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ORIGINAL ARTICLE **OPEN ACCESS**

Phytosociology of Associated Aquatic Macrophytes coexisted with *Nymphoides aurantiaca* (Dalzell) Kuntze in Eastern Himalayan Foot Hill plain of West Bengal, India

Mallika Mazumder[1], Manas Dey[2] and Anup Kumar Sarkar[1]*
[1] Department of Botany, Dukhulal Nibaran Chandra College, Murshidabad, West Bengal, India. Pin-742201.
[2] Department of Life Science, Government Model School, Malbazar, Jalpaiguri, West Bengal, India. Pin-735218.
Corresponding Author,'s Email Id**:** anupsarkar.jpg@gmail.com

ABSTRACT
The species Nymphoides aurantiaca (Dalzell) Kuntze is commonly known as yellow-flowered snowflake plant. Recently the species has been re-discovered in some shallow ponds and ditches of Jalpaiguri district, which is topographically situated in Eastern Himalayan Foot-hill plain. Many aquatic plants and aquatic animals were recorded from this region. In this region most of the habitats of Nymphoides aurantiaca (Dalzell) Kuntze comprise a mosaic of different aquatic and semi-aquatic plants of various seral stages. Such plants are collectively called as associated flora and each plant of the habitat has significant influence on existence and establishment of all the species of the assemblage. As Nymphoides aurantiaca (Dalzell) Kuntze is still not abundant in this region it needs proper conservation. Implementation of conservation policy is almost impossible without proper knowledge of habitat specially phytosociological attributes of associated flora. In the present work, a gradual survey was conducted during pre-mansoon, mansoon and post monsoon seasons of 2017-2020 in order to determine the phytosociological status of aquatic macrophytes which inhabit with Nymphoides aurantiaca (Dalzell) Kuntze in the region. Including Nymphoides aurantiaca (Dalzell) Kuntze 17 plants were recorded from the assemblages.
Keywords: *Nymphoides aurantiaca (Dalzell) Kuntze, Eastern Himalyan Foot Hill plain, Jalpaiguri, Phytosociology, Associated flora.*

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INTRODUCTION

Aquatic and semi aquatic habitats of Eastern Himalayan foot hill region is well known for its biodiversity and richness in floral and faunal assemblages. Aquatic flora of this region is very unique in structure and composition. Aquatic macrophytes are remarkable components of aquatic ecosystems as well as other ecosystems. Technically aquatic macrophytes are those plants, which are completely or partially submerged or floating in water but visible to human eye [6]. Taxonomically aquatic macrophytes includes angiosperms, gymnosperms, pteridophytes , bryophytes and macroscopic algae that inhabit the inland aquatic ecosystem [17]. The aquatic ecosystem provides an important refuge for various plant species as well as other organisms like animal, microbes etc., [13, 16]. In Eastern Himalyan foot hill plain most of the aquatic vegetation comprise a mosaic of different aquatic plants of various seral levels [7]. Many aquatic plants were also reported from the region and some of them were newly discovered species where as some were rediscovery of rare and threatened species. Recently a rare and little known aquatic plant *Nymphoides aurantiaca* (Dalzell) Kuntze has been rediscovered from few ditches of Jalpaiguri district (Fig19-20) of West Bengal, India, which is a part of Eastern Himalyan foot hill plain [8]. The species is previously reported from Thailand, Oceania, Southern part of India and Srilanka [23].

Nymphoides aurantiaca (Dalzell) Kuntze is commonly known as water snowflake (Fig1-18) and is best grown in 30-60cm of standing water in organically rich sandy bottom loams or in submerged containers [7]. It needs full sun for its growth, however it may grows under partially shaded aquatic body. Although plants may be propagated by seed, the easiest method of reproduction is by dividing plantlets (http[1]). The plant mainly propagated by viviparous leaves. Though the genus is not common in occurrence but it is also not considered as threatened. According to Sivarajan [23] the species inhabit in shallow ponds, pools,

flooded lowlands, canals etc and usually coexisted with *Eleocharis, Eriocaulon and Najas*. However still there is no proper documentation of associated flora of the species as per our knowledge. When species interactions involve two or more plant species, intransitive competitive hierarchies promote coexistence even when species show large overlap in their niche requirements [1, 11]. Diversity of associated flora is an important factor for the ecesis and stability of any plant species as coexistence of any organism can influence the existence of that plant. Since last few decades considerable emphasis has been placed on associated flora during ecological study of any plant species, specially rare or threatened plant species. To assess the status of associated flora phytosociological measure is very useful as it allows rigorous statistical and mathematical evaluation [9]. It is also very effective to conserve any newly discovered or rediscovered rare species in a habitat or locality. To assess any kind of vegetation most of the ecologists prefer phytosociological attributes as it deals with quantification of plant communities, their composition, development, and the relationships between the species within the ecosystem [21]. Phytosociological parameters provide a clear view to look at the interaction between the plant species as well as between the plant and environment and it can also provide a clear cut evidence about status of diversity [4].

MATERIAL AND METHODS

Study Sites:

Present work deals with the phytosociological study of associated flora of *Nymphoides aurantiaca* (Dalzell) Kuntze in some aquatic and semi aquatic habitat of Eastern Himalayan Foot hill plain specifically in district Jalpaiguri. The entire topography of the study site is crisscrossed with rivulets, rivers and also characterized by presence of several ponds, ditches, jhoras and similar small aquatic bodies. Relatively sizeable population resides in Tea Gardens and Forest villages which are isolated and mostly inaccessible.

Vegetation survey and data analysis:

The vegetation survey was undertaken during pre mansoon, mansoon and post mansoon season of 2017 and 2020. The diversity of the associated vegetation of *Nymphoides aurantiaca* (Dalzell) Kuntze in this region was studied by quadrate method. For this purpose regular excursions were arranged in all sites at least once in a week. The excursions were arranged in such a way that most of the associated plants could be collected in different growth stages. All the plants encountered in the field sites were collected and identified carefully. Random quadrate method was adopted for studying phytosociological attributes of aquatic plants. For phytosociological analysis of the macrophytes, ten quadrats (50 X 50c.m.) were laid down at random at different places in the aquatic body where the plant was resided. The number of individuals and percentage cover value for each plant species were recorded [14, 15]. Plants were uprooted, thoroughly washed and collected separately in polythene bags. After drying, the collected plants were pressing in news papers, weather specimens collected free floating and rooted floating were stored in 4% formaline solution [5]. Macrophytes sorted out to species wise and given to them number, data collected from location about their frequency, abundance, density. The species are identified with standard books, Laboratory manuals and also compared with relevant articles [2, 6, 19]. For confirmation of identification some experts and workers were interviewed.

Data Analysis Techniques:

There are many ways in which aquatic vegetation can be studied and analyzed. In the present communication, several phytosociological parameters like abundance, Relative abundance, frequency, Relative frequency, density and Relative density etc., were calculated [18] to evaluate the diversity in associated flora. To assess the overall impact of a species Importance Value Index was determined by adding Relative frequency, Relative density and Relative abundance .

(a) Frequency (%): This term refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage. It is calculated by the equation:

$$\text{Frequency } (\%) = \frac{\text{No. of plot in which the species is present}}{\text{Total No. of plot sampled}} \times 100$$

(b) Relative Frequency (%): The degree of dispersion of individual species in an area in relation to the number of all the species occurred.

$$\text{Relative Frequency } (\%) = \frac{\text{Frequency of the species}}{\text{Frequency of all the species}} \times 100$$

(c) Density: Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrates is divided by the total number of quadrats studied. Density is calculated by the equation:

$$\text{Density} = \frac{\text{No. individuals of the species}}{\text{Total No. of plots sampled}}$$

(d) Relative Density (%): Relative density is the study of numerical strength of a species in relation to the total number of individuals of all the species and can be calculated as:

$$\text{Relative Density} = \frac{\text{Density}}{\text{Density of all the species}} \times 100$$

(e) Abundance: It is the study of the number of individuals of different species in the community per unit area. By quadrats method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrats divided by the total number of quadrats in which the species occurred. It is represented by the equation:

$$\text{Abundance} = \frac{\text{No. individuals of the species}}{\text{Total No. of plots in which the species is present}}$$

(f) Importance Value Index: This index is used to determine the overall importance of each species in the community structure. In calculating this index, the percentage values of the relative frequency, relative density and relative abundance are summed up together and this value is designated as the Importance Value Index or IVI of the species.

IVI= Relative Frequency + Relative Density + Relative Abundance

RESULT

Table 1: Phytosociological Parameters of associated flora of *Nymphoides indica* (L.) Kuntze in Eastern Himalayan Foot Hill Plain. [A-Abundance, D-Density, Fr-Frequency, RA-Relative Abundance, RD- Relative Density, RF- Relative Frequency, IVI-Importance Value Index]

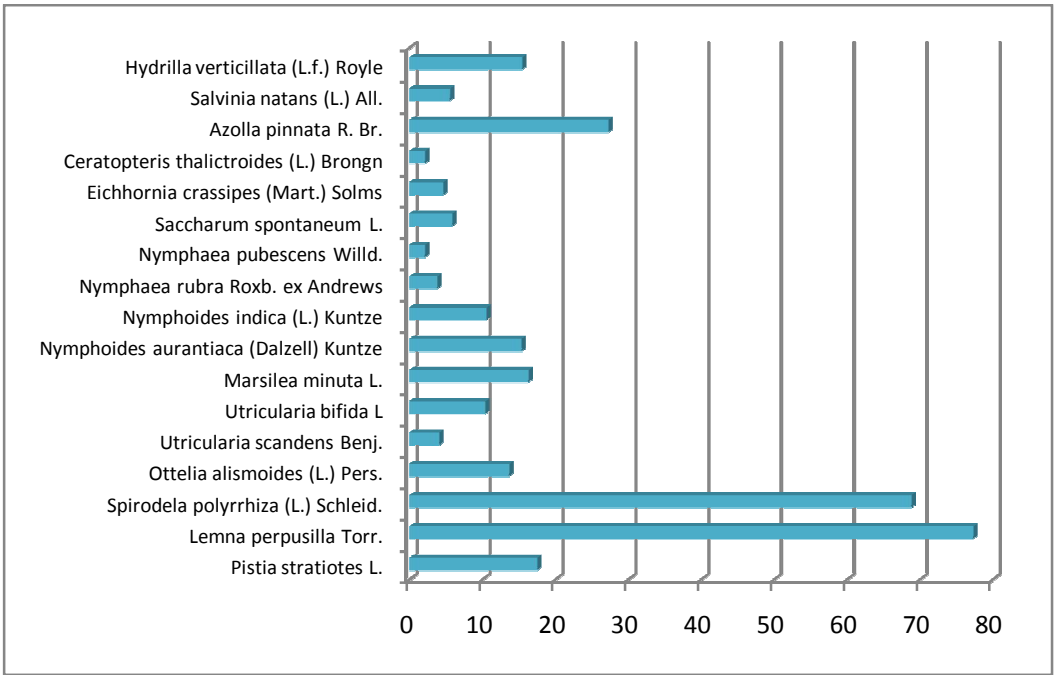
Sl. No.	Name of The Plant	Family	A	D	Fr (%)	RA (%)	RD (%)	RF (%)	IVI
1	Pistia stratiotes *L.*	Araceae	8.500	6.375	75.000	3.368	4.624	9.524	17.516
2	Lemna perpusilla *Torr.*	Araceae	81.600	51.000	62.500	32.329	36.990	7.937	77.256
3	Spirodela polyrrhiza *(L.) Schleid.*	Araceae	82.250	41.125	50.000	32.586	29.828	6.349	68.763
4	Ottelia alismoides *(L.) Pers.*	Hydrocharitaceae	4.333	3.250	75.000	1.717	2.357	9.524	13.598
5	Utricularia scandens *Benj.*	Lentibulariaceae	5.000	0.625	12.500	1.981	0.453	1.587	4.021
6	Utricularia bifida *L*	Lentibulariaceae	5.250	2.625	50.000	2.080	1.904	6.349	10.333
7	Marsilea minuta *L.*	Marsileaceae	9.800	6.125	62.500	3.883	4.442	7.937	16.262
8	*Nymphoides aurantiaca* (Dalzell) Kuntze	Menyanthaceae	2.375	2.375	100.000	0.941	1.723	12.698	15.362
9	*Nymphoides indica* (L.) Kuntze	Menyanthaceae	3.000	1.875	62.500	1.189	1.360	7.937	10.486
10	Nymphaea rubra *Roxb. ex Andrews*	Nymphaeaceae	1.000	0.250	25.000	0.396	0.181	3.175	3.752
11	Nymphaea pubescens *Willd.*	Nymphaeaceae	1.000	0.125	12.500	0.396	0.091	1.587	2.074
12	*Saccharum spontaneum* L.	Poaceae	4.500	1.125	25.000	1.783	0.816	3.175	5.774
13	Eichhornia crassipes *(Mart.) Solms*	Pontederiaceae	2.500	0.625	25.000	0.990	0.453	3.175	4.618
14	Ceratopteris thalictroides *(L.) Brongn*	Pteridaceae	1.000	0.125	12.500	0.396	0.091	1.587	2.074
15	Azolla pinnata *R. Br.*	Salviniaceae	27.500	13.750	50.000	10.895	9.973	6.349	27.217
16	Salvinia natans *(L.) All.*	Salviniaceae	4.000	1.000	25.000	1.585	0.725	3.175	5.485
17	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	8.800	5.500	62.500	3.486	3.989	7.937	15.412

During field visit, distribution of *Nymphoides aurantiaca* (Dalzell) Kuntze was found in different natural and semi-natural aquatic sites of Eastern Himalayan foot hill plains located in West Bengal, India. Its association found with other plant species also noticed in the study sites The present communication reflects a rich diversity of associated vegetation of the newly recorded aquatic plant species *Nymphoides aurantiaca* (Dalzell) Kuntze from the study sites. Seventeen species were recorded from the sampling

area where *Nymphoides aurantiaca* (Dalzell) Kuntze resided. Among them seven species are monocot, six species are dicot and four species are pteridophytes. In this phytosociological study it was found that Lemna perpusilla *Torr*. had highest IVI where as lowest IVI was recorded for *Ceratopteris thalictroides* (L.) Brongn (Table 1). The survey also showed that these aquatic species belong to various families. To aquire sufficient nutrients these plants resides in different zones of the aquatic habitat. Based on the morphoecological aspects aquatic plants are classified in to six groups- Free-floating hydrophytes, Rooted hydrophytes with floating Leaves, Submerged floating hydrophytes, Rooted submerged hydrophytes, Rooted emergent hydrophytes and Wetland hydrophytes. In this aquatic plant assemblage 6 species were free floating, 5 species were rooted submerged, 4 species along with *Nymphoides aurantiaca* (Dalzell) Kuntze were rooted hydrophytes with floating leaves, 1 species was Rooted emergent hydrophyte and 1 species was semi aquatic Rooted aerial plant (Table 2).

Table 2. Type of associated plants based on their preferable zone in the aquatic habitat.

Sl. No.	Name of the Plant	Seral Stage
1.	Pistia stratiotes *L.*	Free Floating
2.	Lemna perpusilla *Torr.*	Free Floating
3.	Spirodela polyrrhiza *(L.) Schleid.*	Free Floating
4.	Ottelia alismoides *(L.) Pers.*	Rooted submerged
5.	Utricularia scandens *Benj.*	Rooted submerged
6.	Utricularia bifida *L*	Rooted submerged
7.	Marsilea minuta *L.*	Rooted emergent hydrophytes
8.	*Nymphoides aurantiaca* (Dalzell) Kuntze	Rooted hydrophytes with floating leaves
9.	*Nymphoides indica* (L.) Kuntze	Rooted hydrophytes with floating leaves
10.	Nymphaea rubra *Roxb. ex Andrews*	Rooted hydrophytes with floating leaves
11.	Nymphaea pubescens *Willd.*	Rooted hydrophytes with floating leaves
12.	*Saccharum spontaneum* L.	Semi aquatic Rooted aerial plant
13.	Eichhornia crassipes *(Mart.) Solms*	Free Floating
14.	Ceratopteris thalictroides *(L.) Brongn*	Rooted submerged
15.	Azolla pinnata *R. Br.*	Free Floating
16.	Salvinia natans *(L.) All.*	Free Floating
17.	*Hydrilla verticillata* (L.f.) Royle	Rooted submerged



Graph 1: Graphical representation of IVI of associated plants

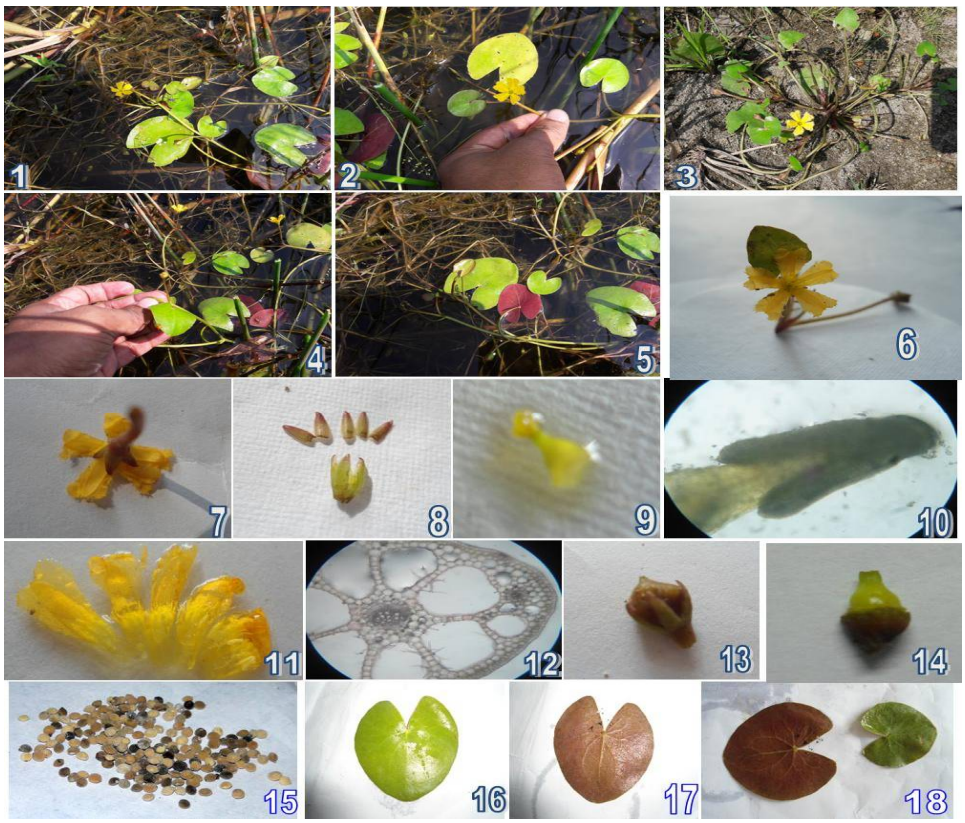


Fig: 1.– 5. Habit of the plant, 6. Flower, 7. Dorsal view of flower 8. Sepal, 9. Stamen, 10. Microscopic view of Anther, 11. Epipetalous stamen with Corolla, 12. T.S. of Petiole, 13. Persistent fruit, 14. Gynoecium, 15. Seeds, 16. Dorsal view of leaf, 17. Ventral side with gland of leaf, 18. Dorsal and Ventral view of Leaf

Fig: 19.Plant Specimen after Drying. 20.Harbarium Specimen Submitted at BSI, SHRC(Acronym BHSC, Accession No.0223)

Fig: 21. *Nymphoides indica* (L.) Kuntze; 22. *Eichhornia crassipes* (Mart.) Solms; 23. *Nymphaea pubescens* Willd.; 24. *Ottelia alismoides* (L.) Pers.; 25. *Spirodela polyrrhiza* (L.) Schleid.; 26. *Azolla pinnata* R. Br.; 27. *Pistia stratiotes* L.; 28. *Lemna perpusilla* Torr.; 29. *Marsilea minuta* L.; 30. *Hydrilla verticillata* (L.f.) Royle; 31. *Ceratopteris thalictroides* (L.) Brongn; 32. *Nymphaea rubra* Roxb. ex Andrews; 33. *Utricularia scandens* Benj.; 34. *Salvinia natans* (L.) All.; 35. *Saccharum spontaneum* L.

DISCUSSION

Eastern Himalayan foot hill plain region contain unique ecological feature and considered as one of the richest biodiversity region. Aquatic habitats of this region are also unique and harbor many plant and animal species. Aquatic plants provide various ecological services and make a substantial contribution to the structure and function of ecosystems and its components. Aquatic macrophytes not only contribute towards primary production but also influence the hydro-chemical processes and also serve as a substrate for the development of some animals [20]. Research interest in aquatic plants ranges from the use of aquatic plants as model organisms, to the roles of aquatic plants within ecosystems and to the conservation of aquatic plants themselves [16]. Identification of different associated plant is an important activity for monitoring of ecological health of an aquatic habitat and the changes of plant assemblages can be used as an indication of either pace of disappearance of a species or pace of colonization of the species. In an aquatic ecosystem plants of different seral stages adjusted themselves in such a way that all component get sufficient natural resources from the habitat. Each of them also contribute to the general fitness and diversity of healthy ecosystem by aiding in nutrient recycling [12]. Some macrophytes affect nutrient cycling by transference of chemical elements from sediment or other sources and affect other macrophytes. Many ecologists opined that macrophytes effectively influence several physicochemical properties of the water column like, conspicuous changes in oxygen, inorganic carbon, pH and alkalinity may result from their metabolism [3, 11]. Increases in the abundance and diversity of several attached floral group also influence the status of a particular species in a habitat. Usually plants growing together have mutual relationship among themselves and with the environment and such interactions among

different plants and between plants and their environment result in the outcome of different vegetation types in different areas [15, 22].

CONCLUSION

The present study reflects the phytosociological attributes of associated plants which share habitat with the plant *Nymphoides aurantiaca* (Dalzell) Kuntze in Eastern Himalayan Foot Hill plain. The region is widely known for its biodiversity. The aquatic habitats like reservoir, ponds, dams, drainage ditches jhoras of the study sites are very rich in plant diversity. The plant assemblage is composed of ferns and angiosperms (Fig 21-35). In general there was low abundance of Rooted hydrophytes with floating leaves and high abundance of free floating plants. Some plants were noted in most of the sampling sites inhabited by *Nymphoides aurantiaca* (Dalzell) Kuntze and these are Pistia stratiotes *L.,* Ottelia alismoides *(L.) Pers.,* Lemna perpusilla *Torr.,* Marsilea minuta *L., Nymphoides indica* (L.) Kuntze, *Hydrilla verticillata* (L.f.) Royle. As the plant is newly discovered and found very rarely in the ditches, the study recommends further research to be carried out about interrelationship patterns of *Nymphoides aurantiaca* (Dalzell) Kuntze and these frequently found associated plant. However increase of less frequent plants should also be checked as some of them may cause local extinction of *Nymphoides aurantiaca* (Dalzell) Kuntze.

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CONFLICT OF INTEREST

There is no conflict of interest.

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