone species among 22 pre-dominant mangrove species being found in pH range 7.5 to 7.8. However, more mangrove species are seen in high salinity zone with pH ranges from 7.9 to 8.5 whereas, the non mangrove species found in non salinity region.

Keywords: Mangrove, salinity gradient, phytosociology

INTRODUCTION

Mangroves are the highly productive wetland ecosystems, strategically located in the interface between land and sea, which serve as an ecotone. They are salt tolerant trees and shrubs that grow in tropical, sub-tropical, tidal coast and extending along estuaries and creeks throughout the world. This is forming a mangrove ecosystem which is highly productive or extending extreme tolerant to different salinity gradients. Specifically, these grow in mud flat areas that are frequently submerged with salt water due to tidal activities of gulfs, seas and oceans. It supports a special kind of food chain called detritus food chain, where mangrove plays a role of a producer. The mangroves are frail ecosystem and mostly depend upon fresh water influx and tidal inflow from the sea to grow. In Bhitarkanika north zone, the water salinity changes diurnally from fresh to saline, so, the community have adapted to the wide salinity gradients over the years resulting in varied and diversified vegetation. Salinity created due to fresh water and saline water inundation due to regular tides of the sea, causes brackish condition in the ecosystem. Since the ecosystem is very fragile and dynamic, it is vulnerable to salinity changes, thereby causing in diversity pattern of the species and establishment of phytosociology.

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The state of Odisha has a geographical area of 155707 sq. km with an actual forest cover of 47107 sq. km. (30.3%). Area under mangrove forests is 195 sq. km which comes to 0.125 % of geographical area and 0.414% of actual forest cover (Acharya & Mohapatra, 2012. Total area of Bhitarakanika sanctuary is 672 Sq. km of which mangrove forests constitute 130 sq. km. This area receives water from three rivers, known to be rich in species diversity and trees are dense and tall like those of Sunderbans (Selvam, 2003). The Bhitarkanika sanctuary is bounded by river Dhamra in the north, the river Hansua to the west and Bay of Bengal on the eastern and southern sides. The sanctuary encompasses 35 km sea coast known as 'Gahirmatha Coast' from Dhamra mouth to Barunei, the mouth of river Hansua. The estuarine rivers- Brahmani, Baitarani, Kharasrota, Dhamra, Pathasala, Maipura, Hansua, and Hansina during their course flow into the Bay of Bengal are further crass crossed by numerous creeks, channels, and nallahs, thus providing the peculiar ecological niche for the growth, development of rich and varied mangrove life forms, both flora and fauna along with their associates. It is observed from the past study of Upadhaya & Misha (2014) that Acanthus ilicifolius and Avicennia spp. are found to be the dominant species in the soil with high salinity while Aegiceras sp. and *Excoecaria agallocha* in soils with low salinity. Reddy *et al.*(2015) investigated in Netravathi –gurupura and a Mulki-Pavanje estuarine complexes of Dakshila Kannada district and reported that the eumangroves such as *rhizophora apiculata* and *Avicennia mariana* are found in high salinity zone, while *Aegiceras cornicullatum* prefer medium salinity zone, *Rhizophora muronata*, *Avicenneae officinalis , Sonneratia alba, Kandelia candel and Exacoecaria agallocha* are found in high and medium salinity zone. Many taxonomical works on mangroves have been done by Banerjee *et al*. (1989), Banerjee (1984) Bhomia (2016); Banerjee & Rao (1990); Choudhury *et al*. (1991, 1995); Mishra & Panigrahi (1987), Nayak *et al.* (2009) and Chadha & Kar (1999). But, the present paper highlights ecological structures as per salinity gradient of mangroves ecosystem and its phytosociology of Bhitarakanika north mangrove forest particularly, Dangamal forest block in Odisha.

MATERIALS AND METHODS

The research methodology has been detailed under following heads.

- Geographical location of the experimental site
- Climate condition
- Soil analysis
- Water analysis
- Biodiversity study and
- Statistical analysis.

1. Geographical location of the experimental site

The experiment was carried out in the northern zone of Bhitarakanika mangrove forest particularly Dangamal forest block in Odisha and the soil, water and biodiversity study were undertaken in the laboratory of College of Forestry, Odisha University of Agriculture and Technology, Bhubaneswar. The study area satellite imagery is presented in Fig. 1.

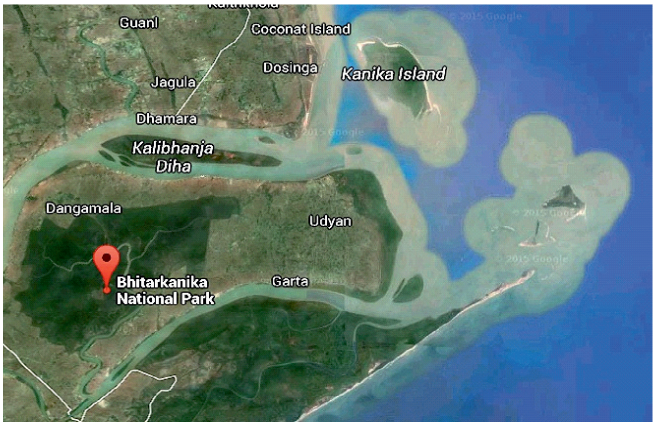

Figure 1: Satellite imagery of Bhitarkanika Mangrove Forest

The present investigation was done on 13 locations (L1 to L13) in Dangamala forest block of north zone in Bhitarakanika mangrove forest as per the treatments (Location as L) as follows-

L1- 10 m from the creek to its left in Dangamal forest

L2- 20 m from the creek (upland) to its left side in Dangamala forest

L3- 30 m from the creek to its left side in Dangamala forest

L4- 50 m from the creek to its left side in Dangamala forest (low land)

L5- 10 m from the estuary region to its left side in Dangamala forest

L6- 20 m from the estuary region to its left side in Dangamala forest

L7- 30 m from the estuary region to its left side in Dangamala forest

L8- 50mfrom the estuary regions to its right side in Bhitarakanika forest

L9- 10 m from the Bay region of Bhitarakanika forest (upland)

L10- 20 m from the Bay region of Bhitarakanika forest

L11- 30 m from the Bay region of Bhitarakanika forest

L12- 50 m from the Bay region of Bhitarakanika forest (upland)

L13- 1 Km from the creek (upland)

The depth of the pit is 0-15cm as Depth 1 and 16-30cm as Depth 2.

2. Climatic condition

The experimental site comes under the eighteenth agro-climatic region of the country i.e. Eastern Coastal Plain and is termed as sub-humid characterized by warm moist climate with mild winter. The average annual rainfall of Bhubaneswar is 1552m (based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September. The average temperature varies from 14°C in winter to 40°C in summer & relative humidity varies between 49 or 90% from June to December.

3. Soil Analysis

Soil sample were collected from the quadrants by making 1ft x1ft x 1ft pits from 2 layers (0-15cm, 16-30cm) of depth. The mechanical composition of soil samples was determined by Bouyoucous hydrometer method .Soil pH to be recorded with the help of glass electrode pH meter from 1:2.5:: soil : water suspension .Organic carbon content of soil to be ascertained by Walkley and Black method . Soil available nitrogen content was estimated by adopting alkaline Potassium Permanganate method. Soil available phosphorus and available potassium content was estimated from $NaHCO_3$ extractable P and Ammonium Acetate extractable K, respectively (Jackson, 1973).

4. Water analysis

The water samples were collected from three zones- estuarine, mangrove region and bay region. Water samples are to be collected during low tide period so as to minimize the tidal fluctuations. The averages of the measure are to be considered for data interpretation. Thermo- Orion water analysis kit is to be used for examining pH, electrical conductivity (EC). Samples are to be collected in pre-washed polypropylene bottles for analysis. The collected samples were stored in ice-chest during sampling and then transferred to the laboratory and stored at 4^0C until further analysis.

5. Biodiversity study (Quadrate Method)

A quadrate is a sample plot of a specific size used for the study of population or a community. For Tree species Sample plot (quadrate) size of 20 x 20 m were laced and systematically surveyed for all trees ≥30 cm diameter of breast height (dbh - above 137 cm from the ground). For Shrub species Sample plot (quadrate) size of 5 x 5 m and for herbs Sample plot (quadrate) size of 1 x 1 m were placed. Data will be obtained from a total of 20 sample plots from each category.

5.1. Data analysis: The data obtained were analysed on

5.2.1 Density

Density is an expression of numerical strength of a species where the total number of individuals of each species in all the quadrates is divided by the total number of quadrates studied.

5.2.2 Frequency

Frequency is the term to the degree of dispersion of individual species in an area and usually expressed in terms of the percentage occurrence. It was studied by sampling the study area at

several places at random and recorded the name of the species that occurred in each sampling units.

5.2.3 Abundance

It is the study of the number of individuals of different species in the community per unit area. By quadrates method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrates divided by the total number of quadrates in which the species occurred.

5.2.4 Dominance

Dominance of a species is determined by the value of the basal cover of the species per unit area. Plant diameter is calculated by the tree calliper.

5.2.5 Importance Value Index (IVI)

In order to identify the Keystone Species, the concept of 'Importance Value Index (IVI)' has been developed for expressing the dominance and ecological success of any species, with a single value. This index utilizes three characteristics, viz. relative frequency, relative density and relative dominance. The three characteristics were computed using frequency, density and basal area for all the species falling in all transects using following formulae-

IVI = Relative Dominance + Relative Density + Relative Frequency.

Relative Dominance = Total basal area of the species x 100 / Total basal area of all species

Relative Density =Number of individuals of the species x 100 / Number of individuals of all species

Relative frequency = Number of occurrences of the species x 100 /Number of occurrences of all the species.

The vegetation data will be quantitatively analysed for basal area, relative density, relative frequency and relative dominance. The importance value index (IVI) for the tree species is to be determined as the sum of the relative frequency, relative density and relative dominance (Lopez *et al.* 2006) as follows-

Basal area (m^2) = Area occupied at breast height (1.37 m) = [3.142 x $(dbh/2)^2$].

Relative density = (Density of the species/Total density of all species) x 100.

Relative frequency = (Frequency of the species /Total frequency of all species) x 100

Relative dominance = (Basal area of the species/ Total basal area for all species) x 100

Species diversity of each provenance determined by Shannon and Weiver method

$$H' = - \Sigma [(ni/N)\log2(ni/N)]$$

Where, *ni*is the total number of individuals of species *i* and

N is the total number of individuals of all species in that vegetation type.

Shannon's index was used to calculate the diversity of fish and shellfish seedlings for each station. The data from the entire species were calculated by the following formula as

$$H' = -\Sigma \text{ pi log pi}$$

Where, H'= Shannon index of diversity

*p*i = the proportion of important value of the i^{th} species

*p*i = *ni*/*N*

niis the important value index of ith species and

N is the important value index of all the species

As a measure of heterogeneity, Shannon's index takes into account the evenness of the abundances of species. The maximum diversity, which could possibly occur, would be found in a situation where all species were equally abundant.

Concentration of dominance was also measured as per Simpson method $C = - S (ni/N)$

Where *ni* and *N* are the same as those for the Shannon–Weaver information function.

6. Statistical analysis

Data collected during the investigation, on various aspects of growth and yield were statistically analysed utilizing "Analysis of Variance (ANOVA)" technique for Randomized Block Design (RBD).Standard error of mean (SEM) and Critical Difference (CD) at 5% level was worked out for each character.

RESULTS AND DISCUSSION

An endeavour has been made to elicit the influence of different ranges of pH in soil on species diversity and the composition such as on tree, shrubs and herbs in Bhitarkanika north mangrove forest. Evaluation is made to identify the keystone species by observing the IVI values specific to different zones in Bhitarkanika north mangrove forest.

The Physico-chemical properties of the soil in study region are analysed such as soil pH, Soil EC (ds/m), available OC(%), available N (Kg/ha), available P (kg/ha), available K (Kg/ha), Sand (%), Silt(%), Clay(%) and textural class in standard procedure. The data of the above character presented in Table 1 and Figure 2, 3, 4, 5, 6 and 7. It is observed that the average pH from location 1 to Location 13 ranges from 6.68(L2) to 7.76 (L11). The maximum pH of the soil is observed in location 11 and the minimum observed in location 2 the pH of all the places are significant in relation to its value. However, the maximum soil pH is observed in 15 to 30 cm deep in all 13 zones as compared to 0 to15 cm deep. The increase in pH is significantly higher in all 13 location) in respect to 15 to 30 cm deep than 0 to15 cm deep in the locations. It is observed that, at location 11 the pH is maximum (7.76) due to its closeness to the creek and vulnerable to regular inundation. The pH (6.68) is seen in location 2 due to upland situation, where it is least affected due to regular inundation. Similarly, the results on EC are observed in all 13 locations. The maximum EC is observed in location 4 (4.27dS/m) due to its closeness to the creek and it is in saline condition due to inundation and the lowest is observed in location 13 (1.6 dS/m) due to distance far from the creek. The EC values of all 13 mangrove location are significant. It is observed that Depth 2 is significantly higher than Depth 1 in all 13 mangrove locations. From the observation, the soil pH ranges from 6.68 to 7.76. Maximum soil pH is observed in creek region followed by mangrove region and non mangrove region. This result is in conformity with Lugo (1980) and Tomilson (1986).

Table 1: Physico-chemical properties of soil of the study site

Locations	*pH*	*EC (dS/m)*	*OC (%)*	*Avl. N (kg/ha)*	*Avl. P (kg/ha)*	*Avl. K (Kg/ha)*	*Sand %*	*Silt %*	*Clay %*	*Textural class*
L1	7.69	4.23	0.762	80.583	37.33	942.50	62.50	9.16	25.30	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.57	4.13	0.997	86.167	43.66	1022.33	22.00	10.00	25.64	
Depth 2	7.82	4.33	0.527	75.000	31.00	862.66	63.00	8.33	25.13	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	1.275	**1.254**	**1.63**	**N/A**	**0.928**	
L2	6.683	2.18	1.013	111.50	26.56	905.00	57.33	8.50	27.13	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.06**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	6.713	2.13	1.027	112.00	26.83	985.33	58.33	9.000	27.93	
Depth 2	6.65	2.23	1.000	111.00	28.30	884.66	56.33	8.00	26.33	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L3	7.38	4.08	0.838	122.50	25.66	926.50	65.00	8.50	22.00	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.31	4.02	0.647	123.33	12.30	924.66	66.00	10.00	21.13	
Depth 2	7.44	4.13	1.030	121.66	39.03	928.33	64.00	7.00	22.86	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L4	7.44	4.27	0.975	117.41	26.83	525.66	64.33	7.20	24.76	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.42	4.22	1.150	123.66	16.00	926.66	66.00	7.20	23.80	
Depth 2	7.46	4.33	0.800	111.66	37.66	124.66	62.66	7.20	25.73	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	

Locations	*pH*	*EC (dS/ m)*	*OC (%)*	*Avl. N (kg/ha)*	*Avl. P (kg/ ha)*	*Avl. K (Kg/ha)*	*Sand %*	*Silt %*	*Clay %*	*Textural class*
L5	7.49	4.22	1.577	119.91	80.00	501.00	65.16	9.86	20.56	Loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.30	4.12	1.44	124.00	124.33	68.00	62.33	11.20	11.80	
Depth 2	7.67	4.32	1.71	115.83	35.66	934.00	68.00	8.53	19.46	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L6	7.25	3.07	1.24	111.00	68.83	509.00	66.83	14.46	15.63	Loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.15	3.02	1.33	98.33	97.33	54.66	76.66	13.13	24.46	
Depth 2	7.36	3.13	1.15	123.66	40.33	963.33	57.00	15.80	23.80	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L7	7.45	2.94	1.28	123.33	27.16	845.16	56.00	15.46	24.13	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.26	2.95	0.67	123.33	19.66	873.33	57.33	15.13	24.46	
Depth 2	7.64	2.94	1.89	123.33	34.66	817.00	54.66	15.80	23.80	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L8	6.76	2.79	0.94	129.41	30.83	906.33	57.00	17.96	22.96	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	6.56	2.92	1.67	123.33	28.00	952.66	57.33	16.13	22.00	
Depth 2	6.96	2.66	0.22	135.50	33.66	860.00	56.66	19.80	23.93	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L9	7.34	2.86	1.17	123.83	18.83	907.50	56.33	14.80	23.61	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.17	2.96	1.22	111.83	25.66	873.33	57.33	13.80	24.76	
Depth 2	7.26	2.77	1.12	135.83	12.00	941.66	55.66	15.80	22.46	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L10	7.34	3.87	2.55	116.91	55.50	466.33	71.50	6.53	16.89	Sandy loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.06**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.23	3.82	2.57	57.66	25.33	822.00	67.00	8.26	18.66	
Depth 2	7.45	3.93	2.53	136.16	85.66	50.66	76.00	4.80	15.12	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L11	7.76	3.69	1.65	161.83	23.50	869.50	62.50	9.20	24.28	Loamy sand
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.64	3.25	1.67	161.83	24.33	906.66	64.00	10.20	23.83	
Depth 2	7.87	4.13	1.63	161.83	22.66	832.33	61.00	8.20	24.73	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L12	7.74	3.46	1.69	126.33	47.66	419.33	81.83	8.03	18.33	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	7.66	3.22	1.69	129.66	52.66	32.33	92.66	6.86	13.33	
Depth 2	7.81	3.70	1.69	123.00	42.66	806.33	71.00	9.26	23.33	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	
L13	6.87	1.60	1.33	121.16	54.16	672.83	53.33	13.98	31.867	Clay loam
LSD(0.05)	**0.040**	**0.027**	**0.248**	**2.096**	**3.251**	**3.198**	**4.16**	**2.229**	**2.503**	
Depth 1	6.27	1.22	1.33	119.33	49.00	824.66	52.66	12.40	27.40	
Depth 2	7.47	1.98	1.33	123.00	59.33	521.00	54.00	15.56	36.33	
LSD(0.05)	**0.016**	**0.011**	**N/A**	**0.822**	**1.275**	**1.254**	**1.63**	**N/A**	**0.982**	

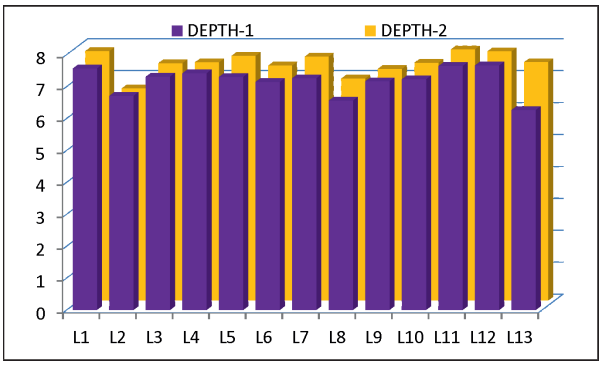

Figure 2: pH of the soil in different locality of the study site

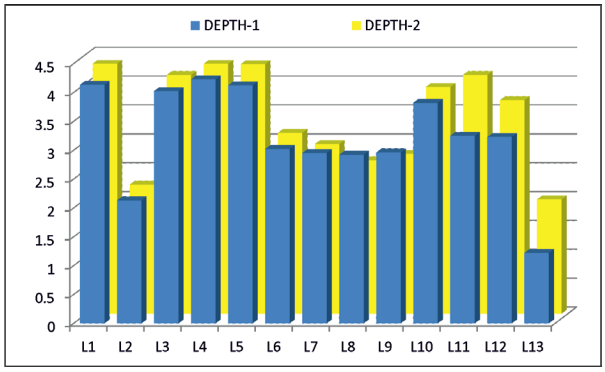

Figure 3: Soil EC (dSm-1) in different locality of the study site

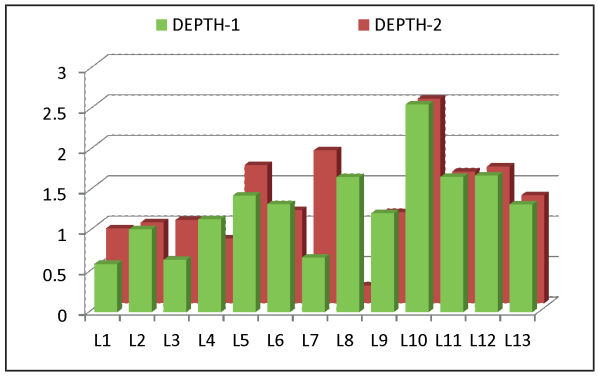

Figure 4: Available Organic Carbon (%) of the soil in different locality of the study site

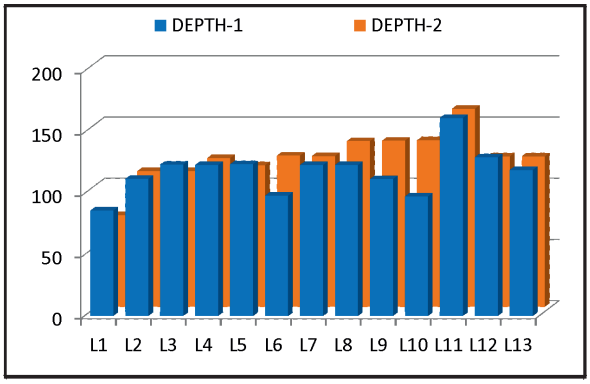

Figure 5: Available Nitrogen (kg ha^{-1}) of the soil in different locality of the study site

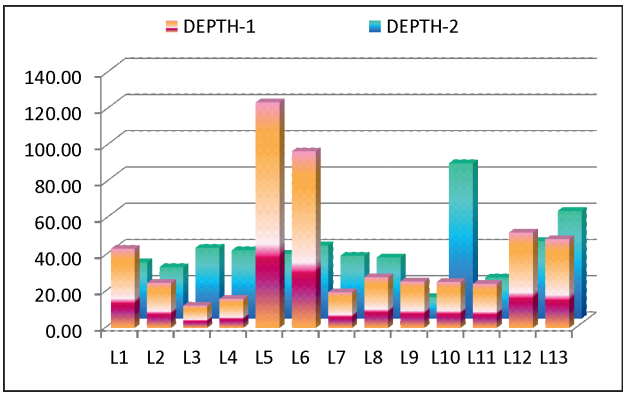

Figure 6: Available Phosphorous (kg ha^{-1}) of the soil in different locality of the study site

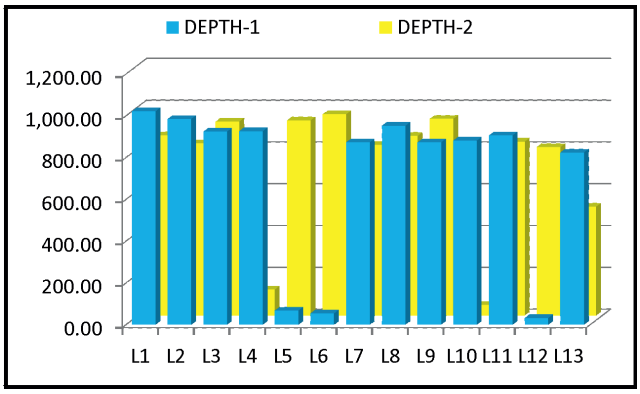

Figure 7: Available Potassium (kg/ha) of the soil in different locality of the study site

The organic carbon percent (OC %) of all13 mangrove locations were observed during the study. The maximum OC (%) was observed in location 10(2.55%) and the minimum is observed in mangrove location 1 (0.762%). The OC content is higher in Depth 1 than Depth 2 region which is significantly higher in all mangrove zones except location 5. Since the LSD value at 0.05 level is very insignificant, it is mentioned N/A in all 13 mangrove locations at its depth level. The available N of the soil is the key factor for growth and abundance of species in the mangrove regions. The maximum available N in the soil is observed in location 11 (161.83 Kg/ha), which is significantly higher from rest 12 mangrove locations and lowest is observed in location 80.583 (Kg/ha). Further it is observed that the maximum available N at 0-15 cm depth level is observed in the location 11 (161.83 Kg/ha), which is significantly higher than the rest 12 mangroves locations. Similarly at the depth 2 level, the maximum available N is observed at location 11, which is significantly higher than rest 12

mangrove locations and the lowest is observed in location 1 of the mangrove regions. However, the available N value was lower due to the effect of the pH in the saline zones in all throughout locations under the study. The available phosphorous contain is observed higher in location 5 (80 kg/ha) and the lowest is observed at location 9 (18.83 kg/ha), which is found significant. In different depth zones the available P content of the soil is observed that, depth 2 level is significantly higher in location 5 and the maximum available P is observed at location 10 region. Accordingly, the species diversity is observed from the mangrove locations. The maximum available Potash in the soil is seen in location 1 (942.5 kg/ha) and the minimum is seen in location 12 (419.33 kg/ha), which is significant in its values. The Potash content of the soil is higher in all 13 mangrove locations, which entails the species diversity and species richness in the mangrove regions. So, the results on soil OC, available N, available P and available K recorded are in conformity with Upadhaya (2008, 2010, 2014) and Upadhaya *et al.* 2007 and 2008.

The pH content of water of bay region, mangrove region and estuary region were analysed and presented in table 2 and figure 8. It is observed that the pH of bay region is significantly higher (8.02) than mangrove region (7.17) and estuary region (7.26). High salinity is observed in water contain at the bay region followed by estuarine region and least is observed in mangrove region. Accordingly the species richness is seen in mangrove zones. The species diversity and richness is more in mangrove region than in bay region due to pH content of water bodies.

Table 2: Water analysis on pH of different regions of Bhitarkanika north mangrove forest

Treatment	*pH value*	
	Mean	*S.E.*
Bay region	8.020	0.006
Mangrove region	7.173	0.023
Estuary region	7.267	0.088
LSD (0.05)	**0.198**	
SE(m)	0.049	
SE(d)	0.070	

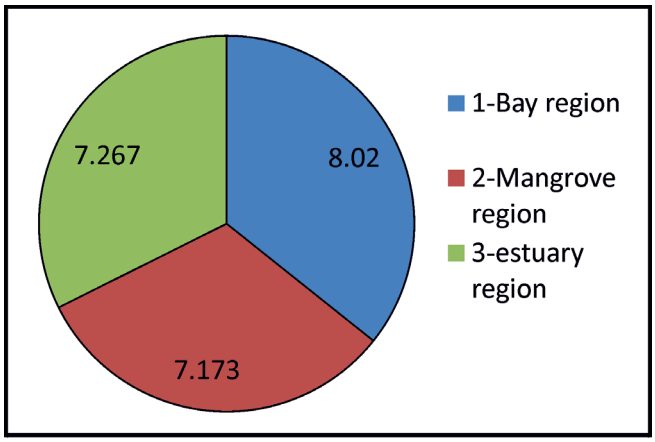

Figure 8: Water analysis on pH of different regions of Mangrove forest

The pH content of water in bay region, mangrove region and estuary region are analysed. It is observed that pH of bay region is significantly higher (8.02) than mangrove region (7.17) and estuary region (7.26). High salinity is observed in water content at the bay region followed by estuarine region and least is observed in mangrove region. Accordingly the species richness is seen in mangrove zone. The species diversity and richness are more in mangrove region than in bay region due to pH content of the water bodies. This result is in conformity with Lopez *et al.* (2007) and Achutankutty (1987).

The phytosociology (Table 3.) of different species observed that *Exocarea agallocha* possess total number of individuals (TNI) that is 131 followed by *Hereteria minor* (82) and *Cynometra iripa* (28). Accordingly, among 22 predominant mangrove species, keystone species is observed *Exocarea agallocha* with IVI value (85.158) followed by *Hereteria minor*(65.174) and *Cynometra iripa* (23.48). The distribution of plants of the mangrove regions is described as tree species is contained 89.64% followed by herbs 6.14%, shrubs 2.58% and climbers 1.61%. However, the phytosociology of species (Table 4.) in relation to salinity gradient of the mangrove region is described here as per the result obtained in the study. It is observed that the dominant species such as *Avicennia officinal is Kandelia candal, Eugenia bracteates, Lepisanthes rubiginosa, Phoenix paludosa, Solanum trilobatum , Sonneratia apetala, Aglaea cucullata , Hibiscus tiliaceus, Suaeda nudiflora* and *Trianthema triquetra are* seen in high salinity zones with pH ranges from (7.9-8.5) which are

Table 4: Phytosociology in relation to salinity gradient

Non Mangroves in no salinity zone (pH 5.5-6.8 & EC 2.2-3.2)	*Mangroves associates in Low salinity zone (pH 7- 7.4 & EC 4.0-4.2)*	*True mangroves in Medium salinity zone (pH 7.5- 7.8 & EC 4.2-4.6)*	*True mangroves High salinity zone (pH 7.9- 8.5 & EC 4.6 above)*
Lannea conomondelia Cocus nuciferus Casurina equisetifolia Azaridacta indica Dioscorea malbarica Pterospermum caneslens	Pongammia pinnata Cenabena odolum Crateva magna Aegiceras corniculatus Rungia repens Acanthus illicifolius	Heritiera minor Cynometra iripa Excoecaria agallocha Brugeria sexangulata Justicia prostrata Bryophyllum pinnatum	Avicennia officinalis Sonneratia apetala Kandelia candal Aglaea cucullata Eugenia bracteates Hibiscus tiliaceus Lepisanthes rubiginosa Suaeda nudiflora Phoenix paludosa Trianthema triquetra Solanum trilobatum Pavonina procubens

Table 3: Phytosociology of different species and their IVI values

Species	*TNI*	*Frequency*	*Density*	*Dominance*	*Relative Frequency*	*Relative Density*	*Relative Dominance*	*IVI value*
Exoecaria agallocha	131	69.23	10.08	0.29	19.565	47.292	18.3	85.158
Heritera minor	82	61.54	6.31	0.288	17.391	29.603	18.18	65.174
Cynometra iripa	28	38.46	2.15	0.041	10.870	10.108	2.61	23.588
Pongammia pinnata	3	15.38	0.23	0.021	4.348	1.083	1.37	6.801
Hibiscus tiliaceous	1	7.69	0.08	0.001	2.174	0.361	0.09	2.625
Strychnus nuxvomica	3	7.69	0.23	0.01	2.174	1.083	0.67	3.927
Dioscorea malbarica	1	7.69	0.08	0.009	2.174	0.361	0.59	3.125
Lepisanthes rubiginosa	2	7.69	0.15	0.011	2.174	0.722	0.7	3.596
Crateva magna	2	7.69	0.15	0.019	2.174	0.722	1.24	4.136
Eugenia braacteate	1	7.69	0.08	0.008	2.174	0.361	0.54	3.075
Lannea coromandelica	1	7.69	0.08	0.008	2.174	0.361	0.54	3.075
Pterospermum caneslens	1	7.69	0.08	0.005	2.174	0.361	0.34	2.875
Sonneratia apetala	5	15.38	0.38	0.031	4.348	1.805	2.01	8.163
Avicennia officinalis	4	7.69	0.31	0.53	2.174	1.444	33.89	37.508
Agalica cucullata	3	15.38	0.23	0.012	4.348	1.083	0.79	6.221
Aegiceras corniculatus	1	7.69	0.08	0.0005	2.174	0.361	0.03	2.565
Brugeria sexangulati	1	7.69	0.08	0.001	2.174	0.361	0.11	2.645
Cerbera odollam	1	7.69	0.08	0.008	2.174	0.361	0.54	3.075
Cocus nucifera	1	7.69	0.08	0.01	2.174	0.361	0.674	3.209
Casurina equisetifolia	`1	7.69	0.08	0.207	2.174	0.361	13.04	15.575
TOTAL	277	353.85	21.31	1.569	100.00	100.00	99.90	299.90

true mangrove species followed by *Heritiera minor, Cynometra iripa, Excoecaria agallocha, Brugeria sexangulata , Justicia prostrate* and *Bryophyllum pinnatum* are seen in medium salinity zones with pH ranges from (7.5-7.8) and mangrove associates in low salinity zones ranges from (7-7.4) include *Pongammia pinnata, Cenabena odolum, Crateva magna, Aegiceras corniculatus, Rungia repens and Acanthus illicifolius.*

But, 6 species like *Lannea conomondelia, Cocus nuciferus, Casuarina equisetifolia, Azaridacta indica, Dioscorea malbarica, Pterospermum caneslens* are found in non mangrove areas with no salinity zones. It is further observed that mangrove species are gradually merged with mesophytic species in relation to high salinity (7.9-8.5) to no salinity zones.

CONCLUSION

It is concluded that Bhittarkanika north mangrove forest possesses maximum saline zone in the bay region followed by estuarine region and mangrove region. The tree species are maximum followed by herb species, shrub species and climber species. The salinity with high pH is observed in bay zone followed by nearer to the estuary & creeks and it gradually merged and decrease to no salinity zones. The phytosociology and keystone analysis are observed that, *Exocareaea agallocha* is the keystone species with IVI value 85.158 followed by *Heriteria minor* (65.174). The distribution of plants in the mangrove regions are studied where, the maximum occurred are tree species (89.64%) followed by herbs (6.14%), shrubs (2.58%) and climbers (1.61%). Further, it is observed that non mangrove species are seen in no salinity zones and mangrove species are gradually merged with mesophytic species in no salinity zones.

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