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Seasonal variation in Importance Value Index (IVI), Diversity Indices and Biomass of aquatic macrophytes at Biratnagar and adjoining areas, eastern Nepal

Bhabindra Niroula[1*] and K.L.B. Singh[2]

[1]*Department of Botany, Post Graduate campus, Tribhuvan University, Biratnagar, Nepal*
[2]*University Department of Botany, T.M. Bhagalpur University, Bhagalpur- 812 007, India*
[*]*E-mail: niroulab@gmail.com*

Abstract

Aquatic macrophytes of three freshwater bodies of Biratnagar and adjoining areas in eastern Nepal namely, Betana-a natural oxbow pond, Bhattapokhari-an aged derelict depression, and Singhia river were analysed for their importance value index (IVI), diversity indices and biomass seasonally from January 2008 to December 2009. Singhia river had high species richness-d (2.08-3.84) and Shannon Wienner index-H' (2.16-2.68). Betana pond and Bhattapokhari had low diversity indices; however, nutrient rich Bhattapokhari had highest primary productivity (2675.5 g/m^2/yr) in comparison to Betana pond (303.7 g/m^2/yr) and Singhia river (479.09 g/m^2/yr). Seasonally vittates dominated Betana pond had IVI range between 6.3 and 258.8 and biomass range between 168.1±7.3 and 265.8±38.7 g/m^2); pleustophytes dominated Bhattapokhari had IVI range between 41.6 and 192.8 and biomass range between 925.5±353.2 and 2020.02±213.1 g/m^2), and hyperhydate dominated Singhia river had IVI ranged between 2.5 and 160.9 and biomass ranged between 120.7±55.8 and 283.5±28.3 g/m^2.

***Key words*:** Growth form, species richness, productivity, oxbow pond, Singhia river.

Introduction

Aquatic macrophytes form important components whose abundance influences the structural and functional characteristics of aquatic ecosystems (Canfield, 1984). They affect the species composition and richness of aquatic biota and finally the water quality through consequent nutrient cycling. They often act as nutrient pump, take up nutrients from the bottom sediments, translocating them to the shoots and releasing them in the water body when they perish. In the aquatic environment they are essential for manufacturing and producing food for aquatic heterotrophic communities and contribute significantly to the total primary production (Adoni & Yadav, 1985).

Some floristic and resource based works on aquatic macrophytes are available but quantitative status is almost unknown to Nepal, few of them include Burlakoti & Karmacharya (2004), Shrestha (1997, 2000) and Upadhyay (2008). Present work aims to highlight importance value index (IVI), diversity indices and biomass from three fresh water bodies- Betana pond, Bhattapokhari (stagnant) and Singhia river (flowing) at Biratnagar and adjoining areas, eastern Nepal.

Material and Methods

Study area

Biratnagar township (26°20′ N and 87°16′ E, 72 m msl) is characterized by pollution / nutrient loaded derelict depressions and other water bodies- ponds, pools, ditches along the roadsides due to municipal and industrial discharges and agricultural run off.

An aged perennial derelict depression- Bhattapokhari (1.5 ha) 1 km south from Post Graduate campus surrounded by cultivated land from Biratnagar township (water depth 0.5-1m), Singhia river- a small perennial flowing water body at the eastern boarder of Biratnagar township and Betana (26°39′N and 87°25′E, 115 m msl), spreaded in 5.5 ha at the Charkoshe Jhadi- a natural oxbow pond (water depth 1-1.5 m) about 26 km north east away from Biratnagar township were selected for the present study.

The study area has alluvial soil, tropical monsoon climate with three distinct seasons *viz.*, winter (November-February), summer (March-June) and rainy (July-October) in a year. The average annual rainfall is 1312 mm, and average annual maximum and minimum temperatures 30.6°C and 14.2°C, respectively.

Observation and sampling of aquatic macrophytes were made from January 2008 to December 2009. They were sampled by harvest method at monthly intervals using a quadrat of 50×50 sq cm with adequate numbers. Collected samples were washed and brought to the laboratory and after proper sorting and processing oven dried to constant weight at 80°C. Importance value index was calculated by summing relative density, relative frequency and relative coverage of the species (Zobel *et al.*, 1987). Coverage was determined by Braun-Blanquet cover-class scale. Diversity indices were calculated following Margalef (1958), Pielou (1966), Shannon Weaver (1963) and Simpson (1949). The annual net production of aquatic macrophytes was calculated by summing positive increments on successive sampling dates during the study period (Singh & Yadava, 1974). The plant species were identified with the help of standard literature (Hooker, 1887-1897; Cook, 1996) and visual inspection. The identified specimens were confirmed by making crosschecks with the specimens housed at the Tribhuvan University Herbarium (TUH), Department of Botany, Post Graduate Campus, T.U., Biratnagar Nepal and Herbarium Section, University Department of Botany, T.M. Bhagalpur University, Bhagalpur, India. The specimens were deposited at Tribhuvan University Herbarium (TUH) for reference.

Results and Discussion

Thirty eight aquatic macrophyte species- Betana pond (7), Bhattapokhari (6), and Singhia river (32) were recorded with helophytes (7), tenagophytes (10), hyperhydates (11), vittates (7) and pleustophytes (3) by their growth form categories (Table 1). Emergents (helophytes, tenagophytes, hyprehydates) outnumbered submerged (vittates) and free floating (pleustophytes) as substantiated by Burlakoti and Karmacharya (2004), Sheerwani (1962) and Shrestha (1996, 1998). Betana pond was dominated with vittates and that of Bhattapokhari and Singhia river by hyperhydates. Species richness (d) and Shannon Weinner index (H') were higher in the Singhia river (d = 3.84, H' = 2.68) during winter but the values were lower (d = 2.08, H'= 2.16) during rainy season. Betana pond showed higher species richness and Shannon Weinner index (d = 0.94, H' = 1.58) during rainy (Table 4). Bhattapokhari had similar

trend for Shannon Weinner index (H'= 0.85), however, species richness was maximum (d = 0.69) and minimum (d = 0.55) during summer and winter, respectively.

Table 1. Floristic composition of aquatic macrophytes in Betana pond (I), Bhattapokhari (II) and Singhia river (III). (+) presence, (-) absence.

Growth forms	Name of plants	Site		
		I	II	III
Helophytes	*Alternanthera. sessilis* (L.) DC.	-	-	+
	Commelina benghalensis L.	-	-	+
	Cynodon dactylon L.	-	-	+
	Cyperus compressus L.	-	-	+
	Eclipta prostrata (L.) L.	-	-	+
	Gnaphalium polycaulon Pers.	-	-	+
	Sphaeranthus indicus L.	-	-	+
Tenagophytes	*Colocasia esculenta* (L.) Schott.	-	-	+
	Cyperus difformis L.	-	-	+
	Fimbristylis miliacea (L.) Vahl	-	-	+
	Hemarthria compressa (L.f.) R.Br.	-	-	+
	Hygrophila polysperma (Roxb.) T. Anders	-	-	+
	Ludwigia perennis L.	-	-	+
	Polygonum barbatum (L.) Hara	-	-	+
	P. hydropiper L.	-	-	+
	Rumex dentatus L.	-	-	+
	Veronica anagallis-aquatica L.	-	-	+
Hyperhydates	*Alternanthera philoxeroides* Griseb	-	+	+
	Ipomoea camea Jacq. subsp. *Fistulosa* (Mart. ex Choicy) D.F. Austin	-	+	+
	Marsilea crenata Presl	-	-	+
	Oenanthera javanica (Blume) DC.	-	-	+
	Panicum psilopodium Trin.	+	-	+
	Paspalum distichum L.	-	-	+
	Polygonum lapathifolium L.	-	-	+
	Ranunculus scleratus L.	-	-	+
	Sacciolepis interrupta (Willd.) Stapf	-	-	+
	Schoenoplectus mucronatus (L.) Palla	-	-	+
	Typha angustifolia L.	-	+	-
Vittates	*Blyxa japonica* (Miq.) Maxim	+	-	-
	Ceratophyllum demersum L.	+	-	-
	Chara schweinitzii A. Braun	-	+	-
	Enydra fluctuans Lourerio	+	-	-
	Hydrilla verticillata (L.f.) Royle	-	-	+
	Lymnophila heterophylla (Roxb.) Benth.	+	-	-
	Potamogeton crispus L.	-	+	+
Pleustophytes	*Azolla imbricata* (Roxb.) Nakai	+	-	+
	Eichhornia crassipes (Mart.) Solms.	-	+	+
	Pistia stratioites L.	+	-	+

Singhia river had higher values of equitability (e = 0.79-0.88) and Simpson index (c = 0.85-0.92) than Betana pond (e = 0.40-0.92, c = 0.32-0.77) and Bhattapokhari (e = 0.27-0.61, c = 0.14-0.48) showing seasonal variation (Table 2). This trend may be attributed to the increase in species richness with decrease in water depth (Burlakoti & Karmacharya 2004; Van der Valk & Davis 1976).

Table 2. Seasonal changes in biomass of different growth form communities of aquatic macrophytes at three sites. (W= winter, S= summer, R= rainy; figure in parenthesis represents percentage value).

Growth form	Biomass (g/m^2)								
	Betana pond			Bhattapokhari			Singhia river		
	W	S	R	W	S	R	W	S	R
Helophytes	-	-	-	-	-	-	8.55 (8.8)	26.1 (6.3)	3.4 (1.7)
Tenagophytes	-	-	-	-	-	-	103.48 (49.3)	155.92 (37.3)	8.29 (4.2)
Hyperhydates	32.1 (9)	-	11.4 (5.3)	288.6 (29.3)	414.7 (35.5)	942.2 (45.7)	74.11 (35.3)	199.05 (47.7)	162.15 (81.2)
Vittates	229.54 (65)	155.99 (93)	191.4 (89.3)	45.7 (4.6)	62.1 (5.4)	-	4.65 (2.2)	15.75 (3.8)	16 (8)
Pleustophytes	21.02 (6)	12.1 (7)	11.5 (5.4)	650.7 (66.1)	689.3 (59.1)	1120.5 (54.3)	9.3 (4.4)	20.5 (4.9)	9.7 (4.9)
Total	352.66	168.09	214.3	985	1166.1	2062.7	210.09	417.32	199.54

IVI as an index of dominance, in each growth form ranged 2.5-258.8, seasonally in these water bodies (Table 3). Vittates had maximum IVI (258.8) during rainy followed by pleustophytes IVI (152.3) during winter and hyperhydates IVI (6.3) the least during winter at Betana pond. The order of IVI values with respect to seasons at Bhattapokhari: pleustophytes IVI (192.8) rainy > vittates IVI (144.6) winter > hyperhydates IVI (107) rainy; Singhia river: hyperhydates IVI (160.9) rainy > tenagophytes IVI (103.3) winter > pleustophytes IVI (64.9) summer > helophytes IVI (42.3) winter > vittates IVI (35.7) rainy were recorded. Burlakoti and Karmacharya (2004) reported seasonal average values in the order: emergents IVI (131.42) > submerged IVI (80.79) > free floating IVI (59.14) > rooted floating (28.47) of aquatic macrophytes of Beeshazar Tal, Chitwan, Nepal. Summer season was reported to be most favourable for emergents, winter- for free floating, spring- for submerged and summer- for rooted floating. In the present study, rooted floating leaved (epihydates) species were absent but occurrence of maximum IVI at Singhia river for emergents was similar to the condition of Beeshazar Tal.

Table 3. Seasonal variation in importance value index (IVI) of different growth form communities of aquatic macrophytes at three sites. (W= winter, S= summer, R= rainy).

Growth form	IVI								
	Betana pond			Bhattapokhari			Singhia river		
	W	S	R	W	S	R	W	S	R
Helophytes	-	-	-	-	-	-	42.3	30.8	24.8
Tenagophytes	-	-	-	-	-	-	103.3	33.9	32.8
Hyperhydates	6.3	-	13.4	41.6	65.7	107.2	116.9	143.5	160.9
Vittates	141.4	239.5	258.8	144.6	138.8	-	2.5	26.9	35.7
Pleustophytes	152.3	60.5	27.8	113.8	95.5	192.8	12.5	64.9	45.8
Total	300	300	300	300	300	300	300	300	300

Variation in biomass (monthly/seasonal) of aquatic macrophytes communities at Betana pond, Bhattapokhari and Singhia river is given in Table 5. Maximum and minimum biomass recorded at Betana pond was 265.8±38.7 g/m^2 (winter), 168.1±7.3g/m^2 (summer); Bhattapokhari 2020.02±213.1 g/m^2 (rainy), 925.5±353.2 g/m^2 (winter) and that of Singhia river 283.5±28.3 g/m^2 (summer), 120.7±55.8 g/m^2 (rainy) on seasonal basis. Percent contribution to total biomass at maximum and minimum, by growth forms recorded at Betana pond- vittates (65-89.3%),

hyperhydates (0-9%); Bhattapokhari- pleustophytes (54.3-66.1%), vittates (0-5.4%) and Singhia river- hyperhydates (35.3-81.2%), vittates (2.2-8%), respectively. Maximum and minimum monthly dry biomass of whole communities recorded were December (379.8 g/m^2), August (109.8 g/m^2); August (2725.2 g/m^2), January (536 g/m^2) and February (274.76g/m^2), December (39.9 g/m^2) at Betana pond, Bhattapokhari and Singhia river, respectively.

Table 4. Seasonal variation in diversity indices of aquatic macrophytes at Betana pond (I), Bhatta pokhari (II) and Singhia river (III).

Parameter	Winter			Summer			Rainy		
	I	II	III	I	II	III	I	II	III
Species richness (d)	0.86	0.59	3.84	0.73	0.69	3.45	0.94	0.66	2.08
Shannon Wienner index (H')	0.79	0.60	2.68	1.49	0.50	2.41	1.58	0.85	2.16
Equitability (e)	0.40	0.37	0.88	0.92	0.27	0.79	0.88	0.61	0.86
Simpson index (c)	0.32	0.27	0.92	0.75	0.14	0.85	0.77	0.48	0.86

Table 5. Biomass (g/m^2) and productivity (g/m^2/yr) of aquatic macrophytes communities at Betana pond (I), Bhattapokhari (II) and Singhia river (III) (mean ± standard error).

Monthly biomass	I	II	III
January	188.5	536	101.3
February	200.5	329.06	274.76
March	142.8	779.3	233.8
April	175.5	992.2	380
May	174	1169.3	261.2
June	180.2	1459.8	259.2
July	183	1583.8	199.8
August	109.8	2725.2	- *
September	247.5	1847.1	- *
October	294.4	1924	41.79
November	294.5	2126.7	98.08
December	379.8	710	39.9
Seasonal biomass			
Winter	265.8±38.7	925.5±353.2	128.4±43.9
Summer	168.1±7.3	1100.1±124.6	283.5±28.3
Rainy	208.6±67	2020.02±213.1	120.7±55.8
Productivity	323.7	2675.7	479.09

Seasonal biomass represents average of monthly values. * No biomass was recorded due to over flooding in river.

Ambasht (1971) reported 2.21 kg/m^2 dry biomass in shallow zone with emergent vegetation and 0.57 kg/m^2 in floating leaved *Trapa bispinosa* central zone from a non polluted small pond in the Banaras Hindu University campus (India). Mean standing crop of floating macrophyte (*Eichhornia crassipes*) was 561.0-619.96 g dry wt/m^2 and that of submerged macrophyte (*Hydrilla verticillata*, *Potamogeton crispus*) was 166.27-167.18 g dry wt/m^2 in a eutrophic pond of Bhagalpur (Sharma & Rai, 1989). In marshy and attached emergents dominated macrophytes at Kewar lake wetland, Bihar, India, monthly biomass ranged 114-230 g/m^2, maximum- December and minimum- July (Sharma, 1995). Pandey *et al.* (1995) reported 597.4 g dry wt/m^2/yr macrophytic productivity of Kewar lake wetland (Begusarai), Bihar with maximum total dry wt biomass 2077.12 g dry wt/m^2 at November and minimum 843.09 g dry wt/m^2 at June.

Biomass of macrophytic community in the selected wetlands of Biratnagar, Nepal ranged 118.4-2039.6 g/m^2 (Upadhyay, 2008). Minimum was reported in September from submerged paddy field and maximum from *Typha* community dominated marshland- Koshi Tappu Wildlife reserve in June. Biomass reported from other communities was: Betana pond 524.8 g/m^2 (March); Singhia river 197.6 g/m^2 (January); ditches 1238 g/m^2 (September); Derelict depression 476 g/m^2 (June) at Biratnagar and adjoining areas, eastern Nepal.

Water hyacinth dominated Bhattapokhari was the most productive 2675.7 g/m^2/yr in comparison to natural oxbow pond- Betana (323.7 g/m^2/yr) and Singhia river (479.09 g/m^2/yr). Water hyacinth is one of the most productive plant of the world (Sinha & Sahai, 1979). This plant has exhibited its phenological rhythms related to temperature gradients, since gradual increase in biomass during summer and significant decrease during winter months. In Ramgarh wetland of Gorakhpur (India), Sinha (1969) calculated 930 g/m^2/yr production in emergent zone and a little over 1000 g/m^2/yr in floating and submerged zones. In temperate climate of Srinagar (Kashmir, India), Kaul (1971) found 2800 g/m^2/yr productivity in the emergent and 880 g/m^2/yr in floating zone of Dal lake.

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References

Adoni, A.D. & M. Yadav. 1985. Chemical and productional characteristics of *Potamogeton pectinatus* L. and *Hydrilla verticillata* Royle in an eutrophic lake. In: *Bulletin of Botanical Socciety* (Ed. A.D. Adoni). Sagar. pp. 96-105.

Ambasht, R.S. 1971. Ecosystem study of a tropical pond in relation to primary production of different vegetation zones. *Hydrobiologia* **12**: 57-61.

Burlakoti, C. & S.B. Karmacharya. 2004. Quantitative analysis of macrophytes of Beeshazar Tal, Chitwan, Nepal. *Himalayan Journal of Sciences* **2(3)**: 37-41.

Canfield, D.E., J.V. Shirman & J.R. Jones. 1984. Assesing the trophic status of lakes with aquatic macrophytes. *Lakes & Reservoir Management* **1**: 446-450.

Cook, C.D.K. 1996. *Aquatic and wetland plants of India*. Oxford University Press, Oxford-New York-Delhi.

Hara, H. & L.H. Williams. 1979. *An enumeration of the flowering plans of Nepal* Vol. 2. British Museum (Nat. Hist). London.

Hara, H., A.O. Chater & L.H. Williams. 1982. *An enumeration of the flowering plants of Nepal* Vol. 3. British Museum (Nat. Hist). London.

Hara, H.W., T. Stearn & L.H. Williams. 1978. *An enumeration of the flowering plants of Nepal* Vol. 1. British Museum (Nat. Hist). London.

Hooker, J.D. 1872-1897. *The flora of British India, 7 volumes* L. Reeve, London.

Kaul, V. 1971. Production and ecology of some macrophytes of Kashmir lakes. *Hydrobiologia* **12**: 63-69.

Margalef, R. 1958. Information theory on ecology. *General systematics* **3**: 36-71.

Pandey, K.N., V. Prakash & U.P. Sharma. 1995. Assessment of primary productivity of phytoplankton and macrophytes of Kewar lake wetland (Begusarai), Bihar. *Journal of Freshwater Biology* **7(4)**: 237-239.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* **13**: 131-144.

Shannon, C.E. & W. Weaver. 1963. *The mathmetical theory of communication*. University of Illnois press, Urbana, USA.

Sharma, U.P. 1995. Role of macrophytes in the ecosystem of Kewar lake wetland (Begusarai), Bihar, India. *J. Freshwater Biol.* 7(2): 123-128.

Sharma, U.P. & D.N. Rai. 1989. Biomass of hydrophytes in an eutrophic pond of Bhagalpur (Bihar). *Journal of Freshwater Biology* **1(2)**: 173-176.

Sheerwani, A.B. 1962. A study on the hydrophytes and plants of low lying habitats in Jabalpur. *Bulletin of Botanical Survey, India*. **4(1-4)**: 227-231.

Shrestha, P. 1996. Diversity of aquatic macrophytes in the Koshi Tappu Wildlife Reserve and Surrounding areas, eastern Nepal. In: *Environment and Biodiversity in the context of South Asia* (Eds. P.K. Jha, G.P.S. Ghimire, S.B. Karmacharya & P. Lacoul). Ecological Society (ECOS), Kathmandu. pp. 203-211.

Shrestha, P. 1997. *Ecological study on aquatic macrophyte vegetation of lake Phewa and lake Rupa, Nepal*. Ph.D. Thesis, University of Vienna, Australia. 366 p.

Shrestha, P. 1998. *Aquatic macrophyte vegetation of lake Ghodaghodi, Western Nepal: existing status and management perspectives*. A report submitted to the IUCN/ Nepal.

Shrestha, P. 2000. Vegetation analysis of aquatic macrophytes by using line intercept in lake Phewa, Nepal. *Ecoprint* **7(1)**: 7-14.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163**: 688.

Singh, J.S. & S.P. Yadava. 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland of Kurukshetra, India. *Ecological Monographs* **44**: 351-376.

Sinha, A.B. 1969. *Investigation on the ecology of Ramgarh lake*. Ph.D. Thesis, Gorakhpur University, Gorakhpur.

Sinha, A.B. & R. Sahai. 1978. Studies on the factors affecting growth and productivity of free floating macrophytes in Ramgarh lake, Gorakhpur. In: *Glimpses of ecology* (Eds. J.S. Singh & B. Gopal). International Scientific Publisher, Jaipur. pp. 377-382.

Upadhyay, B.P. 2008. *Use of aquatic macrophytes as a low cost water quality monitoring tool at Biratnagar, Nepal*. Report submitted to the Dean, Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur, Kathmandu.

Vander valk A.G. & C.B. Davis. 1976. Changes in the composition, structure and production of plant communities along a perturbed wetland coenocline. *Vegetation* **32**: 87-96.

Zobel, D.B., P.K. Jha, U.K. Yadav & M.J. Behan. 1987. *A practical manual for ecology*. Kathmandu, Ratna Book Distributors. 149 p.