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Total Biomass and Carbon Estimates in Mangrove Species of Bhitarkanika Wildlife Sanctuary (BWLS), Odisha

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Abstract

We estimated total biomass and total carbon in 18 selected woody mangrove species based on the IVI values along with physico-chemical parameters of sea water and soil. AGB and BGB values were calculated as per the standard protocol in BWLS in five sampling stations namely Dangmal, Bhitarkanika, Habalikhati, Ekakula and Gupti. The highest values of IVI were noted for *E. agallocha* followed by *A. officinalis*, *A. marina*, *H. fomes* and *C. decandra*. Total biomass of species range was found to be varying between 0.69 tha^{-1} in *X. molluccensis* and 2122.17 tha^{-1} in *A. officinalis*. Total site-wise biomass ranged between 0.22 tha^{-1} in *B.* cylindrica at Gupti and 1419.26 tha^{-1} in *A. officinalis* at Bhitarkanika. Total carbon was considered to be 50% of total dry biomass which varied from 188.45±21.87 tha^{-1} at Ekakula to 941.31±201.17 tha^{-1} at Bhitarkanika, respectively. The higher biomass and carbon in *A. officinalis* proves it to be highly adaptive to the environmental changes in the present geographical locale. The maximum biomass and carbon of all the mangrove species in station Bhitarkanika is due to the fact that this station receives the fresh water discharge of Baitarani river thereby the adequate lower salinity is maintained. The present study reveals that mangroves of Bhitarkanika Wildlife Sanctuary can store substantial amount of atmospheric carbon and therefore needs to be conserved and sustainably managed.

1. Introduction

Mangroves are salt tolerating autotrophic trees/forests community distributed in the intertidal coast between the sea and land masses near the river bank and deltas of the world. They are distributed between latitude 32°20' in northern hemisphere in Bermuda to 38°59' in southern hemisphere in New Zealand (Spalding *et al*., 1997). The total area covered by mangroves forest globally between 137760 to 152000 km^2 which depend upon the number of countries (118 to 124) they exist (FAO, 2007, Alongi, 2008, Spalding *et al*., 2010, Giri *et al*., 2011). Mangrove forest coverage is extremely low accounting less than 0.4 percentage of global forest. The total number of true mangroves and associates species varies between 69 to 73 globally (Tomlinson, 1986; Ellison *et al*., 2005; Hogarth, 2007; Polidoro *et al*., 2010; Osland *et al*., 2014). Mangroves are biologically very important ecosystem of the world; it provides ecological services like natural barrier, breeding and nursing grounds for marine and pelagic species, mitigate climate change through atmospheric carbon dioxide sink, provides natural resources to human society such as food material, medicine, fuel and building materials for local communities (Robertson and Phjillips, 1995; Yoshiro *et al*., 1997).

Mangrove total biomass (AGB+BGB) and soil could sequester approximately 22.8 million metric tons of carbon each year (Giri *et al*., 2011). It traps the atmospheric carbon dioxide through the process of photosynthesis and store it as biomass and finally in soil, as organic carbon. Forests act as both sink and source of CO_2 when it is conserved and destroyed respectively. Mangroves could store four times more carbon per unit area in compared to terrestrial forests (Khan *et al*., 2007; Donato *et al*., 2011). Although mangroves account for only 0.7% of tropical forest area, but it can generate emissions up to 10% from total global deforestation (Van der Werf *et al*., 2009; Giri *et al*., 2011). Hence, mangroves are considered as an important component in climate change mitigation and reducing emissions from deforestation and degradation (REDD+) schemes (Siikamäki *et al*., 2012). In terms of biodiversity, mangrove forests are highly productive and biologically complex ecosystems.

India has a total mangrove cover of 4921 km^2 (FSI, 2017), or 0.15% of the country's land area, 3% of the global mangrove area, and 8% of Asia's mangroves, thus accounting for 2nd largest mangrove forest in south Asia. The recent report of the 2013 to 2017 indicates that most of the states of India are experiencing an increase in area under mangroves (FSI, 2017). Mangroves in India are unique in terms of their extent, variability and biodiversity. A total of 4011 species, including 920 plant (23%) and 3091 animal (77%) species have been recorded from Indian mangrove ecosystems, which is highest in the world (Bhatt and Kathiresan, 2011). However, there has been an overall continuous decline in mangrove forest wetland caused by conversion to agriculture, aquaculture, tourism and urban development (Upadhyay *et al.*, 2002). The Bhitarkanika Wildlife Sanctuary is located in the deltaic region of Brahmani and Baitarani rivers in the Kendrapara district of Orissa. The Sanctuary is bounded by rivers Dhamara in the north, Maipura in the south, Brahmani in the west and the Bay of Bengal in the east. According to FSI (2017) the forest cover of Kendrapara district is 197 km2 and covers a 35 km coast line from the mouth of river Maipura till Barunei that forms the eastern boundary of the Sanctuary. It accounts for 102 species of mangroves from which 29 are true mangroves and 72 are associates (Panda *et al.*, 2017). But the core area is dominated by species like *Heriteria fomes, Excoecaria agal-*

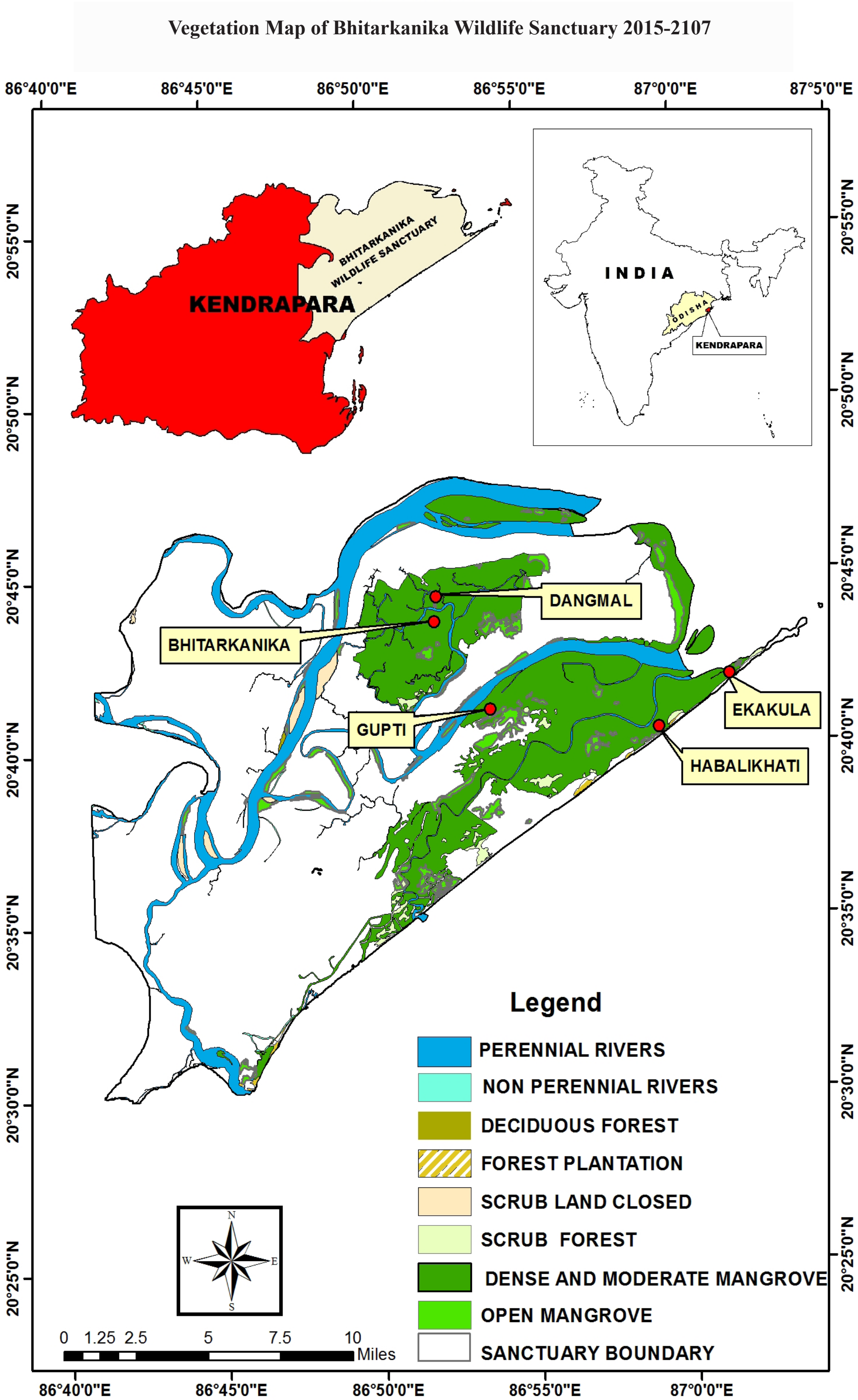

Fig. 1: Map of sampling stations.

locha, Avicennia officinalis, Sonneratia apetala and its mixed form, of which more than 50% area was covered by *Heriteria fomes* (Kumar *et al*., 2012).

Considering the importance of mangroves forest and its role in mitigating climate change, the present study was undertaken to assess biomass and carbon in natural mangrove forests of Bhitarkanika Wildlife Sanctuary, Odisha.

2. Materials and Methods

2.1 Study area

The Bhitarkanika Wildlife Sanctuary (BWLS) is located 20°04' to 20°08' N latitude and 86°45' to 87°05' E longitude on the east coast of the state of Odisha with an area of 672 km2. The area comes under the tropical monsoon climate with three distinct pronounced seasons: winter (November to February), summer (March to June) and rainy (July to October). The mean annual rainfall is 1670 mm. The general elevation above mean sea level is between 1.5 to 2 meters. Higher ground extends to 3-4 meters (Fig. 1). The dominant species of the study area are shown in Figure 2.

2.2. Analysis of physico-chemical parameters of ambient media

In-situ analysis of soil (temperature, pH and EC) and water (temperature, pH and salinity) were measured by dipping digital thermometer (Systronics), pH meter (Sigma) and EC

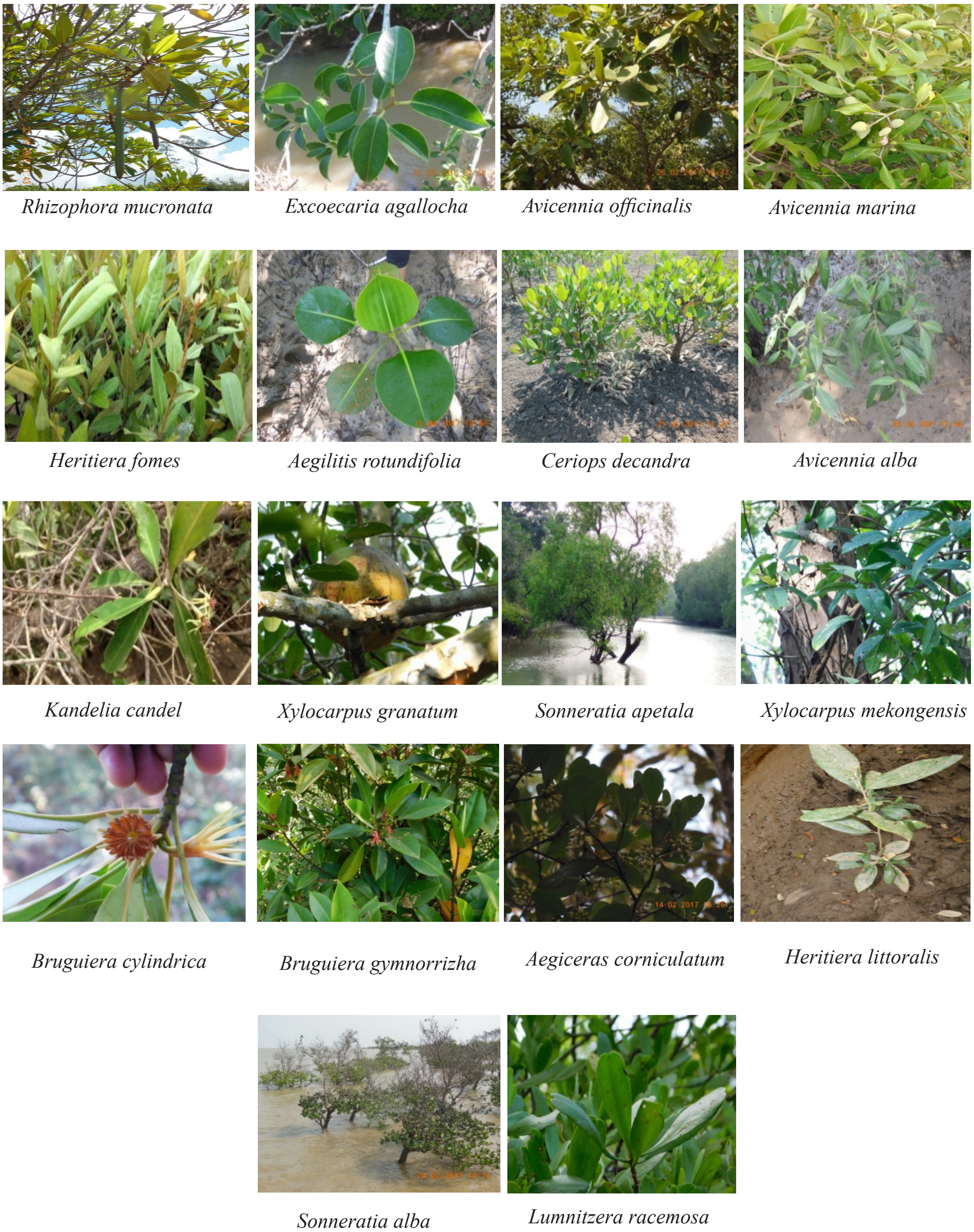

Fig. 2: Dominant mangrove species of study area.

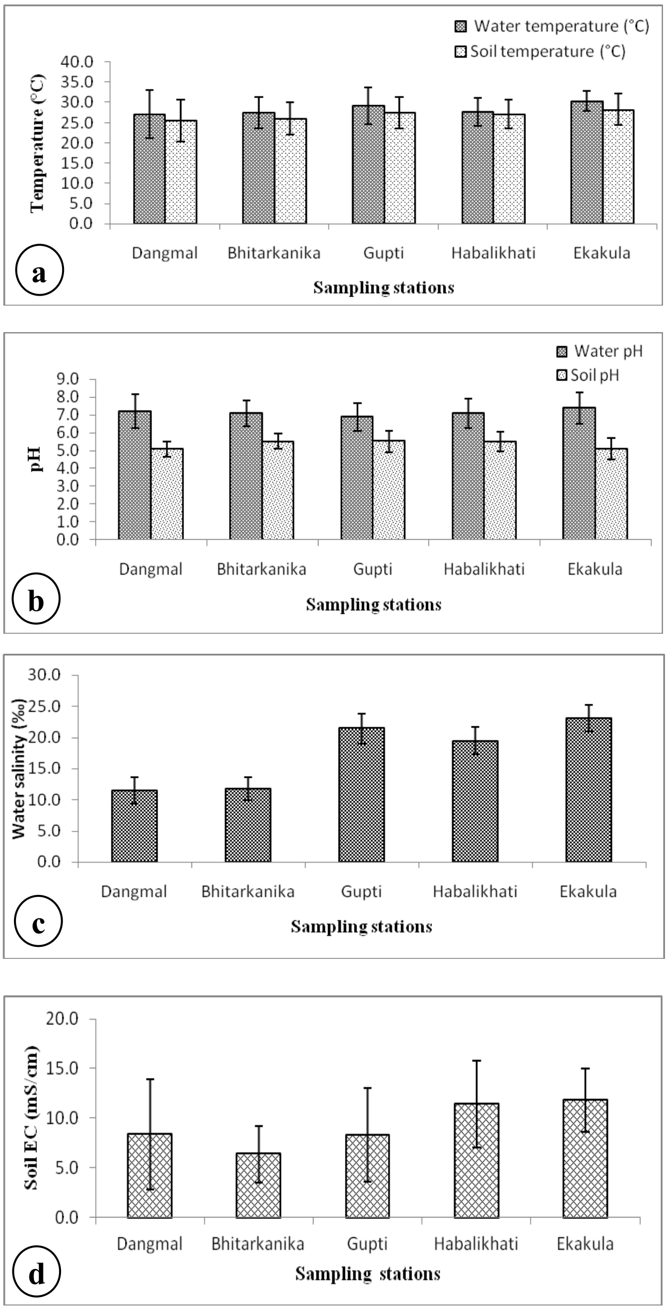

Fig. 3(a-d): Physico-chemical parameters of seawater and soil.

meter (Eco Testr) respectively. Water salinity was measured with the handy portable refractometer (Atago, Japan). Sampling was done from August 2016 to July 2017 seasonally (pre-monsoon, monsoon and post monsoon).

2.3. Analysis of Total Biomass and Total Carbon

Total biomass and carbon constitutes the summation of AGB, BGB, AGC and BGC respectively. The sampling stations were selected randomly in the Bhitarkanika Wildlife Sanctuary. About 25 quadrates of 10m × 10m size were placed randomly in the selected five stations to study the importance value index (IVI), above ground biomass, above ground carbon, total biomass and total carbon of mangrove species. Above ground biomass in mangrove species refers to the sum total of stem, branch and leaf biomass that are exposed above the soil. The total biomass (AGB and BGB) are estimated through the standard formulae given by Komiyama *et al*. (2005). For the same species stored carbon was estimated through the thumb rule i.e. 50% of dry weight.

$$\text{Above Ground Biomass } (W_{top}) = 0.251\rho D^{2.46}$$

$$\text{Below Ground Biomass } (W_{blow}) = 0.199\rho^{0.899} D^{2.22}$$

Where:

W_{top} = Above ground biomass, W_{below} = Below ground biomass, ρ = Wood density of the species, D = Diameter at breast height in cm.

3. Results and Discussion

Data presented here is the average of 3 seasons (pre-monsoon, monsoon and post monsoon).

3.1. Physico-chemical parameters of seawater

The temperature, salinity and pH are the major essential parameters which are generally influenced by the intensity of solar radiation, evaporation, insulation, freshwater influx and cooling. The average water temperature varied spatially in all the sampling stations depending on the location and sampling time. The maximum water temperature recorded in study area was 30.4±2.5°C in station Ekakula and minimum of 27.2±5.9°C in station Dangmal with an average temperature of (28.4±4.0°C). The maximum water salinity was recorded 23.1±2.2‰ in station Ekakula and minimum of 11.5±2.1‰ in station Dangmal with an average water salinity 17.4±2.1‰. The water pH fluctuation is not very high between the sampling stations due to freshwater influx in the system by the river discharges. Maximum water pH was recorded from station Ekakula (7.4±0.9) and minimum from station Gupti (6.9±0.8) with an average pH of 7.1±0.8 (Fig. 3).

3.2. Physico-chemical variables of soil

The average soil temperature varied spatially among the sampling stations depending on the location and sampling time. The maximum soil temperature was recorded in station Ekakula (28.2±3.9°C) and minimum at Dangmal (25.5±5.1°C) with an average soil temperature of 26.9±4.1°C. The soil pH of all the sampling stations showed acidic nature but it did not fluctuate very high between the stations. The maximum soil pH was recorded from station Gupti (5.5±0.6) and the minimum at station Dangmal (5.1±0.4) with a average soil pH of 5.3±0.5. The maximum soil EC was recorded at station Ekakula (11.8±4.4mS/cm) and minimum of 6.4±2.9 mS/cm in the station Bhitarkanika with an average soil electrical conductivity (EC) of 9.3±4.2 mS/cm (Fig. 3).

3.3. Importance Value Index (IVI)

Our study revealed 32 species of mangroves and associate species (Table 1). For determination AGB and BGB species with DBH > 10cm were selected. The mean IVI values ranged from 1.35 in *Rhizophora apiculata* to 101.98 in *Excoecaria agallocha*. Considering the woody mangrove species only, the variation in mean IVI values of 18 mangrove species were estimated and the values varied as per the order *E. agallocha* (101.98) > *A. officinalis* (40.75) > *A. marina* (38.97) > *H. fomes* (36.40) > *C. decandra* (26.96) > *R. mucronata* (20.33) > *A. alba* (10.81) > *A. rotundifolia* (8.51) > *S. apetala* (6.53) > *A. corniculatum* (5.79) > *L. racemosa* (5.78) > *B. gymnorizha* (4.63) > *S. alba* (4.05) > *X. granatum* (4.02) > *H. littoralis* (3.96) > *B. cylindrical* (3.24)

Table 1: Important Value Index of mangroves at the selected stations.

S.N.	Name of Species	Dangmal	Bhitarkanika	Gupti	Habalikhati	Ekakula	Mean IVI
1	*Aegiceras corniculatum*	5.34	1.11	1.05	1.08	20.39	5.79
2	*Aegilitis rotundifolia*	-	-	-	-	8.51	8.51
3	*Amooron cucullata*	6.36	6.62	-	-	-	6.49
4	*Avicennia alba*	-	-	6.58	5.15	20.71	10.81
5	*Avicennia marina*	-	-	17.76	25.88	73.26	38.97
6	*Avicennia officinalis*	46.06	80.79	21.98	38.00	16.93	40.75
7	*Browneria tersa*	-	4.25	-	-	-	4.25
8	*Bruguiera cylindrica*	1.26	7.01	1.46	-	-	3.24
9	*Bruguiera gymnorrizha*	-	-	4.63	-	-	4.63
10	*Bruguiera sexangula*	-	-	1.47	-	-	1.47
11	*Cerbera odollam*	5.0	3.85	-	-	-	4.43
12	*Ceriops decandra*	-	1.29	26.75	52.99	26.82	26.96
13	*Cynometra iripa*	12.63	8.68	0.96	-	-	7.42
14	*Dalbergia spinosa*	2.94	-	-	-	-	2.94
15	*Excoecaria agallacha*	82.34	101.09	107.26	124.55	94.65	101.98
16	*Heritiera fomes*	108.07	56.36	3.86	11.36	2.34	36.40
17	*Heritiera littoralis*	6.54	1.37	-	-	-	3.96
18	*Hibiscus tiliaceus*	-	-	0.89	2.05	1.17	1.37
19	*Kandelia candel*	1.47	3.00	2.05	-	-	2.17
20	*Lumnitzera racemosa*	-	-	3.70	7.86	-	5.78
21	*Rhizophora apiculata*	-	1.35	-	-	-	1.35
22	*Rhizophora mucronata*	-	3.51	55.10	10.73	11.97	20.33
23	*Salvadora persica*	-	-	6.88	6.81	2.09	5.26
24	*Sapium indicum*	2.31	-	0.87	-	-	1.59
25	*Sonneratia alba*	-	-	1.36	1.40	9.38	4.05
26	*Sonneratia apetala*	7.70	8.82	7.54	1.23	7.36	6.53
27	*Tamarix diocea*	2.81	-	-	-	-	2.81
28	*Tamarix trupii*	2.33	-	13.30	5.78	-	7.14
29	*Thespesia populnea*	3.16	1.09	6.18	2.53	-	3.24
30	*Xylocarpus granatum*	3.34	5.29	6.16	2.61	2.70	4.02
31	*Xylocarpus mekongensis*	-	3.13	-	-	1.72	2.43
32	*Xylocarpus molluccensis*	-	1.13	2.22	-	-	1.68

> *X. mekongensis* (2.43) > *B. sexangula* (1.47).

3.4. Total Biomass (TB) and Total Carbon (TC)

Total biomass was calculated on the basis of addition of AGB and BGB compiling all the species in one site. The AGB values ranged from 263.90±30.63 tha^{-1} at Ekakula to 1050.12±224.43 tha^{-1} at Bhitarkanika. The BGB values ranged from 113.0±13.11 tha^{-1} at Ekakula to 832.49±177.91 tha^{-1} at Bhitarkanika. The total biomass values ranged from 376.89±43.74 tha^{-1} at Ekakula to 1882.62.12±402.34 tha^{-1} at Bhitarkanika. Similar trend was also observed for AGC, BGC and TC with values ranging from 131.95±15.31 to 525.06±112.21, 56.50±6.56 to 416.25±88.96 and 188.45±21.87 to 941.31±201.17 tha^{-1} at Ekakula and Bhitarkanika respectively (Table 2 and Fig. 4).

The total biomass and total carbon of all the selected species of all the selected stations were estimated. The trend of total biomass of *A. corniculatum* varied between 0.46 tha^{-1} in Bhitarkanika and 9.32 tha^{-1} in Ekakula with an average of 2.53 tha^{-1}. The values of *A. alba* varied between 6.79 tha^{-1} at Habalikhati to maximum of 24.31 tha^{-1} in Ekakula with an average of 8.68 tha^{-1}; the minimum values of 42.39 tha^{-1} in Gupti to maximum of 143.59 tha^{-1} in Ekakula with an average of 53.62 tha^{-1} for species *A. marina*; the minimum values of total biomass 51.64 tha^{-1} in Ekakula to maximum of 1419.26 tha^{-1} in Bhitarkanika with an average of 424.43 tha^{-1} for *A. officinalis;* the minimum of 0.22 tha^{-1} in Gupti to maximum of 6.89 tha^{-1} in Bhitarkanika with an average of 1.61 tha^{-1} for *B. cylindrica*; for *B. gymnorrhiza* the minimum and maximum value is 1.72 tha^{-1} as it is found only in Gupti; the minimum of 0.71 tha^{-1} in Bhitrakanika to maximum of 66.91 tha^{-1} in Habalikhati with an average of 20.66 tha^{-1} for *C.decandra*; the minimum of 88.77 tha^{-1} in Dangmal to maximum of 180.19 tha^{-1} in Bhitarkanika with an average of 129.34 tha^{-1} for *E.agallocha*; the minimum

Table 2: Species wise total biomass and total carbon in tha[-1].

S.N.	Name of species		Dangmal	Bhitarkanika	Gupti	Habalikhati	Ekakula	Total	Average
1	*Aegiceras corniculatum*	Biomass	2.35	0.46	0.50	-	9.32	12.63	2.53
		Carbon	1.18	0.23	0.25	-	4.66	6.32	1.27
2	*Avicennia alba*	Biomass	-	-	12.29	6.79	24.31	43.39	8.68
		Carbon	-	-	6.15	3.40	12.16	21.70	4.34
3	*Avicennia marina*	Biomass	-	-	42.39	82.12	143.59	268.11	53.62
		Carbon	-	-	21.20	41.06	71.80	134.06	26.81
4	*Avicennia officinalis*	Biomass	307.22	1419.26	142.70	201.36	51.64	2122.17	424.43
		Carbon	153.61	709.63	71.35	100.68	25.82	1061.09	212.22
5	*Bruguiera cylindrica*	Biomass	0.95	6.89	0.22	-	-	8.05	1.61
		Carbon	0.48	3.45	0.11	-	-	4.03	0.81
6	*Bruguiera gymnorrhiza*	Biomass	-	-	1.72	-	-	1.72	0.34
		Carbon	-	-	0.86	-	-	0.86	0.17
7	*Ceriops decandra*	Biomass	-	0.71	18.24	66.91	17.43	103.30	20.66
		Carbon	-	0.36	9.12	33.46	8.72	51.65	10.33
8	*Excoecaria agallacha*	Biomass	88.77	180.19	113.85	173.24	90.65	646.70	129.34
		Carbon	44.39	90.10	56.93	86.62	45.33	323.35	64.67
9	*Heritiera fomes*	Biomass	351.72	158.57	5.77	25.44	1.63	543.12	108.62
		Carbon	175.86	79.29	2.89	12.72	0.82	271.56	54.31
10	*Heritiera littoralis*	Biomass	5.37	-	-	-	-	5.37	1.07
		Carbon	2.69	-	-	-	-	2.69	0.54
11	*Kandelia candel*	Biomass	2.86	4.64	0.55	-	-	8.05	1.61
		Carbon	1.43	2.32	0.28	-	-	4.03	0.81
12	*Lumnitzera racemosa*	Biomass	-	-	3.88	9.88	-	13.75	2.75
		Carbon	-	-	1.94	4.94	-	6.88	1.38
13	*Rhizophora mucronata*	Biomass	-	24.02	113.38	24.39	13.15	174.94	34.99
		Carbon	-	12.01	56.69	12.20	6.58	87.47	17.50
14	*Sonneratia alba*	Biomass	-	-	1.06	1.93	12.59	15.58	3.12
		Carbon	-	-	0.53	0.97	6.30	7.79	1.56
15	*Sonneratia apetala*	Biomass	29.72	54.11	14.14	0.77	7.13	105.87	21.17
		Carbon	14.86	27.06	7.07	0.39	3.57	52.94	10.59
16	*Xylocarpus granatum*	Biomass	3.94	17.58	5.03	2.83	3.07	32.46	6.49
		Carbon	1.97	8.79	2.52	1.42	1.54	16.23	3.25
17	*Xylocarpus mekongensis*	Biomass	-	15.50	1.37	-	2.39	19.26	3.85
		Carbon	-	7.75	0.69	-	1.20	9.63	1.93
18	*Xylocarpus molluccensis*	Biomass	-	0.69	-	-	-	0.69	0.14
		Carbon	-	0.35	-	-	-	0.35	0.07
Total biomass (t/ha)			792.91± 140.11	1882.62± 402.34	477.08± 47.97	595.66± 71.36	376.89± 43.74		
Total carbon (t/ha)			396.46± 70.06	941.31± 201.17	238.54± 23.99	297.83± 35.68	188.45± 21.87		

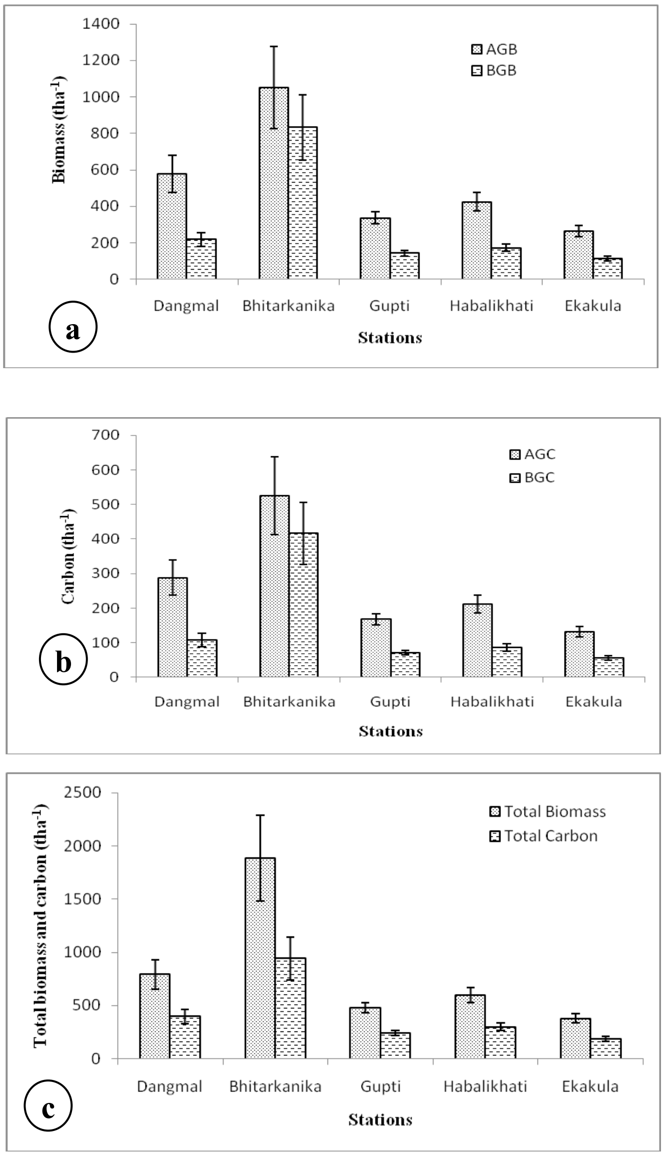

Fig. 4(a-c): Station wise AGB, BGB, AGC, BGC, TB and TC of selected mangrove species at different stations.

of 1.63 tha^{-1} in Ekakula to maximum of 351.72 tha^{-1} in Dangmal with an average of 108.62 tha^{-1} for *H. fomes*; the minimum and maximum biomass for *H. littoralis* is 5.37 tha^{-1} all along the Dangmal; the minimum of 0.55 tha^{-1} in Gupti to maximum of 4.64 tha^{-1} in Bhitarkanika with an average of 1.61 tha^{-1} for *K. candel*; the minimum of 3.88 tha^{-1} in Gupti to maximum of 9.88 tha^{-1} in Habalikhati with an average of 2.75 tha^{-1} for *L. racemosa*; the minimum of 13.15 tha^{-1} in Ekakula to maximum of 113.38 tha^{-1} in Gupti with an average of 34.99 tha^{-1} for *R. mucronata*; the minimum of 1.06 tha^{-1} in Gupti to maximum of 12.59 tha^{-1} in Ekakula with an average of 3.12 tha^{-1} for *S. alba*; the minimum of 0.77 tha^{-1} in Habalikhati to maximum of 54.11 tha^{-1} in Bhitarkanika with an average of 21.17 tha^{-1} for *S. apetala*; the minimum of 2.83 tha^{-1} in Habalikhati to maximum of 17.58 tha^{-1} in Bhitarkanika with an average of 6.49 tha^{-1} for *X. granatum*; the minimum of 1.37 tha^{-1} in Gupti to maximum of 15.50 tha^{-1} in Bhitarkanika with an average of 3.85 tha^{-1} for *X. mekongensis* and for *X. molluccensis* the minimum and maximum values of biomass is 0.69 tha^{-1} in all along Bhitarkanika (Table 2). Calculation of total carbon was considered to be 50% of total dry biomass which varied species-wise from 0.35 tha^{-1} for X. molluccensis to 1061.09 tha^{-1} for *A. officinalis* and station-wise from 188.45 ± 21.87 tha^{-1} at Ekakula to 941.31 ± 201.17 tha^{-1} at Bhitarkanika respectively (Table 2).

Mangrove forest biomass varies enormously across the globe, with variations within regions caused by many factors, including stand age, species composition, and responses to environmental conditions. Critical to our ability to estimate the role of mangroves in regional and global carbon cycling is an accurate estimation of net primary production. About 2% of the radiant energy reaching the Earth's surface is used by plants to assimilate atmospheric CO^2 into organic compounds used to construct new leaf, stem, branches, and root tissue, as well as to maintain existing tissue, create storage reserves, and to provide chemical defense (e.g. polyphenolic acids) against insects, pathogens, and herbivores. Net production and biomass is the balance between gross photosynthesis and leaf dark respiration, and represents the amount of carbon available for growth and tissue maintenance. Above-ground biomass ranges from 619 tha^{-1} of mature Rhizophora forests in Hinchinbrook Channel, Australia (Clough, 1998) to 6.8 tha^{-1} of small A. marina in Tuff Crater, New Zealand (Woodroffe, 1985). The amount of standing biomass stored in mangrove forest is a function of system's productivity, age and organic matter allocation and exportation strategies (Kasawani *et al.*, 2007).

Correlation coefficient computed between physico-chemical parameters (water and soil), TB and TC of the selected species have shown a negative relationship with water temperature both for water and soil ($r_{TB/TC \times water\ temperature}$= -0.605/-0.653; $p < 0.01$). Similar trend was also observed for water salinity and soil electrical conductivity (EC) ($r_{TB/TC \times water\ salinity}$= -0.703/-0.753; $p < 0.01$). With water pH total biomass and total carbon showed insignificant relationship. The results of correlation coefficient suggests that pH of sea water being a buffer system has played insignificant role in contributing to total biomass and total carbon of mangrove species. With respect to water temperature and salinity the highly significant negative relationship has proved that with the increasing temperature and salinity the total biomass and carbon stock of mangrove species is highly affected. This in turn has cleared the fact that with the increasing temperature in the present *era* of climate change, there is increased water and soil salinity due to excessive evaporation. This increased evaporation will lead to increased moisture content in the atmosphere that will contribute to global warming in the localized frame work.

The present study is close to the findings of Komiyama *et al.* (1987), Banerjee *et al.* (2013), Mitra *et al.* (2011), Sahu *et al.* (2015). Other studies in Thailand (Komiyama *et al.*, 1987), India (Mall *et al.*, 1991) and Sri Lanka (Komiyama *et al.*, 2008) reported an above ground biomass of 298.5 t ha^{-1}, 214 tha^{-1} and 71 tha^{-1} respectively (Komiyama *et al.*, 2008). These results indicate great variability in the total biomass and carbon of mangrove across the world. The present research programme can pave its way towards target oriented afforestation programme which is very much applicable to the changes in water and soil quality parameters for such an important Wildlife Sanctuary like Bhitarkanika.

4. Conclusion

Knowledge on mangrove biodiversity, total biomass and carbon is an extremely important study in BWLS as it is known for its floral and faunal diversity. From the study it is clear that temperature fluctuations and salt stress plays a major role in mangrove growth, regeneration and biomass. More over the adaptability of different species of mangroves is highly species specific towards change in ambient physico-chemical parameters. There is need of time to focus on more research on mangrove with respect to its physiological and anatomical adaptation to changing climate.

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