

CONTRIBUTION TO AQUATIC MACROPHYTES OF BIRATNAGAR AND ADJOINING AREAS, EASTERN NEPAL

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ABSTRACT

One hundred and fifty three species of aquatic macrophytes (Angiosperms 141, Pteridophytes 8, Bryophytes 2, and Macroalgae 2) were collected from different aquatic habitats of Biratnagar and adjoining areas representing growth forms in the order: hyperhydrites (42 species) > tenagophytes (40) > helophytes (36) > vittates (16) > epihydrites (9) > pleustophytes (6) > rosulates (4). Emergent species dominated in number over floating and submerged species in all the water bodies. Fifty nine percent of collected species had flowering and fruiting in late rainy season, whereas 21.5 and 14.8% species had flowering and fruiting in winter and summer seasons, respectively. Most of the species had white flowers. Among the collected specimens, 46 species were used as feed for livestock, 20 species were pot-herb (edible), 7 species were used in handicrafts, and 3 species for thatch and cordage.

Key words: Aquatic habitats, Betana pond, species composition, growth forms, human use, Koshi Tappu Wildlife Reserve.

INTRODUCTION

Wetlands in Nepal are exclusively fresh water in nature. They occupy approximately 5% of the total area of the country mainly in the form of rivers, lakes, reservoirs, village ponds, paddy fields and marshes (HMG/N 1992). They harbour natural biotic components whose abundance influences the structural and functional characteristics of aquatic ecosystems (Canfield *et al.* 1984). Aquatic ecosystems in Nepal are crucial for food production: rice-paddy, fish and several types of vegetables; for the occurrence of medicinal plants, wild food, etc. and for the wild genetic resources of agro biodiversity (Bhandari 1998). The fisher folk and other ethnic communities depend on

aquatic ecosystems for fishing, river-transport and traditional crafts produced from aquatic macrophytes. These ecosystems are also important as bird's habitat, and out of 39 nationally protected species of fauna of Nepal under the National Parks and Wildlife Conservation Act 1973, the wild water buffalo, Gangetic dolphin, crocodile, tiger, elephant and rhinoceros are highly dependent upon aquatic ecosystems. Other importance of aquatic ecosystems includes water retention, replenishment of underground aquifers, and improvement of water quality.

Earlier, Joshi (1973), Hara *et al.* (1978-82), Pandit (1984), Shrestha (1994, 1996, 1999), Sah (1997), Jha *et al.* (2004, 2005) and Siwakoti

(2006) have listed some of the aquatic macrophytes found in Terai plain of eastern Nepal. This report enumerates (along with the growth form, habitat, frequency of occurrence, season of flowering and fruiting, and human use) aquatic macrophytes occurring in various types of water bodies at Biratnagar town, Singhia river (which forms the eastern border of Biratnagar town), Betana pond (located at the fringe of Char-koshe-Jhadi at about 27 km distance in north-east direction from Biratnagar town), and the Koshi Tappu Wildlife Reserve (KTWR) located at nearly 55 km distance in north-west direction from Biratnagar town.

MATERIALS AND METHODS

Study site: Biratnagar town (lat N 26°20', long E 87°16'; alt 72 m asl) is a part of riverine flood plain of Koshi river. It is bordered by Keshaliya river in the west and Singhia river in the east, and possesses several derelict depressions usually inundated during the rainy season. Besides these perennial water bodies the Biratnagar township has numerous seasonal wetlands such as irrigation canal, ditches along the road sides, man made ponds, marshes and paddy fields. Most of the industries as well as rapidly expanding municipality discharge their untreated effluents directly into these water bodies.

Koshi Tappu Wildlife Reserve (KTWR) (lat 26°34'- 36°45' N, long 86°55'- 87°05'E; alt 70-120 m msl) lies in the flood plain of Saptakoshi river spreading over 17,500 ha area in Sunsari and Saptari districts. The river has formed many permanent ponds and marshy lands along its lengths and seepage stream.

Betana (lat 26°39' N, long 87°25' E, alt. 115 m msl) spreads in 5.5 ha at the fringe of the Char-Koshe-Jhadi, is a natural freshwater oxbow pond. The pond is fed by direct atmospheric precipitation

and water released by the forest vegetation surrounding the pond. The water is drained out through outlets constructed at the southern bank particularly during rainy season when the pond becomes completely filled with water.

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

The specimens of the aquatic macrophytes were collected manually at monthly intervals from January 2008 to December 2009. The specimens were recorded, tagged and pressed to prepare herbaria. Identification was done with the help of standard literature (Hooker 1872-1897, Cook 1996). The identified specimens were confirmed by making crosschecks with the specimens housed at the Herbarium Centre, University Department of Botany, T.M. Bhagalpur University, India. The specimens are deposited at Herbarium Centre, University Department of Botany, T.M. Bhagalpur University, India for reference. The nomenclature of plants is based on Hara *et al.* (1978-1982) and Press *et al.* (2000). Growth form categories of the plants were determined as per Cook (1996). Uses of the plant species were determined either through interviews with local people or with the help of standard literature (Anonymous 1948-1976, GON 2007). Use categories were recorded as green manure/compost (GM/C), fish poison (FP), fodder (FO), food (F), genetic resource for breeding (GR), handicrafts (HC), medicinal (M), religious (R), and thatch and cordage (TC). Other specific uses (if any) were also noted. Coefficient of similarity of the plants occurring in different water bodies was also calculated using the Sorensens similarity index (SSI).

RESULTS AND DISCUSSION

Species composition: Altogether 153 species of aquatic macrophytes comprising angiosperms (Dicots 82, Monocots 59, Pteridophytes 8, Bryophytes 2, and Macroalgae 2), belonging to 107 genera and 52 families were recorded (Table 1). Among the families of angiosperms, the dominant ones in number of species included: Poaceae (26), Cyperaceae (20), Asteraceae (8), Scrophulariaceae (7), Polygonaceae (6), Hydrocharitaceae (6), Commelinaceae (5), Acanthaceae (4), Araceae (4), Lythraceae (4), Pontederiaceae (3), Potamogetonaceae (3), Onagraceae (3), and Nymphaeaceae (3). The dominance of grasses and sedges corresponded with the findings of Dangol *et al.* (1986) and Shrestha (1996). The dominance of monocots over dicots by species count but reverse case by number of families approached the study of Shrestha (1996), and Satyanarayan (1962). Number of species was highest in the KTWR (127), followed by Biratnagar township (108), Betana pond (66), and Singhia river (44). Aquatic macrophytes comprised 83.7% annuals (winter - 13.8%, summer - 21.6% rainy - 48.3%) and 16.3% perennials. Accumulation of nutrients, partially stagnant habitats and interconnection with other water bodies in KTWR may be favourable habitats for aquatic macrophytes. Biratnagar township showed maximum similarity (79%) with KTWR in species composition than and Singhia river (42%) and Betana pond (53%). Betana pond was a typical wetland habitat as it was physically isolated from surrounding water bodies, and it harboured specific plant species such as *Pandanus nepalensis* - a nationally threatened plant; *Calamus tenuis*, *Osbekia stellata*, *Blyxa japonica*, *Eriocaulon trilobum*, *Hydrocharis morsus-ranae* and *Riccia fluitans* not found in other habitats.

Growth forms: The growth forms of the aquatic macrophytes recorded in the present study were hyperhydrites (42) > tenagophytes (40) > helophytes (36) > vittates (16) > epihydrites (9) > pleustophytes (6) > rosulates (4). Emergents (helophytes, tenagophytes and hyperhydrites) had highest contribution in comparison to submerged (vittates, rosulates); rooted floating-leaved (epihydrites) and free-floating (pleustophytes) species. The dominance of emergents over floating and submerged species corresponded with the findings of Sheerwani (1962), Rajbhandari (1982), and Shrestha (1996). The dominance of emergents implies ecotone area (as in swamps and marshes) having high species diversity of aquatic macrophytes which can be attributed to the edge effect of ecotone area (Odum 1971). There was a general decreasing trend in diversity of aquatic macrophytes from shore line to the centre of all the water bodies, however, vittates and rosulates were more abundant than epihydrites and pleustophytes in the number of species in the centre of the water bodies.

Habitats and seasonal distribution: Species richness was maximum (87.5%–97%) during rainy and minimum (38%–48%) in winter season in all water bodies except Singhia river where maximum number of species occurred in winter (75%) and minimum in rainy (44%) season. Rivers, in general, represent the dynamic ecosystem in which spatial and temporal variations in water current, turbidity, and other physico-chemical characteristics of water create different types of fluvial environments (Gregory *et al.* 1991, Malanson 1993).

There was a seasonal variation in the occurrence of different growth forms and species composition. Most annual grasses and sedges; epihydrites, helophytes, hyperhydrites, rosulates and tenagophytes were abundant in the rainy season.

Table 1. Enumeration of aquatic macrophytes occurring at Biratnagar and adjoining areas (A- Betana pond, B-Biratnagar, C-Koshi Tappu Wildlife Reserve, D-Singhia river; + presence, - absence; Hel-helophytes, Ten-tenagophytes, Hyp-hyperhydrites. Eph-epiphytes, Ple-leustophytes, Ros-rosulate; Vit-vittates, F-food, FO-fodder, FP-fish poison, GM/C-green manure, compost, GR-genetic resource for breeding, HC-handicrafts, M-medicinal, R-religious, TC-thatch and cordage).

Family/Species	Growth form	Habitat	Occurrence				Flowering fruiting	Uses
			A	B	C	D		
A. Macroalgae								
Characeae								
1 <i>Chara schweinitzii</i> A. Braun	Vit	Clayey hard bottomed ditches, ponds	+	-	-	-	Jan -Mar	Larvicide
2 <i>Nitella mucronata</i> (Thuill) Kuentz	Vit	Silty bottomed pond	+	-	-	-	Oct - Dec	-
B Bryophytes								
Marchantiaceae								
3 <i>Marchantia palmata</i> Nees	Ten	East facing river beds	-	-	-	+	Feb -Jan	Soil binder
Ricciaceae								
4 <i>Riccia fluitans</i> L.	Ple	Shaded pond surface	+	-	-	-		-
C Pteridophytes								
Athyriaceae								
5 <i>Diplazium esculentum</i> (Retz.) Sw	Hel	Edge of water course, dams	-	+	+	-	Jul- Nov	F
Azollaceae								
6 <i>Azolla imbricata</i> (Roxb.) Nakai	Ple	Ditches, ponds	+	+	+	+		GM/C
Equisetaceae								
7 <i>Equisetum debile</i> Roxb. ex Vaucher	,	River beds, fringe of ponds	+	-	+	-	Aug-Nov	M
8 <i>E. diffusum</i> D. Don	Hel	River beds, fringe of ponds	-	+	+	-	Aug-Nov	-
Marsileaceae								
9 <i>Marsilea crenata</i> Presl	Hyp	Edge of water course, ditches	-	+	+	-	Aug-Dec	-
Parkeriaceae								
10 <i>Ceratopteris thalictroides</i> Brongn	Ten	Muddy edge of ponds, ditches	+	+	+	-	Jul-Nov	F/GM/C
Thelypteridaceae								
11 <i>Meniscium proliferum</i> (Retz.) Sw	Hel	Edge of water course	+	-	+	+	Jul-Nov	-
12 <i>Thelypteris dentata</i> (Forsk.) St. John	Ten	Marshes	+	-	-	-	Jul-Nov	-
D. Angiospermae - Dicotyledones								
Acanthaceae								
13 <i>Hygrophila auriculata</i> (Schumach.) Heine	Hyp	Edge of water course, ditches	-	+	+	-	Nov-Feb	M
14 <i>H. difformis</i> (L. f.) Blume	Hyp	Edge of water courses, ponds	+	-	+	-	Sep-Dec	-

15	<i>H. polysperma</i> (Roxb.) T. Anders	Ten	Edge of water courses, ponds	+ - + -	Sep-Dec	-
16	<i>H. quadrivalvis</i> (Ham.) Nees	Hyp	Edge of water courses, ponds	+ - + -	Sep-Dec	-
Amaranthaceae						
17	<i>Alternanthera philoxeroides</i> Griseb	Hyp	Muddy ponds, canals, ditches	- + - +	May-Sep	F/GM/C
18	<i>A. sessilis</i> (L.) DC.	Hel	Edge of ditches, moist soil	- + + +	Apr-Sep	F
Apiaceae						
19	<i>Centella asiatica</i> (L.) Urb.	Hel	Moist soil	- + + +	Feb-May	M
20	<i>Hydrocotyle sibthorpioides</i> Lam.	Hel	Moist soil	- + + +	Feb-May	-
21	<i>Oenanthe javanica</i> (Blume) DC.	Hyp	Marshes	+ - + +	May-Jul	F
Asteraceae						
22	<i>Caesulia axillaris</i> Roxb.	Hel	Wet paddy fields	- + + -	Sep-Nov	FO
23	<i>Cotula hemispherica</i> (Roxb.) Wall. ex C. B. Clarke	Hel	Paddy field	- + + -	Jan-Apr	-
24	<i>Eclipta prostrata</i> (L.) L.	Hel	Moist soil, edge of water course	- + + +	Jan-Dec	M
25	<i>Enydra fluctuans</i> Lourerio	Vit	Silty ponds, slow running water	+ - - -	Mar-June	FO
26	<i>Grangea maderaspatana</i> (L.) Poiret	Hel	Moist soil	- + - +	Jan-June	GM/C
27	<i>Mikania micrantha</i> Kunth	Hel	Ponds, ditches, moist soil	+ + + +	Nov-March	-
28	<i>Sphaeranthus indicus</i> L.	Hel	Paddy field	- + + +	Nov-Jan	M/Insect repellent
29	<i>Spilanthes iabadicensis</i> A. H. Moore	Ten	Edge of water course, marshes	+ + + +	Jan-Dec	-
Brassicaceae						
30	<i>Rorippa nasturtium-aquaticum</i> (L.) Hayek.	Hyp	Marshes	+ + + +	Dec-July	F
Cabombaceae						
31	<i>Caboma aquatica</i> Aublet	Vit	Silty ponds	+ - + -	Oct-Dec	Aquarium plant
Callitrichaceae						
32	<i>Callitriche stagnalis</i> Scopoli	Vit	Silty ponds	+ - + -	Oct-Dec	-
Ceratophyllaceae						
33	<i>Ceratophyllum demersum</i> L.	Vit	Silty ponds, canals	+ + + -	Oct-Nov	-
Convolvulaceae						
34	<i>Ipomoea aquatica</i> Forssk.	Eph	Ditches, ponds	- + + +	Mar-Dec	F/M
35	<i>I. carnea</i> Jacq. subsp. <i>fistulosa</i> (Mart. ex Choicy) D.F. Austin	Hyp	Edge of water courses, ponds	+ + + +	Apr-Jan	Fire wood
Fabaceae						
36	<i>Aescynemone asper</i> L.	Ten	Wet paddy fields	- + + -	Sep-Nov	FO
37	<i>Smithia ciliata</i> Royle	Ten	Moist, sandy edge of water course	- + - -	Sep-Nov	FO
Gentianaceae						
38	<i>Nymphoides hydrophyllum</i> (Lour.) O. Kuntze	Eph	Muddy ditches, canals	- + + -	Mar-Nov	M

39	<i>N. indica</i> (L.) O. Kuntze	Eph	Muddy ponds	- - + -	Mar-Nov	-
Hydrophyllaceae						
40	<i>Hydrolea zeylanica</i> (L.) Vahl	Hyp	Wet paddy fields	+ + + -	Nov-Feb	M
Lentibulariaceae						
41	<i>Utricularia aurea</i> Lour.	Vit	Muddy edge of permanent ponds	- + - -	Nov-Feb	-
42	<i>U. exoleta</i> R. Br.	Vit	Muddy permanent ponds, ditches	- + - -	Nov-Jan	-
Lythraceae						
43	<i>Ammania auriculata</i> Willd.	Ten	Edge of water courses	- + - -	Sep-Nov	FO
44	<i>Ammania baccifera</i> L.	Hel	Paddy fields	- + + -	Aug-Jan	-
45	<i>Rotala indica</i> (Willd.) Koehne	Ten	Wet paddy fields	- + + -	Sep-Aug	-
46	<i>R. rotundifolia</i> (Buch.-Ham. Roxb.) ex D. Don	Ten	Marshes	+ + + -	Apr-Aug	-
Melastomaceae						
47	<i>Osbeckia stellata</i> Buch.-Ham. ex D. Don	Hel	Fringe of oxbow pond	+ - - -	Aug-Jan	F
Nymphaeaceae						
48	<i>Euryale ferox</i> Salisb.	Eph	Cultivated, ponds, ditches	- + + -	Jun-Sep	F/R
49	<i>Nelumbo nucifera</i> Gaertn.	Eph	Muddy permanent ponds	- - + -	Aug-Nov	F/R
50	<i>Nymphaea pubescence</i> Willd.	Eph	Muddy ditches	- + + -	Aug-Nov	F/R
Onagraceae						
51	<i>Ludwigia adscendens</i> (L.) Hara	Eph	Ponds, ditches	- + + -	Nov-Feb	M
52	<i>L. octovalvis</i> (Jacq.) Raven	Hyp	Marshes	+ - + -	Oct-Jan	-
53	<i>L. perennis</i> L.	Ten	Marshes, ditches	+ + + +	Sep-Jan	M
Polygonaceae						
54	<i>Polygonum barbatum</i> (L.) Hara	Ten	Edge of water courses	- - + +	Jul-Jan	M
55	<i>P. glabrum</i> Willd.	Hyp	Muddy edge of permanent ponds	- + + -	Oct-Jan	M
56	<i>P. hydropiper</i> L.	Ten	Wet fields, ditches	+ + + +	Jul-Dec	FP
57	<i>P. lapathifolium</i> L.	Hyp	Muddy ditches, water course	+ + + -	Aug-Nov	FP
58	<i>P. plebeium</i> R. Br.	Hel	Moist sandy soil	- + + -	Jan-Jul	-
59	<i>Rumex dentatus</i> L.	Ten	Ditches	- + + +	Jan-Apr	F/ GM/C
Ranunculaceae						
60	<i>Ranunculus scleratus</i> L.	Hyp	Muddy ditches	- + + +	Jan-Apr	M
Scrophulariaceae						
61	<i>Bacopa monnieri</i> (L.) Pennell	Hel	Moist sandy soil	- - + -	Nov-Feb	M
62	<i>Linnophila heterophylla</i> (Roxb.) Benth.	Vit	Muddy permanent pond	+ - - -	Jan-Dec	M
63	<i>L. indica</i> (L.) Druce	Hyp	Edge of muddy ponds	+ - - -	Oct-Dec	-
64	<i>Lindernia ciliata</i> (Colsm.) Pennell	Hel	Moist sandy soil	+ + + +	Jul-Dec	F/M
65	<i>L. crustacea</i> (L.) F. Muell.	Hel	Moist soil	+ + + -	Jul-Feb	-

66	<i>L. antipoda</i> (L.) Alston	Hel	Moist sandy soil	- - + +	Jul-Feb	-
67	<i>Veronica anagallis-aquatica</i> L.	Ten	Moist sandy soil	- + + +	Jan-Apr	-
Sphenocleaceae						
68	<i>Sphenoclea zeylanica</i> Gaertn.	Ten	Paddy fields	+ + + -	Jul-Nov	F
Tamaricaceae						
69	<i>Tamarix dioica</i> Roxb.	Hel	Freshly formed sandy river beds	+ - - -	Aug-Nov	-
Trapaceae						
70	<i>Trapa natans</i> var. <i>bispinosa</i> (Roxb.) Makinno	Eph	Cultivated, ponds, ditches	- + + -	Nov-Jan	F
Verbenaceae						
71	<i>Lippia nodiflora</i> (L.) Rich.	Hel	Shaddy moist soil	+ + + +	Apr-Dec	M
E. Angiospermae-Monocotyledones						
Alismataceae						
72	<i>Sagittaria guyanensis</i> Kunth.	Eph	Paddy fields, ditches	- + + -	Sep-Nov	M
73	<i>S. trifolia</i> L.	Ten	Marshes	- - + +	Jan-Jul	-
Amarylidaceae						
74	<i>Crinum asiaticum</i> L.	Hel	Edge of ditches, water course	- + - -	May-July	-
Aponogetonaceae						
75	<i>Aponogeton appendiculatus</i> H. Bruggen	Ros	Sandy bottomed running water	+ - + -	Aug-Jan	-
Araceae						
76	<i>Acorus calamus</i> L.	Ten	Marshes	+ + + +	Apr-Aug	M/Insect repellent
77	<i>Colocasia esculenta</i> (L.) Schott.	Ten	Muddy ditches, canals	- + - +	Jul-Oct	FO/F
78	<i>Lasia spinosa</i> (L.) Thwaites	Ten	Fringe of oxbow pond-silty marshes	+ - - -	Apr-Aug	F
79	<i>Pistia stratiotes</i> L.	Ple	Ponds, ditches	+ + + +	Oct-Dec	M/GM/C
Areaceae						
80	<i>Calamus tenuis</i> Roxb.	Ten	Silty marshes	+ - - -	Jul-Dec	HC
Butomaceae						
81	<i>Butomopsis latifolia</i> (D. Don) Kunth	Hyp	Wet paddy fields	- + + -	Sep-Nov	-
Cannaceae						
82	<i>Canna indica</i> L.	Ten	Muddy ditches	- + + -	Jan-Dec	FO
Commelinaceae						
83	<i>Commelina benghalensis</i> L.	Hel	Edge of water course, ditches	+ + +	Jul-Nov	-
84	<i>C. paludosa</i> Blume	Hel	Paddy fields	- + + -	Aug-Dec	-
85	<i>Floscopa scandense</i> Lour.	Ten	Edge of ditches, ponds	+ + + -	Jul-Nov	FO
86	<i>Murdania nudiflora</i> (L.) Brenan	Hel	Paddy fields	- + + -	Aug-Nov	FO
87	<i>M. vaginata</i> (L.) Brueckns	Hel	Paddy fields	- + + -	Aug-Nov	FO

Cyperaceae						
88	<i>Carex nubigana</i> D. Don	Hyp	Swamps	+ - - -	Mar-Dec	-
89	<i>Cyperus compressus</i> L.	Hel	Marshes	+ + + +	June-Dec	FO
90	<i>C. corymbosus</i> Rottb.	Ten	Marshes	+ + + -	June-Nov	HC
91	<i>C. difformis</i> L.	Ten	Marshes	- + + +	Aug-Dec	-
92	<i>C. esculentus</i> L.	Hyp	Marshes, paddy fields	- + + -	Aug-Nov	HC
93	<i>C. iria</i> L.	Hel	Fallow paddy fields	- + + -	Aug-Nov	FO
94	<i>C. natans</i> Vahl	Ten	Muddy edge of ponds	+ - + -	Aug-Nov	FO
95	<i>C. pilosus</i> Vahl	Hyp	Swamps	- + + -	Sep-Dec	-
96	<i>C. platystylis</i> R. Br.	Ten	Marshes	- - + -	Aug-Oct	-
97	<i>Eleocharis atropurpurea</i> (Retz.) Kunth	Hyp	Marshes	- + + -	Aug-Nov	FO
98	<i>Fimbristylis dichotoma</i> (L.) Vahl	Hyp	Edge of ponds	+ - + -	Aug-Dec	FO
99	<i>F. littoralis</i> Gaud.	Ten	Wet paddy fields	- + + -	Aug-Nov	FO
100	<i>F. miliacea</i> (L.) Vahl	Ten	Wet paddy fields	- + + +	Aug-Nov	FO
101	<i>F. schoenoides</i> (Retz.) Vahl	Ten	Wet paddy fields	- + + -	Sep-Nov	FO
102	<i>Kyllinga brevifolia</i> Rottb.	Hel	Moist fields	- + + -	Aug-Feb	FO
103	<i>Mariscus compactus</i> (Retz.) Druce	Ten	Marshes	+ + + -	Aug-Dec	-
104	<i>Pycreus flavidus</i> (Retz.) Koyama	Ten	Edge of silty ponds	+ - + -	Aug-Nov	-
105	<i>Schoenoplectus grossus</i> (L. f.) Palla	Hyp	Swamps	- + + -	Oct-Jan	F/M/HC
106	<i>S. juncooides</i> (Roxb.) Palla	Hyp	Marshes	- + + -	Sep-Nov	-
107	<i>S. mucronatus</i> (L.) Palla	Hyp	Marshes, edge of ponds	+ - + +	Jan-Dec	HC
Eriocaulaceae						
108	<i>Eriocaulon cinereum</i> R. Br.	Hyp	Wet paddy fields	- + + -	Sep-Nov	-
109	<i>E. trilobum</i> Ham. Kornicke	Hyp	Marshes	+ - - -	Jul-Nov	-
Hydrocharitaceae						
110	<i>Blyxa japonica</i> (Miq.) Maxim	Vit	Silty permanent pond	+ - - -	Sep-Nov	FO
111	<i>Hydrilla verticillata</i> (L. f.) Royle	Vit	Muddy river beds, ponds	- + + +	Sep-Nov	-
112	<i>Hydrocharis morsus-ranae</i> L.	Ros	Silty ponds	+ - - -	Sep-Dec	-
113	<i>Nechamandra alternifolia</i> (Roxb.) Thwaites	Vit	Silty ponds	- - + -	Oct-Nov	-
114	<i>Ottelia alismoides</i> (L.) Pers.	Ros	Muddy ditches, canals	+ + + -	Aug-Dec	M
115	<i>Vallisneria natans</i> (Lour.) Hara	Ros	Muddy ditches, canals	- + + -	Aug-Dec	M
Juncaceae						
116	<i>Juncus bufonius</i> L.	Hyp	Marshes	+ - + -	Jul-Nov	FO

Lemnaceae						
117	<i>Lemna minor</i> L.	Ple	Ditches	- + + +	Sep-Nov	-
118	<i>Spirodela polyrhiza</i> (L.) Schleiden	Ple	Ditches	- + + +	Sep-Nov	-
Najadaceae						
119	<i>Najas graminea</i> Dulile	Vit	Silty permanent ponds	- - + -	Oct-Nov	-
Pandanaceae						
120	<i>Pandanus nepalensis</i> St. John	Hel	Fringe of oxbow ponds	+ - - -	July-Nov	R
Poaceae						
121	<i>Arundinella bengalensis</i> (Sprengel) Druce	Hyp	Muddy ditches, canals	+ + + +	Aug-Nov	FO
122	<i>A. nepalensis</i> Trin.	Hyp	Muddy ditches, canals	- + + -	Aug-Nov	FO
123	<i>Brachiaria mutica</i> (Forsskal) Stapf	Hyp	Paddy fields	- + + -	Sep-Dec	FO
124	<i>Coix lacryma-jobi</i> L.	Hel	Edge of ditches	- + - -	Aug-Feb	FO/M
125	<i>Echinochloa colona</i> (L.) Link	Ten	Paddy fields, ditches	- + + -	Aug-Nov	FO
126	<i>E. crus-galli</i> (L.) Beauvois	Hyp	Paddy fields	- + + -	Apr-Sep	FO
127	<i>E. crusgavonis</i> (H. B. & K.) Schult.	Ten	Sandy marshes	- - + -	Apr-Dec	FO
128	<i>E. stagnina</i> (Retz.) Nees ex Steudel	Ten	Ditches	- + + -	Aug-Jan	FO
129	<i>Eragrostis unioides</i> (Retz.) Nees ex Steudel	Hel	Moist fields	+ + + -	Aug-Dec	FO
130	<i>Hemarthria compressa</i> (L. f.) R. Br.	Ten	Moist fields	- + + -	Jan-Nov	FO
131	<i>Isachne dispar</i> Trin.	Ten	Marshes	+ + + -	Sep-Dec	FO
132	<i>Ischaemum rugosum</i> Salisb.	Hel	Paddy fields	- + + -	Aug-Dec	FO
133	<i>Leersia hexandra</i> Swartz.	Hyp	Ditches, marshes	- + + -	Jan-Dec	FO/GR
134	<i>Leptochloa chinensis</i> (L.) Nees	Ten	Ditches	- + + -	May-Nov	FO
135	<i>Oryza rufipogon</i> Griff.	Hyp	Ditches	- + + -	Sep-Jan	GR
136	<i>O. sativa</i> L.	Hyp	Cultivated	- + + -	Jul-Nov	F
137	<i>Panicum paludosum</i> Roxb.	Hyp	Ditches, ponds	+ + + -	Aug-Nov	FO
138	<i>Panicum psilopodium</i> Trin.	Hyp	Edge of water course	+ + + +	June-Oct	FO
139	<i>Paspalidium punctatum</i> (Brum.) A. Camus	Hyp	Ditches	- + + -	Jul-Dec	FO
140	<i>Paspalum distichum</i> L.	Hyp	Ditches	- + + +	Aug-Feb	FO
141	<i>P. scrobiculatum</i> L.	Ten	Marshes	+ + + -	Jul-Feb	FO
142	<i>Phragmites karka</i> (Retz.) Trin. ex Steudel	Hel	River beds, fringe of ponds	+ - + -	Jul-Dec	FO/TC
143	<i>Saccharum spontaneum</i> L.	Hel	River beds, edge of water course	+ + + +	Aug-Nov	FO/TC
144	<i>Sacciolepis indica</i> (L.) Chase	Hyp	Ditches	- + + -	Aug-Dec	FO
145	<i>S. interrupta</i> (Willd.) Stapf	Hyp	Ditches, water course	- + + +	Nov-Jan	FO
146	<i>Vetiveria zizanioides</i> (L.) Nash	Ten	Marshes	+ + + -	Jul-Dec	HC
Pontederiaceae						
147	<i>Eichhornia crassipes</i> (Mart.) Solms.	Ple	Ditches, ponds	+ + + +	Apr-Nov	GM/C

148	<i>Monochoria hastata</i> (L.) Solms.	Hyp	Muddy ditches	+++ -	Jul-Oct	F
149	<i>M. vaginalis</i> (Brum.) Kunth	Hyp	Wet paddy fields, ditches	- ++ -	Aug-Nov	M
Potamogetonaceae						
150	<i>Potamogeton crispus</i> L.	Vit	Clayey hard bottomed ditches, canals	- ++ +	Feb-Apr	Prown habitat
151	<i>P. nodosus</i> Poir.	Vit	Silty permanent ponds	- - + -	Feb-June	FO
152	<i>P. pectinatus</i> L.	Vit	Silty permanent ponds	- - + -	Feb-May	-
Typhaceae						
153	<i>Typha angustifolia</i> L.	Hyp	Marshes, swamps	+++ -	Jul-Nov	HC/ TC

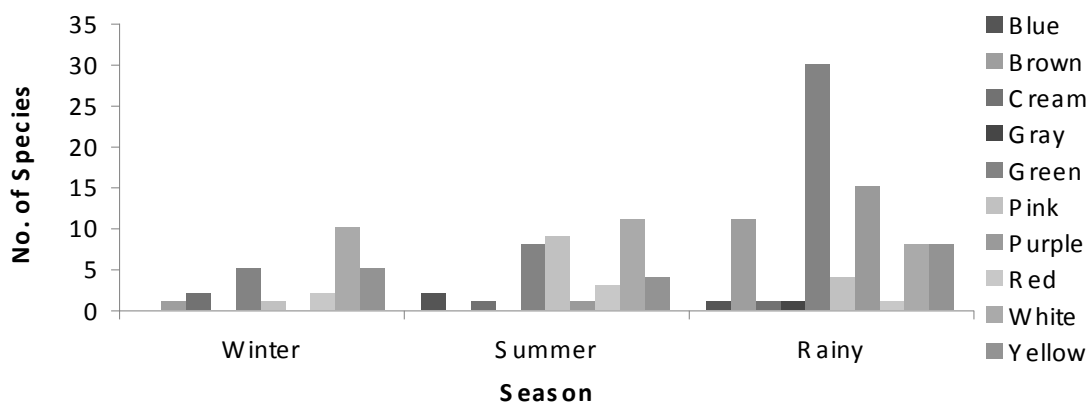


Fig. 1. Seasonal distribution in flower colour of the aquatic macrophytes in the study

Some vittates (*Blyxa japonica*, *Ceratophyllum demersum*, *Enydra fluctuans* and *Hydrilla verticillata*) occurred throughout the year. Most free floating- pleustophytes (*Azolla imbricata*, *Lemna minor*, *Spirodela polyrhiza* and *Pistia stratioites*); some tenagophytes (*Rumex dentatus*, *Sagittaria trifolia* and *Veronica anagallis-aquatica*); hyperhydrites (*Ranunculus scleratus*) and vittates (*Chara* sp., *Potamogeton* spp., *Utricularia* spp.) were the common winter species. Among pleustophytes *Eichhornia crassipes* manifested gregarious monospecific stands in all seasons. It was also found as hyperhydrite in wetlands enriched with organic nutrient load. Some hyperhydrites and tenagophytes including *Hydrolea*

zeylanica, *Ipomoea carnea*, *Lasia spinosa*, *Spilanthus iabadicensis*, *Typha angustifolia* were found in both marshes as well as in moist terrestrial habitats. An invasive alien species (IAS), *Alternanthera philoxeroides*, occurring frequently in nutrient loaded/polluted water bodies of Biratnagar, was absent in Betana and KTWR. *Eichhornia crassipes*, *Ipomoea carnea* and *Mikania micrantha* as well as *Azolla imbricata*, *Arundinella bengalensis*, *Cyperus compressus*, *Lindernia ciliata*, *Lippia nodiflora*, *Ludwigia perennis*, *Pistia stratioites*, *Polygonum hydropiper*, *Rorippa nasturtium-aquaticum* and *Spilanthus iabadicensis* were present in all the water bodies.

Flowering, fruiting and flower colours: In all the water bodies, many of the plant species had white flowers in all the seasons; however most of the annuals growing during the rainy season had green flowers, and many of those growing in fall had purple flowers (Fig. 1). Dubey and Agrawal (1978) observed white flowers in majority of aquatic species throughout the year but complete absence of species with indigo flowers and fewer species with violet and blue flowers in a low-lying aquatic vegetation of Allahabad. Flowering and fruiting time for the aquatic macrophytes was maximum during late rainy season (59%) followed by winter (21.5%), and summer (14.8%) season. Some species (4.7%) had flowering and fruiting throughout the year as in *Spilanthus iabadicencis*, *Canna indica*, *Eclipta prostrata*, etc.

Human use potentials: Aquatic macrophytes were observed to play substantial role in the local socio-economy as feed for livestock (46 species), edible/pot-herb (20 species), green manure/compost (7 species), handicrafts as mats/brooms/basketry (7 species), fish poison (2 species), genetic resource for breeding stock (2 species), medicinal (25), religious (4 species), thatch and cordage (3 species) and of miscellaneous uses (food plates-*Nelumbo nucifera*, insect repellent-*Acorus calamus*, *Sphaeranthus indicus*, fire wood-*Ipomoea carnea*).

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