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The Relationship between water quality and Macrophyte biomass of Kongba River, Manipur, India

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ABSTRACT

The present study aims to assess the relationship between water quality and macrophytes biomass of Kongba River, Manipur (Latitude 25.80^0 N to 25.68^{0}N and 93.03^{0}E to 94.78^{0}E longitude). Pearson correlation (r) test was carried out to identify the association between water quality for sampling sites and the macrophytes biomass. The analysis indicated that D.O is correlated negatively with all the macrophytes biomass. However, the values of nitrate and phosphate were positively correlated with the macrophytes biomass. Water quality with regard to temperature, pH, DO, Cl, Ca, Mg, Hardness, Alkalinity, NO_3 andPO_4 were analysed. The present communication reflects seasonal variation of water quality in the river. Seasonal variation in biomass of macrophytes functional groups were estimated from the five study sites. Macrophytes biomass exhibited the trend as E>FF>Sub>RF in site (II, III, IV and V) whereas in site I macrophytes biomass was observed as E>Sub>RF>FF. The study reveals that the water quality of the Kongba River were found to be related to macrophytes biomass either positively or negatively but the nutrients levels were within the normal range for macrophytes growth. Concentration of morenutrients in the water bodies can lead to eutrophication and results in macrophyte bloom. Therefore, there is need to monitor and check the water quality at regular intervals and the growth of macrophytes to ensure the healthy development and maximum production of biomass.

Key word: *Pearson correlation, Water quality, Macrophytes biomass.*

Introduction

Aquatic macrophytes are group of large macroscopic photosynthetic organisms usually growing with their roots in soil or water (Jones *et al.,* 2010). They can be categorized as Free floating(FF), Rootedfloating(RF), Submerged (Sub) and Emergent(E). Dumen *et al*., (2007) noted that aquatic macrophytes growing in the river are known to induce substantial changes to the water quality. Aquatic vegetation especially macrophytes are vulnerable to changes in climate. Climate-induced changes in air temperature, precipitation and other stressors affect the physical, chemical and biological characteristics of fresh water ecosystems (Wrona *et al*., 2006; Alahuhta, 2015; Ejankowski and Lenard, 2015). The changes in the water quality characteristics of water affect the growth, productivity and survival of aquatic plant species. The species composition gets alteredbecause of impacts such as habitat loss/transition, shifting ranges and phenological alterations.

Like many ecosystems, fresh water ecosystems are confronted with the effects of climate change (Hossain *et al*., 2016). Freshwater ecosystems are naturally heterogeneous systems. For example, rivers can be seen as a patchwork of different zones that vary in hydrogeomorphology and are affected bydifferences in the stands (Singhal and Singh, 1978) catchment and the climate (Reitsema *et al*., 2018), those different patches may have different inputs of C and may vary in C processing rates (Thorp *et al.*, 2006). The aquatic macrophytes may produce large amounts of biomass comparable to the highly productive plants of the terrestrial ecosystems (Reddy, 1984). Wetlands have been recognised as one of the most productive ecosystems in the world and reported that pure stand of any macrophytes species had greater biomass as compared to those of the mixed species stands. Macrophytes are capable to accumulate man- caused pollutants in their biomass (Gudkov *et al.*, 2002; Cecal *et al.*, 2002; Bolsunovsky, 2004) and thus to play the role of biological filter. The study therefore focussed on the relationship between water quality parameters and macrophytes biomass of Kongba River.

Materials and Methodology

Study Area

The present work was carried out in Kongba River of Manipur (Latitude 25.80^{0}N to 25.68^{o}N and 93.03^{o}E to 94.78^{o}E longitude) which has about 120 km^2 catchment area. The state enjoys moderately cold, sub-tropical monsoon type of climate with mean maximum temperature ranging from 23.03 ^{o}C to 30.77 ^{o}C and mean minimum temperature varied from 4 ^{o}C to 22.33 ^{o}C. The maximum rainfall recorded was 256.7mm. The relative humidity percentage during the study period ranged from 62.80% to 86.67%.

Material and Methods

Collection and spot analysis of water samples were done regularly at a fixed time particularly in morning hours during November 2006 to October 2007 at five selected sites (Fig.1). The sites selected were: Site I (Khundrakpam village), Site II (Kongpal), Site III (Kongba bazaar), Site IV (Kongba Uchekon) and Site V (Kongba Meilombi).

For analysis of water quality parameters, the standard methods were used given by (APHA, 1989), (Trivedy *et al.*, 1987). Plant samples were collected on seasonal basis using quadrates of 25x 25 cm^2 from the five study sites and the plant materials

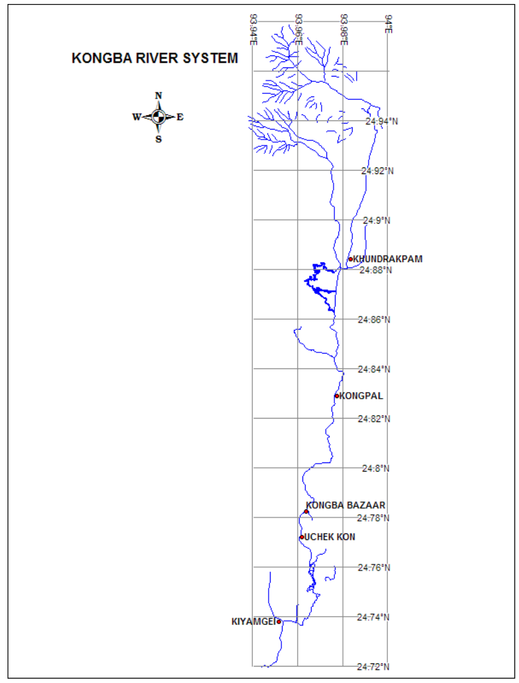

Fig. 1. Map showing the five sites of Kongba River, Manipur.

were dried at 80^{o}C for 48 hours in an oven. The dry weights of the shoot and root portions which were separated before drying were measured. Biomass thus calculated on dry weight basis was expressed in grams per square metre (gm^{-2}). Biomass was calculated according to harvest method (Odum, 1956).

Results and Discussion

A total of 29 macrophytes species were recorded. Of which E species (19) were found to be highest followed by FF(6), RF(1) and Sub species (3). The results of present investigation were coincides with the work of (Shah and Abbash, 1979) who reported 28 macrophytic species in Ganga River at Bhagalpur, out of which 22 species were emergent, 4 submerged and 2 species were free floating.In Ketar River, Ethiopia (Chibsa *et al.*, 2021) recorded 16 macrophytic species which was followed as E(11), RF(3) and FF(2).

Pearson coefficient correlation between water quality parameters (limnological variables) and macrophytes biomass from Kongba River, Manipur are shown in Table 1.

The correlation found to be very highly significant at the 0.05 level between water quality parameters were Mg and A_T (r=0.937), Mg and Cl(r=0.930),

Table 1. Pearson coefficient co-relation between water quality parameters (limnological variables) and macrophytes biomass of Kongba River, Manipur

Parameters	Temp (^{0}C)	pH	DO (mgl^{-1})	EC (µmhos cm^{-1})	A_T (mgl^{-1})	Cl (mgl^{-1})	Hardness (mgl^{-1})	Ca (mgl^{-1})	Mg (mgl^{-1})	Nitrate (mgl^{-1})	PO_4 (mgl^{-1})	BFF (g^{-2})	BRF (g^{-2})	B Sub (g^{-2})	BE (g^{-2})
Temp (^{0}C)	1														
pH	-0.013														
DO (mgl^{-1})	-0.806	-0.004													
EC (µmhoscm^{-1})	0.729	0.564	-0.960**												
A_T(mgl^{-1})	0.754	0.142	-0.889	0.595											
Cl (mgl^{-1})	0.517	0.505	-0.587	0.609	.962**										
Hardness (mgl^{-1})	0.317	0.276	-0.096	0.555	.987**	.984**									
Ca (mgl^{-1})	0.772	0.172	-0.956*	0.731	.963**	.970**	.970**								
Mg (mgl^{-1})	-0.595	-0.025	0.679	0.307	.937*	.930*	.958*	0.86							
Nitrate (mgl^{-1})	0.437	0.468	-0.189	0.482	-0.374	-0.361	-0.445	-0.242	-0.646						
PO_4(mgl^{-1})	0.776	0.150	-0.494	0.593	-0.285	-0.203	-0.312	-0.085	-0.546	.943*					
BFF (g^{-2})	0.859	0.077	-0.887	.899*	0.616	0.508	0.521	0.666	0.304	0.423	0.410				
BRF (g^{-2})	0.138	-0.813	-0.016	-0.061	-0.447	-0.411	-0.383	-0.263	-0.502	0.165	0.309	-0.145			
B Sub (g^{-2})	0.804	-0.510	-0.742	0.381	-0.172	-0.198	-0.168	0.024	-0.391	0.432	0.540	0.364	0.865		
BE (g^{-2})	0.696	-0.122	-0.819	0.717	0.026	0.077	0.033	0.267	-0.245	0.623	0.790	0.558	0.628	0.872	1

*.Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
Key: Temp=Temperature, pH=Hydrogen ion, D.O=Dissolved oxygen, Free CO_2=Free carbon dioxide, A_T=Alkalinity, Cl=Chloride, Ca=Calcium, EC=Electrical Conductivity, Mg=Magnesium, PO_4=Phosphate, Na=Sodium, K=Potassium, BFF=Biomass Free floating, BRF= Biomass Rooted floating, B Sub= Biomass Submerged, B E= Biomass Emergent

Mg and Hardness (r=0.959), $P0_4$ and $N0_3$(R=0.943) whereas the correlation found to be significantly inverse at 0.05 level was Ca and DO (r= -0.956). The correlation which were highly significant at the 0.01 level between water qualities parameters were Cl and A_T (r=0.962), Hardness and A_T (r=0.987), Hardness and Cl(r=0.984), Ca and A_T (r=0.963), Ca and Cl(r=0.970), Ca and Hardness (r=0.970). However, the correlation found to be negatively significant at 0.01 was EC and DO(r= -0.960)

Macrophytes biomass exhibited the trend as E>FF>Sub>RF in sites (II, III, IV and V) whereas in Site I the trend of biomass accumulation was observed as E>Sub>RF>FF. It can be said that the species in the Sub and RF macrophytes are adjusted in the limnological condition prevailing in the river.

Biomass accumulation was more in E macrophytes followed by FF which act as moderator for other groups causing interaction in the river system. Hence the limnological changes cause by the dominance of E and FF groups adjust the other species from Sub and RF macrophytes groups allowing the co-existence. The structuring of macrophytes communities is guided by the competition and coexistence, this phenomenon was also observed by (Moura *et al.,* 2016).

(Camargo and Florentino, 2000; Byun *et al.,* 2017) works to verified the extraordinary capacity of the interspecific interactions between macrophytes to influence the growth of biomass of these plants. The Emergent macrophytes in nutrient rich water are accumulating more biomass, the limnological variables (D.O, pH) were indirect relation with species biomass in case of other types of macrophytes. It specified for interspecific coexistence due to moderator of limnological changes widening the availability of nutrients to Sub and RF species allowing coexistence. Such interaction and coexistence are supported by reduced biomass of Sub and RF macrophytes.

The above indication of impact of limnological variables on biomass accumulation in functional macrophytes groups is supported by the magnitude of observed between these limnological variables and macrophytes biomass. Free floating macrophytes can also accumulate more biomass as their leaves and reproductive organs are aerial and since they are not rooted in the sediments; their nutrient absorption is completely from water. Light is an essential factor that limits the growth of macrophytes. Therefore, our results noted that Sub macrophytes may get limited availability of light, hence suppressing the growth of macrophytes. It is well known that rooted macrophytes are able to obtain a large part of required nutrients from the sediment indicating the impact on macrophytes biomass (Carigan and Kalff, 1980; Halbedel, 2016). But, in our studies accumulation of biomass is least in RF as the nutrients are absorbed by the other competitors like E, FF and Sub. So, the growth of RF is reduced.

Our results showed that F.F with NO_3 and PO_4 showed a positive correlation (Scheffer *et al.,* 2003) reported that free floating macrophytes showed a positive correlation to nutrient levels of the water column. (Vymazal, 2007) reflected that emergent and free floating macrophytes species have mainly been used for nutrient removal in constructed wetlands and can remove around 250-630 gN.m^{-2}.y^{-1} and 45- 70g P.m^{-2}.y^{-1} under high nutrient loading (Srivastava *et al.,* 2008) revealed that FF macrophytes have a high capability of improving water quality by removing heavy loads of nutrients and toxic metals from the water.

High temperature increases the growth of macrophytes. Therefore, the relationship between macrophytes biomass and temperature was found to be positive (E and temp, r=0.669) in the present investigation. Barko *et al.* (1986) mentioned the increased in growth of macrophytes due to high temperature influence the metabolic reaction controlling the enzyme activities. They further pointed out the influence of interactive relationship between solar radiation and water temperature over biomass. Our result of low biomass in submerged aquatic plants due to the impact of water temperature, tallies to their findings. There is a close relationship between biomass of FF and EC(r=0.899), E and EC(r=0.717). Conductivity has a relationship with the presence of ions in water. Plant body of FF and E absorb ions from water and helps in the increment of plant growth.

Biomass productivity of aquatic macrophytes is related with their capacity to absorb NO_3 and/ or PO_4, transforming them in organic compounds (Camargo *et al.,* 2003; Henry –Silva *et al.,* 2008; Bottino *et al.,* 2013). Studies indicate that rise of NO_3 and PO_4 discharge from agricultural fields support the growth of emergent plants (E and NO_3, r=0.623; E and PO_4, r=0.79). Our results show that macrophytes biomass is positive relation with NP in rainy season. This trend of biomass variation could be explained due to nutrient availability in rainy season (O' Brien *et al.,* 2013). The interplay between macrophytes biomass and water quality variables represent a fundamental characteristics of River system, which has importance for River flow and ecological functioning (Xiao *et al.,* 2010). The Pearson correlation revealed that D.O is correlated negatively with BFF, BRF, B-Sub and E while Temperature, NO_3 and PO_4 were positively correlated with all the macrophytes biomass. BFF with EC is positively significant $P< 0.05$. Frankouich *et al.,* 2006; Uedeme-Naa *et al.,* 2011, reported that aquatic macrophytes distribution and growth is associated with nutrient rich environments particularly nitrate and phosphate which have been noted to favour macrophytes growth.It can be predicted that changes in water quality variables directly affects the growth of macrophytes and biomass. Same type of observation was noticed by (Feijoo *et al.,* 1996). Thus, feature management of water resources can get a clue from variation in water quality and macrophytes biomass. It strengthens the notion that aquatic macrophytes play a crucial role in river metabolism.

Data of Water Quality

Water quality parameters are considered as one of the most important factors that are capable of influencing the aquatic environment and have shown wide temporal and spatial differences.

Seasonal water quality parameters from Kongba River are summarized in (Table 2).

Temperature lies within the range of 18.42 ^{o}C - 27.75 ^{o}C. The data reveal that the pH value was varied between 6.98 at Site II (summer) to 7.29 at Site IV (winter). Higher values of pH during winter can be attributed to high growth rate of algal population which utilized CO_2 through photosynthetic activity (Gandseca *et al.,* 2011; Perking, 1976). The river found slightly alkaline throughout the year. Change in pH of river water is attributed due to the climatic condition as reported by (Iyyapan *et al*., 1998). The values of pH in my study site was found to be within the permissible limit of 6.5-8.5 according to

Table 2. Seasonal Water quality parameters from Kongba River, Manipur

Sl. No.	Parameters	SITE-IKhundrakpam			SITE-IIKongpal			SITE-IIIKongba			SITE-IVUchekon			SITE-VKiyamgei		
		Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy
1	Temp (^{0}C)	18.42	20.87	25.82	18.62	21.12	26.82	19.20	21.80	27.10	19.87	22.05	27.60	20.53	22.37	27.75
2	pH	7.15	7.06	7.08	7.10	6.98	7.13	7.20	7.01	7.18	7.29	7.03	7.22	7.29	7.13	7.18
3	D.O (mgl^{-1})	12.05	11.44	11.11	11.40	10.98	10.12	11.01	10.68	9.80	10.99	9.89	8.88	10.71	9.66	6.55
4	EC (µmhoscm^{-1})	113.30	234.50	58.00	135.00	256.50	76.25	155.00	260.50	83.00	184.50	292.8	106.50	189.50	323.80	113.30
5	Alkalinity (mgl^{-1})	169.00	122.50	58.50	191.50	146.00	73.50	188.00	172.50	67.50	191.50	170.00	76.00	197.50	161.00	97.00
6	Cl (mgl^{-1})	61.77	63.90	25.91	67.45	66.80	22.70	67.20	86.62	44.37	75.97	80.94	31.18	74.30	72.42	34.08
7	Hardness (mgl^{-1})	111.50	118.00	31.00	117.00	126.50	38.50	132.50	164.50	45.00	147.50	126.00	49.00	139.50	140.50	51.50
8	Ca (mgl^{-1})	19.89	17.31	8.60	21.57	17.83	10.38	23.80	20.75	11.78	26.85	21.91	13.16	29.85	22.04	14.98
9	Mg (mgl^{-1})	15.13	18.36	2.286	15.37	19.95	3.05	17.80	20.14	3.79	19.61	17.36	3.93	15.82	19.57	3.42
10	Nitrate (mgl^{-1})	0.33	0.53	0.72	0.23	0.67	0.83	0.28	0.64	0.86	0.38	0.78	0.92	0.45	0.67	0.95
11	Phosphate (mgl^{-1})	0.096	0.16	0.31	0.11	0.21	0.36	0.11	0.21	0.65	0.14	0.28	0.64	0.18	0.28	0.77

Key: Temp=Temperature, pH=Hydrogen ion, D.O-Dissolved oxygen, Free CO_2= Free carbon dioxide, A_T= Alkalinity, Cl= Chloride, Ca=Calcium, EC=Electrical Conductivity, Mg=Magnesium, PO_4 = Phosphate, Na=Sodium, K=Potassium

(BIS, 2003).

The value of D.O ranged within 6.55 mgl^{-1} during rainy season at Site V to 12.05 mgl^{-1} during winter season at Site I. The present observation finds support with the work of Akumtoshi *et al.*, 2020 in Doyang River, Nagaland. The raised values of D.O during winter season in Site I were due to high photosynthetic rate by phytoplankton during which more CO_2 is utilised and O_2 is released (Jadhav and Jadhav, 2018). The DO level in our study site was found to be higher than the acceptable limits of 5 mg^{-1} (BIS, 2003). The highest value of electrical conductivity was 323.75 µmhos/cm at site V (summer season) and lowest value was 58 µmhos/cm at site I (rainy season). Minimum concentration of electrical conductivity in rainy season may be due to dilution of water in the river (Patel and Parikh, 2013). Here all the values are within the permissible limits of 300µmhos cm^{-1} (BIS, 2003) except at site V during summer season. This is attributed to the increased water inflow from the agricultural fields and land drainage.

Alkalinity value ranged between 67.5mgl^{-1} at Site III (rainy) and 197.5 mgl^{-1} at Site V (winter). High alkalinity in winter months might be attributed to lower concentration of other anions like sulphates, nitrate, phosphate and low water level (Adebisi, 1980). The values recorded are above the desirable limit of 120 mg^{-1}(BIS, 2003). Chloride content of the river varied from 22.7 mgl^{-1} (Site II) during rainy season to 86.62 mgl^{-1} (Site III) during summer season. Low chloride concentration during rainy season might be due to dilution of river water and rapid flow of water (Palharya *et al.,* 1993; Kshirsagar and Gunale, 2011. The chloride content of the sample was found to be within the permissible level of 250mgl^{-1} (BIS, 2003). Hardness value was obtained minimum at site I (31 mgl^{-1}) during rainy season and maximum at site III (164.5 mgl^{-1}) during summer season. (Akshata *et al.*, 2017) opined that addition of sewage, detergents and large scale human use might be the cause of elevation of hardness. The values recorded were all under the desirable limits of 300mgl^{-1}(BIS, 2003). Ca value varied between 8.6 mgl^{-1} (Site I, rainy) to 29.85 mgl^{-1}(Site V, winter). The calcium content of the sample was found to be within the permissible level of 75 mgl^{-1}(BIS, 2003) Mg lies within the range of 2.28 mgl^{-1} (Site I, rainy) to 20.14 mgl^{-1} (Site III, summer). The values of Mg were all under the desirable limit of 30 mgl^{-1} (BIS, 2003). Maximum values of nitrates were found during rainyseason at site V (0.95 mgl^{-1}) and minimum in winter at Site II (0.23 mgl^{-1}). Higher value of nitrate during rainy season might be due to inflow of flood-water, land drainage and precipitation (Sheeba and Ramanujan, 2009). The findings of nitrate values were below the desirable limit of 45 mgl^{-1} (BIS, 2003). Phosphate value ranged between 0.096 mgl^{-1} at Site 1 (winter) and 0.77 mgl^{-1} at Site V (rainy). Maximum values of phosphate are found in rainy season which might be due to agriculture run-off from paddy field carried by the inflow of water. Phosphate values are found to be a bit higher as compare to the permissible limit of 0.1 mgl^{-1} (WHO, 1993).

Data of Macrophyte biomass

Seasonal biomass of Macrophytes functional groups from Kongba River were shown in (Table 3).

At Site II, biomass of FF Macrophyte varied from 378.24 g^{-2} (summer) to 458.46 g^{-2} (winter) whereas in the RF biomass ranged from 60.0 g^{-2} (rainy) to 120.96 g^{-2} (summer). In Submacrophytes, biomass fluctuated between 93.44 g^{-2} (rainy) to 119.04 gm^{-2} (winter) whereas in E, biomass ranged from 1008.92 g^{-2} during summer to 2364.71 g^{-2} during rainy season.

At Site III, maximum biomass in FF was obtained during rainy season (531.08 g^{-2}) and minimum was attained during winter (403.42 g^{-2}) whereas in RF, the highest biomass was 95.52 g^{-2} (winter) and lowest biomass was found during rainy season (69.60 g^{-2}). In Sub and E macrophytes, the maximum biomass was observed in rainy season as 105.59 g^{-2}, and 2534.4 gm^{-2} respectively and minimum biomass in summer season as 98.88 g^{-2} and 1199.26 g^{-2} respectively

At Site IV, the maximum biomass in FF and Submacrophytes was recorded during rainy season (537.51 g^{-2}), (126.26 g^{-2}) whereas the minimum biomass was obtained during summer season (289.39 g^{-2}), (99.76 g^{-2}). In RF macrophytes, the highest biomass was observed during summer season (102.0 g^{-2}) and the lowest biomass was obtained during rainy season (84.0 g^{-2}). In Emacrophytes, the highest biomass was 2760.63 gm^{-2} and the lowest as 1734.71 g^{-2} obtained during rainy and winter seasons respectively.

At Site V, the biomass of FF macrophytes ranged between 618.13 g^{-2} (rainy) and 724.58 g^{-2} (winter) whereas in RF and Sub, the biomass varied from 84.41 g^{-2} to 185.88 g^{-2} during winter and 139.83 g^{-2} to 206.97 g^{-2} during rainy season respectively. In E, the maximum biomass was obtained during rainy sea-

Table 3. Seasonal biomass of Macrophytes functional groups from Kongba River, Manipur

Sl. No.	Parameters	SITE-IKhundrakpam			SITE-IIKongpal			SITE-IIIKongba			SITE-IVUchekon			SITE-VKiyamgei		
		Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy
1	B F.F(gm^{-2})	99.57	98.22	81.76	458.46	378.24	431.63	403.42	485.76	531.08	487.80	289.39	537.51	724.58	657.13	618.13
2	B R F (gm^{-2}	94.66	108.66	137.95	93.0	120.96	60.0	95.52	77.68	69.60	92.32	102.0	84.0	84.41	121.2	139.83
3	B Sub (gm^{-2})	122.58	136.44	156.36	119.04	111.52	93.44	123.2	98.88	105.59	107.84	99.76	126.26	185.88	192.08	206.97
4	B E (gm^{-2})	1225.85	1669.01	2653.72	1138.37	1008.92	2364.71	1459.91	1199.26	2534.4	1734.7	1925.66	2760.63	2524.51	2443.16	3532

Key: BFF = Biomass Free floating B RF= Biomass Rooted floating, B Sub=Biomass submerged, B E=Biomass Emergent
For FF Macrophyte at Site 1, the maximum biomass was recorded during winter season (99.57 g^{-2}) whereas the minimum during rainy season. In RF, Sub and E highest biomass was reported during rainy season (137.97 g^{-2}, 156.36g^{-2}, 2653.72 g^{-2}) and lowest was noted in winter season (94.66g^{-2}94.66 g^{-2}, 122.58 g^{-2} and 1225.85 g^{-2} respectively).

son (3532 g^{-2}) and minimum in summer season (2443.16 g^{-2}).

The study revealed that macrophytes biomass was found to be highest during rainy season from all the five sites. The lowest was observed during winter season at site I and IV and the minimum was shown in summer season at site II, III and V.

The biomass of macrophytes functional groups in the present study was very high in comparison to the data of various workers. The present findings revealed the biomass as FF varied from 81.76 g^{-2} (SiteI) to 724.58 g^{-2} (Site V). RF fluctuated between 60 g^{-2} (Site II) to 139.83 g^{-2}(Site V). Submacrophytes ranged between 93.44 gm^{-2} (Site II) to 206.97 g^{-2} (Site V). E macrophytes showed the variation between 1008.92 g^{-2} (Site II) to 3532 g^{-2} (Site V). (Zotina, 2008) reported from Yenisei river that biomass of plants varied within 310- 470 g^{-2} (Deep water zone) and 70 -360 g^{-2} (Shallow zone). In the Asanwetland, Assam, (Malik, 2013) reported that maximum biomass ranged between 179-183 Kg^{-2} and minimum biomass was found between 55-65 Kg^{-2}. (Vasilean, 2015) from Danube River showed the variation of macrophyte biomass from 25.14 g^{-2} to 171.9 g^{-2} (Khan and Shah, 2010) reported from Hokersar, Kashmir Himalayan wetland that the plant biomass fluctuated from 35-1100 g^{-2} (Junk, 1997; Pettit *et al.,* 2011) reported from Amazon floodplain in Brazil or Magela Creek floodplains in Australia where the peak above-ground biomass often exceeds 4,000 g^{-2}. This data is found to be higher than our present value of biomass.

Our results highlighted considerable variation in different sites and seasons. Seasonal trend in total biomass reflected the pattern as R>S>W at Site I and IV whereas in Sites II, III and V the total biomass exhibited the pattern as R>W>S. The maximum growth was observed during rainy season due to prevalence of nutrients, suitable of temperature and other limnological variables. The marginal emergent macrophytes contributed maximum biomass values compared to the other macrophytes as they are getting the benefit both from the aquatic and terrestrial (Kayranli, 2010). The study reveals that maximum biomass was contributed in emergent plants during rainy season from site I as 87.58%, site II as 80.16%, site III as 78.20%, site IV as 78.68% and site V as 78.54%. The contribution of FF ranged between 2.69% (Site I) – 26.09% (Site III), RF varied from 2.03% (Site II) to 7.46% (site II) and Sub showed the variation between 3.16% (Site II) to 6.88% (Site II). However, (Shardendu and Ambasht, 1991) contributed 6% of the total wetland biomass from submerged zone; the remainder was due to floating and emergent species.

Peak biomass values from the five sites for all available species were recorded from rainy season. The findings are in agreement with the view of (Westlake, 1965) that the maximum values of biomass of the macrophytes species usually occur during the growing periods (July-Aug) in the Northern Hemisphere. In sites I and IV biomass value declined in winter due to prevention of growth. In sites II,III and V, the biomass value declined in summer due to death, senescence and decomposition of plant parts. Accordingto (Wetzel, 1983), water levels influence biomass of emergent plant directly but the water levels have been found to affect the biomass of the submerged plants indirectly (Chambers and Kalff, 1985; Middlefoe and Markager, 1997).

Conclusion

The water quality parameters of the river were found to be related to aquatic macrophytes biomass either positively or negatively but the nutrients level were within the normal range for macrophyte growth. But concentration of more nutrients can lead to Eutrophication causing macrophyte bloom. However, aquatic macrophytes play a significant role in biodiversity conservation and sustainable development in lotic and lentic ecosystems. The growth behaviour of macrophytes strongly depends on nutrient availability and suitable physical parameters in the river system. Therefore, there is need to monitor and check the water quality at regular intervals and the growth of macrophytes to ensure the healthy development and maximum production of biomass.

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