Quantitative analysis of macrophytes of Beeshazar Tal, Chitwan, Nepal

Chudamani Burlakoti* and Siddhi B Karmacharya

Central Department of Botany, Tribhuvan University, Kathmandu, NEPAL

** To whom correspondence should be addressed. E-mail: cmburlakoti@hotmail.com*

The authors undertook a quantitative investigation of aquatic macrophytes in Beeshazar Tal (Beeshazar Lake) in summer and winter of 2002 and spring of 2003. We found a distinct seasonal variation in the distribution of macrophytes: based on importance value index, Leersia hexandra Sw., Eichhornia crassipes (Mart.) Solms, Ceratophyllum demursum L. and Trapa quadrispinosa Roxb. were dominant in the summer; E. crassipes and Hydrilla verticillata (L.f.) Royle were dominant in the winter; and Ceratophyllum submersum L., H. verticillata, E. crassipes and L. hexandra were dominant in the spring. The highest species diversity was observed in the summer, followed by winter and then spring. The luxuriant growth of aquatic macrophytes evinced the highly productive nature of the lake, while the dominance of emergents among the growth forms indicates the encroachment of littoral vegetation, indicating a successional trend toward marsh meadow.

Key words: Oxbow lake, macrophytes, importance value index, species diversity

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Aquatic macrophytes are macroscopic forms of aquatic vegetation, including macroalgae, mosses, ferns and angiosperms found in aquatic habitat. They have evolved from many diverse groups and often demonstrate extreme plasticity in structure and morphology in relation to changing environmental condition (Wetzel 1983). Aquatic macrophytes in different growth forms represent the most important biotic element of the littoral zone in a lake ecosystem (Piecznyska 1990). Two factors, number of species and importance values (numbers, biomass, productivity, and so on) of individuals, determine the species diversity of a community (Odum 1996). Importance Value Index (IVI), a quantative parameter, is useful, as it provides an overall picture of the density, frequency and cover of a species in relation to community (Curtis and McIntosh 1951).

Most of the lakes on the plains of the Terai are oxbow systems (Sharma 1973) and possess a luxuriant growth of aquatic vegetation (BPP 1995, Bhandari 1998b). Some of these lakes are already on the verge of disappearance whereas others are highly vulnerable to degradation due to physiographic features as well as anthropogenic activities (BPP 1995, Bhandari 1998b). Out of 51 wetland sites surveyed by the Biodiversity Profile Project (BPP), 10 sites were identified as meriting immediate protection (BPP 1995); Beeshazar Tal (Lake) in Chitwan District was one. However, no conservation measures have been undertaken to protect the lake. Growth of invasive species, natural eutrophication, seasonal fluctuation of water level and lack of efficient inlet and outlet are the major threats to the lake. The lake therefore demands concerted attention towards a clear understanding of its ecosystem in order to mitigate further deterioration. Though the studies on various aspects of ecology of Beeshazar Tal have been conducted by various workers (Jones et al. 1989, BPP 1995, McEachern 1996, Jayana 1997 and Bhandari 1998a), there are almost no quantitative studies of macrophytes. Hence, the objective of the present study is to assess the richness and composition of macrophytes of the lake in terms of seasonal variation. This study is expected to be helpful in designing a plan for the sustainable management of the lake.

Materials and methods

Study area

Beeshazar Tal is a shallow dissected fern-shaped oxbow lake running northeast to southwest and surrounded by the Sal (*Shorea robusta*) forest and marshy land typical of the inner Terai. Located at 27°37'19"N and 84°26'29"E, at an elevation of 183 m asl (SD 1994), the lake is situated in the buffer zone of Royal Chitwan National Park (RCNP) adjacent to Khageri Irrigation Canal, within the Barandabhar forest patch; it is a habitat corridor between RCNP and the Siwalik forests. Numerous wetlands are found along the canal. Bhandari (1998a) reported the area of the Beeshazar Tal to be 100 ha, while BPP (1995) reported that the entire area of the lake system adjacent to the Khageri Irrigation Canal covers 180 ha, of which only 5.5% is permanent lake. Beeshazar has a maximum depth of 6 m and an average depth of 3 m. The water balance of the lake was found to be determined by precipitation and ground water seepage: the lake has no proper inlet or outlet. The area is famous for its biodiversity. Altogether 21 species of mammals, 13 species of reptiles, 17 species of fishes, 37 species of aquatic insects, 273 species of birds (60 species being wetland dependent) and 131 species of plants (including 99 aquatic species) have been identified in and around Beeshazar Tal (Bhandari 1998a). Some of the more charismatic fauna in the area are the Royal Bengal tiger (*Panthera tigris*), one-horned rhinoceros (*Rhinoceros unicornis*), mugger crocodile (*Crocodylus palustris*), asiatic rock python (*Python molurus*), and the lesser adjutant stork (*Leptoptilos javanicus*, a globally threatened bird); there is also an insectivorous bladderwort (*Utricularia aurea*). In September 2003 the lake, along with its surrounding area (a total of 3200 ha), was named 'Beeshazar and Associated Lakes' as one of the new Ramsar site (RCW 2003).

Methods

We studied quantitative parameters of Beeshazaar Tal macrophytes in the littoral zone of three different sites around the lake during three seasons: summer (5-15 August 2002), winter (5-15 December 2002) and spring (5-15 May 2003). These three sites were selected for macrophyte sampling as representative of the entire lake system. To analyze the macrophytes community, we applied a random sampling method along several transects with the help of a 1m×1m light wooden quadrat. The quadrat size was determined by the species area curve method as mentioned in Zobel et al. (1987). The length of transects and number of quadrats in each transect within each sampling unit were adjusted according to the depth of the littoral zone. Each transect was taken from the shoreline itself perpendicularly towards the centre of the lake as far as the depth where submerged species were seen. The macrophytes were counted by hand picking. The centre of the lake was not covered for quadrat study because of mugger crocodile infestation. Altogether 36 quadrats in the lake were studied during each season – 12 qudrats from each sampling unit.

Importance Value Index (IVI) was calculated by totaling the relative values of density, frequency and cover (by visual estimation); and Shannon-Weiner's (1963) index of species diversity (H) were calculated following the mathematically manipulated formula (cf. Zobel et al. 1987).

The plant species were identified with the help of standard literature (Khan and Halim 1987, Cook 1996, Gurung 1991 and Press et al. 2000) and visual inspection by taxonomists. All specimens were crosschecked against specimens at Tribhuvan University Central Herbarium (TUCH). The voucher specimens were deposited at TUCH, Kathmandu.

Results and discussion

Altogether 61 species of macrophytes were recorded in the present study. The highest number of species was occupied by angiosperms (both dicots and monocots) (**Figure 1**). Lack of shady and moist habitat has limited the pteridophytes to two species.

Macrophytes in the present study were categorized into four main growth forms following Shrestha (1998). Rooted plants with main photosynthetic parts projecting above the water surface were classified as *emergents*, rooted plants with leaves floating on the water surface were classified as *rooted floating-leaved macrophytes*, rooted or floating plants completely or largely submerged were classified as *submerged macrophytes*, and plants with crown floating on the water surface were classified as *free-floating macrophytes*. In terms of the number of species, emergent species constituted the largest group, followed by submerged, rooted floating-leaved, and free-floating species (**Figure 2**). Our conclusion that emergents outnumbered submerged and floating species is substantiated by Sheerwani (1962) and Shrestha (1996 and 1998).

The number of aquatic macrophyte species was higher during the summer (39) and winter (37) and lower during the spring (29) (**Table 1**).

The dominance of species by growth forms on the basis of IVI value is presented in **Table 1**. Emergents were the most dominant form throughout the year. This can be attributed to the emergents' high tolerance for fluctuation of water level (Van der Valk and Davis 1976). Seasonally, emergents' IVI was highest in the summer, followed by winter and spring. Among emergents, *Leersia hexandra* was the most dominant in the summer and the spring, and *Cyperus alternifolius* subsp. *flabelliformis* in the winter.

After emergents, the next highest IVI values were those of free-floating species in the summer and winter, and submerged species in the spring. The dense growth of free-floating and rooted floating-leaved species prevented colonization of submerged species in the summer and the winter season (Kaul et al. 1978). Among the free-floating species, *Eichhornia crassipes* was highly dominant throughout the year. The largest IVI values for this species were found in the winter (43.5), followed by the spring (34.71) and the summer season (27.25). Lesser growth of *E. crassipes* in the spring than in the winter may be the result of human removal of this species from the canal site (which was one of the three sampling units) at the end of winter. During the summer, *E. crassipes* was found to flow with water from the lake to the adjacent canal by means of breaches in the dike between the lake and the canal due to seasonally high water levels. Consequently, the lowest IVI value for *E. crassipes* was observed during the summer. *E. crassipes* was not reported in the earlier studies of Beeshazaar Tal (BPP 1995, Jayana 1997, Bhandari 1998a). Its current dominance may be ascribed to its invasive nature and also its preference for highly eutrophic and stagnant water. Gopal and Sharma (1990) also found a similar relation between growth pattern and level of eutrophication. Beeshazaar Tal has been categorised as hypereutrophic (Burlakoti 2003) on the basis of nutrient criteria proposed by Forsberg and Ryding (1980).

Among the submerged species, *Ceratophyllum submersum*, *Hydrilla verticillata* and *C. demursum* were observed to be the most dominant species throughout the year. The vigorous year-round growth of *H. verticillata* indicates its ability to adapt in diverse conditions. Shingal and Singh (1978) also found this species in a lake area characterized by high silt load and cultural eutrophication. The silt load and the eutrophication in the Beeshazar Tal were found to be due to the transportation of silt, organic matter and litter from the catchment area at the time of flooding. Similar findings regarding *H. verticillata* are reported by Acharya (1997) and Shrestha (2000). The dense growth of *Ceratophyllum demursum* in the summer

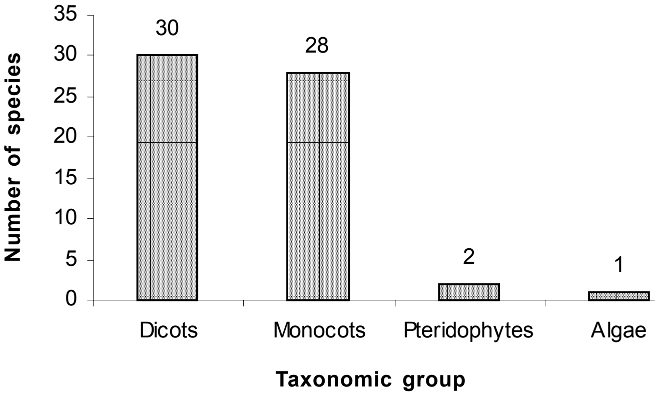

FIGURE 1. Number of species by taxonomic group

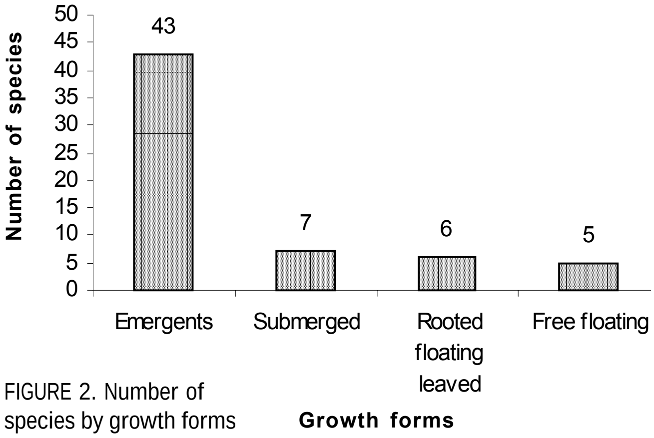

FIGURE 2. Number of species by growth forms

TABLE 1. Seasonal variation in IVI values of macrophytes by growth forms

Species, categorized by growth form	Importance value index (IVI) in			
Submerged	**Summer**	**Winter**	**Spring**	**Average**
Hydrilla verticillata (L.f.) Royle	16.37	24.9	54.54	31.94
Ceratophyllum submersum L.	12.67	23.74	55.83	30.75
Ceratophyllum demursum L.	23.61	11.56	0	11.72
Chara sp.	0	6.03	0	2.01
Potamogeton pectinatus L.	0	0	5.43	1.81
Utricularia aurea Lour.	0	0	4.18	1.39
Vallisneria natans (Lour.) H. Hara	0	3.51	0	1.17
Total	**52.65**	**69.74**	**119.98**	**80.79**
Free-floating				
Eichhornia crassipes (Mart.) Solms	27.25	43.5	34.71	35.15
Azolla pinnata R.Br.	0	21.15	0	7.05
Spirodela polyrhiza (L.) Schleid	19.41	0	0	6.47
Lemna perpusilla Torr.	12.22	6.86	0	6.36
Pistia stratiotes L.	6.04	6.29	0	4.11
Total	**64.92**	**77.8**	**34.71**	**59.14**
Rooted floating-leaved				
Trapa quadrispinosa Roxb.	19.31	0	12.19	10.50
Ipomoea aquatica Forssk.	7.69	13.11	3.05	7.95
Ludwigia adscendens (L.) H. Hara	8.75	5.34	2.78	5.62
Nymphaea stellata var. *versicolor* (Sims) Hook. f. and Thomson	2.1	3.09	0	1.73
Nymphoides hydrophyllum (Lour.) Kuntze	3.23	0	1.91	1.71
Nelumbo nucifera Gaertn.	1.5	0	1.35	0.95
Total	**42.58**	**21.54**	**21.28**	**28.47**
Emergent				
Leersia hexandra Sw.	38.97	18.56	36.83	31.45
Cyperus alternifolius subsp. *flabelliformis* (Rottb.) Kuk.	0	22.04	19.31	13.78
Persicaria hydropiper (L.) Spach	22.54	12.53	5.73	13.60
Alternanthera sessilis (L.) DC.	14.05	0	10.79	8.28
Imperata cylindrica (L.) P. Beauv.	4.87	8.16	6.91	6.65
Phragmites karka (Retz.) Trin. ex Steud.	2.82	5.29	11.28	6.46
Persicaria barbata (L.) H. Hara	0	17.29	0	5.76
Cyperus iria L.	13.8	0	0	4.60
Saccharum spontaneum L.	5.43	6.29	0	3.91
Echinochloa colona (L.) Link	4.49	6.26	0	3.58
Hemarthria compressa (L.f.) R. Br.	4.13	2.38	3.53	3.35
Pennisetum orientale Rich.	0	9.18	0	3.06
Ipomoea carnea subsp. *fistulosa* (Mart. ex Choisy) D.F. Austin	3.57	3.48	0.82	2.62
Panicum sp.	0	0	6.14	2.05

Table continued on next page...

season can be attributed to the high growth potential of this species in sedimentation-prone areas (Segal 1971) and to the eutrophic condition of lake (Zutshi and Vass 1976). The sedimentation load was high in the summer season due to flooding in the catchment.

Among the growth forms, rooted floating-leaved species were the least dominant in terms of IVI value. The dense growth of rooted floating-leaved species, especially *Trapa quadrispinosa* in the spring and summer, may be attributed to better adaptability of the rooted floating-leaved species to the stresses of water level fluctuation, to the tearing action of water turbulence, and to turbidity of water (Papastergiadou and Babalonas 1992).

Estimating annual average IVI values, we found that emergents were dominant, followed by the submerged, free-floating and rooted floating-leaved species. Previously, the lake was mostly covered by submerged and the rooted floating-leaved species (BPP 1995).

Species diversity was highest for the emergents followed by the rooted floating-leaved, submerged and free-floating species respectively (**Table 2**). This trend may be attributed to the increase in species richness with decrease in water depth (Van der Valk and Davis 1976, Handoo and Kaul 1982). The highest species diversity index for the entire community, 4.17, was found in the summer, as compared to 4.06 in the winter and 3.17 in the spring (Shrestha 2000). The seasonal variation in requirements of the diverse growth forms may cause the variation in the species diversity.

Management implications

The excessive growth of macrophytes was probably due to high nutrient level in the Beeshazar Tal. There is no outlet to flush the accumulated nutrients from the decomposed macrophytes; the consequent high rate of oxidative processes renders the lake anoxic. In addition, respiration by the *E. crassipes* (water hyacinth) roots contributes to oxygen depletion and changes the water chemistry (McEachern 1993). When a lake becomes choked by water hyacinth, the number of birds and other animals in the upper strata of the food chain decreases significantly (cf. Sah and Sah 1999).

Though Beeshazar Tal now belongs to the Ramsar Site as well as to the buffer zone of Royal Chitwan National Park, no serious steps have been taken for the sustainable management of the lake. Local people have been removing the unnecessary growth of macrophytes only at the canal site of the lake in the post-winter season for the last few years. However, as the invasive *E. crassipes* from the lake was not completely extirpated, the surface of ➜

the lake was again found to be wholly occupied by the species within a few months.

Accumulation of silt and detritus from the catchment area and decomposition of macrophytes reduces the water quality as well as the core area of the lake and promotes the encroachment of littoral vegetation, a familiar successional trend as the oxbow lake is transformed into marsh meadow (Wetzel 1983). Without inlet or outlet, the lake derives water only from subsurface seepage and precipitation, and water level fluctuation is common. The failure of the dike during the summer due to the rise in water level is also common. Recently the local Lake Management Committee drew up plans to construct a proper inlet and outlet for the lake, but work has been postponed due to the lack of adequate financial support. A sustainable management plan should be formulated and implemented soon if Beeshazar Tal's diverse ecosystem is to be preserved. The highest priority must be given to inlet and outlet construction and to removal of *E. crassipes*.

Conclusion

The luxuriant growth of the macrophytes reveals the productive nature of the lake. The dominance of emergents among other growth forms (as shown by IVI measurements) indicates the encroachment of littoral vegetation, reducing the core area of the lake and showing the trend of succession towards marsh meadow condition. The dominance of previously absent *Eichhornia crassipes* indicates its invasive nature which explains the fact that the lake is becoming anoxic. The fact that emergents have the highest species diversity and submerged species the lowest signifies the increasing richness in species with decreasing water level, a general trend during the course of succession. ■

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TABLE 1. Seasonal variation ...[continued from previous page]

Species, categorized by growth form	**Importance value index (IVI) in**			
Emergent	**Summer**	**Winter**	**Spring**	**Average**
Centella asiatica (L.) Urb.	2.05	1.76	2.11	1.97
Echinochloa crus-galli (L.) P. Beauv.	0	0	5.71	1.90
Agreatum houstonianum Mill.	0	1.64	3	1.55
Monochoria vaginalis (Burm. f.) C. Presl	0	2.5	2.12	1.54
Paspalum scrobiculatum L.	4.62	0	0	1.54
Persicaria lapathifolia (L.) S.F. Gray	0	0	4.16	1.39
Typha angustifolia L.	2.42	1.15	0	1.19
Persicaria glabra (Willd.) M. Gomez	0	3.56	0	1.19
Panicum repens L.	3.4	0	0	1.13
Lindernia anagallis (Burm. f.) Pennell	1.63	1.14	0	0.92
Limnophila chinensis (Osbeck) Merr.	0	0	2.75	0.92
Schoenoplectus mucronatus (L.) Palla	1.16	1.31	0	0.82
Polygonum plebeium R. Br.	2.13	0	0	0.71
Rumex dentatus subsp. *klotzschianus* (Meisn.) Rech. f.	0.9	0.75	0	0.55
Ranunculus sceleratus L.	0.96	0.61	0	0.52
Diplazium esculentum (Retz.) Sw. ex Schrad.	0.94	0.55	0	0.50
Smithia sensitiva Aiton	1.35	0	0	0.45
Paspalum distichum L.	0.56	0	0.65	0.40
Vetivaria lawsoni (Hook. f.) Blatt. and McCann	0	1.17	0	0.39
Phyla nodiflora (L.) Greene	0	1.09	0	0.36
Rotala indica (Willd.) Koehne	0	1.09	0	0.36
Cassia tora L.	1.06	0	0	0.35
Oenanthe javanica (Blume) DC.	0	0	0.98	0.33
Lindernia antipoda (L.) Alston	0	0	0.87	0.29
Eclipta prostrata (L.) L.	0	0	0.7	0.23
Axonopus compressus (Sw.) P. Beauv.	0.61	0	0	0.20
Commelina diffusa Burm. f.	0.56	0	0	0.19
Justicia procumbens var. *simplex* (D. Don) T. Yamaz.	0.56	0	0	0.19
Ottelia alishmoids (L.) Pers.	0	0.51	0	0.17
Total	**139.58**	**130.29**	**124.39**	**131.42**
Grand total	**299.73**	**299.37**	**300.36**	**299.82**

TABLE 2. Seasonal variation in species diversity index values

Growth forms of species	**Shannon-Weiner's index of species diversity (H)**			
	Summer	**Winter**	**Spring**	**Average ± sd**
Submerged	1.527	2.020	1.325	1.624 ± 0.21
Free-floating	1.862	1.656	0.000	1.173 ± 0.83
Rooted floating-leaved	2.083	1.412	1.963	1.819 ± 0.29
Emergent	3.324	3.051	3.229	3.201 ± 0.11
Community as a whole	4.170	4.060	3.170	3.800 ± 0.45

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