International Journal of Pharmacy and Biological Sciences-IJPBS™ (2019) 9 (3): 954-965
Online ISSN: 2230-7605, Print ISSN: 2321-3272
Research Article | Biological Sciences | Open Access | MCI Approved
UGC Approved Journal

Exotic and Invasive Plants (Aquatic and Ecotone) of Nalbari District of Assam

Gunajit Kalita[1*], Durlav Nr Singha[2] and Sarada Kanta Sarma[3]
[1*]Department of Botany, Nalbari College, Nalbari, Assam.
[2]Department of Botany, Dakshin Kamrup College, Mirza, Assam.
[3]Department of Botany, Gauhati University, Assam.

Received: 25 Mar 2019 / Accepted: 27 Apr 2019 / Published online: 1 Jul 2019
*Corresponding Author Email: gunajit_kal@rediffmail.com

Abstract
The exotic aquatic invasive plant species degrades wetlands and initiates succession that causes slow death and gradual loss of productive life of the wetlands. The gregarious growth of aquatic macrophytes during rainy season and subsequent accumulation of organic debris during winter season in wetlands significantly changes the characteristics of the water bodies and reduces the water spread area of the wetlands. Their luxuriant growth and subsequent death and decay, and deposition make the wetland shallow which consequently promotes succession by terrestrial species. The management of aquatic invasive weeds is very important in the wetland conservation strategy. The invasion by aquatic weeds of feeder channels of the wetlands not only clogs the drainage systems but also alters the hydrology of the wetlands. The alteration in the hydrological regime makes the water body shallower in due course of time and this in turn invites more invasions by aquatic as well as terrestrial plant species. Thus once resourceful wetland becomes hydrocere in due course of time due to invasion and subsequent succession. In this context, ecological investigations have been carried out in some of the wetlands, low-lying water logged areas, rice fields etc of Nalbari district of Assam to document the aquatic and ecotone invasive plant species. The menace of invasion by aquatic macrophytes was observed in the above mentioned places. In a typical scenario during investigation it was observed that a floodplain wetland of Pagladia river is completely invaded by aquatic weeds and practically changed its wetland characteristics into that of a marshy land. A large number of aquatic macrophytes were recorded from those wetlands, of which some of the invasive species that grows gregariously *are Eichhornia crassipes, Hygroryza aristata, Cyclosorus gongyloides, Alpinia galanga, Echinochloa colonum, Ipomoea fistulosa, Ipomoea aquatica* etc. Most of these aquatic weeds were present throughout the year in the wetlands of Nalbari district of Assam. Their phenological characters shows interesting features like flowering stages of some species can be observed two to three times in a year. This indicates their resilience and potential to invade and destroy the water bodies in a very short span of time.

Keywords
Aquatic macrophytes, exotic plants, ecotone, invasive weeds, succession.

*****

INTRODUCTION

Invasive plant species are defined as "due to intentional or unintentional human involvement, all plant species which have arrived at an area in which they are alien, and caused negative ecological or economic impacts" (Pyšek *et al*. 2004). Invasive aquatic plants include those that are native to India but have been translocated outside their natural ranges within India or exotic aquatic plants introduced into India from other countries or regions and thereby cause negative impacts. Due to the lack of proper understanding and documentation, it is very difficult to give a comprehensive overview of information about the different routes of movement of native plants into different wetlands within India.

Wetlands and ox-bow lakes are locally known as "beels", "hola", "pitoni", "doloni", "pukhuris" in Assam and are the most resourceful ecosystems, these wetlands provide many resources to the people of the surrounding villages, which they use for themselves and also sells in the market. The wetlands are under threat due to invasion by alien plant species that has resulted in death of many wetlands. The excessive growth and expansion of many exotic plant species threaten the very survival and existence of native ones besides threatening faunal diversity like fishes and waterfowls. In India, invasive plants not only cause infestation to vast tracts of agricultural and forest land but find its way to different aquatic ecosystems including wetlands. The importance of wetland resources is first recognized and highlighted in the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, 1971) which has been instrumental in global action at the governmental level for conservation and wise use of wetlands. Ramsar Convention defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters'.

In Assam, different researchers have reported and made significant contributions from time to time about the wetlands and the aquatic plants including ecological studies of macrophytic species. (Kar *et al*., 2000; Verma, 1971, Malakar, 1995; Baruah *et al*., 1997, Kalita,2009.). In Assam, Kanjilal *et al*. (1934-40) in his book titles "Flora of Assam" records some angiospermic plant species. The pioneering work in the field of the study of hydrophytes was made by Sattya Narayan (1963) who record hydrophytic vegetation of Jalukbari area. Wetlands along with its biodiversity are presently getting dwindle alarmingly due to habitat alterations, pollution effects, overexploitation of aquatic bio-resources, tourism besides the introduction of invasive exotic species along with alien pathogens and parasites.

Thus, the presence and often dominance of invasive species in aquatic habitats has caused comparatively greater ecological and economic consequences than those in terrestrial environments (Vilà *et al*. 2010). Invasive aquatic plants may alter ecosystem structure, resulting in a significant negative impact on aquatic biodiversity and water quality (Zedler and Kercher, 2004; Chamier *et al*. 2012; Brundu, 2015), and thus are of great concern to both ecologists and environmental managers.

The survey of alien invasive plant species was undertaken in different wetlands, low-lying waterlogged areas, rice fields etc of Nalbari district of Assam to identify the most widespread plant invaders that have the potential to alter habitat structure, lower biodiversity, change nutrient cycling and productivity and modify food webs. Furthermore, the study underscores the need to identify key traits and factors that promotes invasiveness of wetlands so as to formulate effective strategies for restoration and management of the wetlands.

STUDY AREA

The name Nalbari means a place of reeds (common name for several tall grasses of wetlands). The Nalbari district of Assam lies between $26^0 10^/$ N and 26^0 47 $^/$ N latitude and $90^0 15^/$ E and 91^0 10 $^/$ E longitude. The area of Nalbari district is 2257 sq.km and is situated between Kamrup and Barpeta district. Baksa district is situated on its northern side. Nalbari district has subtropical climate, chilly winter, hot summer and wet monsoons. The district is influenced by south-west monsoon starting from the month of April and continues till late September with a normal annual rainfall of 2715.5 mm. The district harbours rich aquatic and ecotone plant species diversity owing to its low-lying waterlogged areas, ditches, rice fields and wetlands.

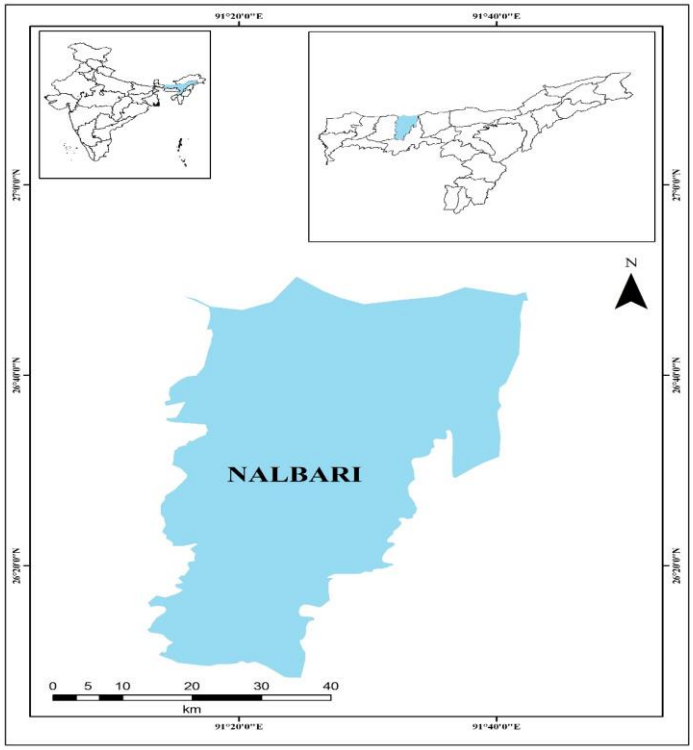

Figure: Location map of Nalbari district, Assam.

MATERIALS AND METHODS

Field observations and data collection were carried out in different low lying water logged areas of the district tried to include as much areas as possible and to get a representative idea of the whole district. Identification and confirmation of the specimen were done by comparing voucher specimens with Herbaria of department of Botany, Gauhati University, Guwahati and Botanical survey of India, Eastern circle, Herbarium, Shillong, Meghalaya. The nomenclature of identified specimens were determined through the consultation of websites Tropicos (www.tropicos.org) and the Plant List (www.theplantlist.org).

Since there is lack of proper monitoring and surveillance network agency for invasive species in India, the information and data used are taken from diverse sources which include community consultations, individual interviews, field observations, literature review, group discussions, unpublished literature, field investigations and internet databases. This study also brings about preliminary inventory of invasive aquatic plants in Assam. For each invasive aquatic plant species, information was recorded regarding the region of origin, habit, distribution in wetland, and life span.

The observations for the frequency data were taken during the period 2015 to 2017 for the three seasons ie. Summer, rainy and winter by quadrate of one square meter randomised in the selected sites. The frequency distributions were done by random sampling method. Frequency class of each species were done by Raunkiaer's method (1934). Frequency class gives an idea of distribution of a species throughout a community.

Frequency classes are **A**: (1-20) 20%, **B**: (21-40) 40%, **C** (41-60) 60%, **D** (61-80) 80%, **E** (81-100) 100%.

High frequency value indicates that the community is homogeneous and low species diversity.

Index of Dominance was done by Simpson's (1949) method.

$D = \sum (n_i / N)^2$

Higher values indicate high dominance and low species diversity.

RESULT AND DISCUSSION

Table 1: Invasive plant species with their ecological characteristics.

Name of the exotic & invasive Species	Family	Growth forms	Life span	Progagules	Nativity	Dominance index	Frequency class (as %)
Aeschynomene aspera L.	Fabaceae	Herb	Perennial	Rhizome, Seeds	Tropical Africa	0.74	80%
Alocasia esculenta (L.) Schott	Araceae	Herb	Perennial	Corm	South India, South East Asia	0.72	80%
Alpinia nigra(Gaertn)Burtt.	Zingiberaceae	Herb	Perennial	Rhizome, Seeds	South East Asia	0.77	80%
Alpinia galanga(L.)Sw.Willd.	Zingiberaceae	Herb	Perennial	Rhizome, Seeds	South East Asia	0.79	80%
Alternanthera philoxeroides (Mar) Grisep.	Amaranthaceae	Herb	Perennial	Rhizomatous root	Tropical America	0.74	80%
Alternanthera tenella Colla	Amaranthaceae	Herb	Perennial	Seeds	Tropical America	0.79	80%
Aponogeton undulatus Roxb.	Aponogetonaceae	Aquatic Herb	Perennial	Rhizome, Seeds	Tropical America	0.80	100%
Argemone mexicana L.	Papaveraceae	Herb	Perennial	Seeds	Tropical America	0.75	80%
Ageratum conyzoides L.	Asteraceae	Herb	Annual	Seeds	Tropical America	0.79	80%
Azolla pinnata R.Brown.	Salviniaceae	Aquatic Herb	Annual	spores	Tropical America	0.81	100%
Barringtonia acutangula L	Lecythidaceae	Herb	Annual	Rhizome, Seeds	Tropical America	0.77	80%
Calotropis procera (Ait.) R.Br.	Asclepiadaceae	Shrub	Perennial	Seeds	Tropical Africa	0.72	80%
Calotropis gigantea (L.) R.Br.	Asclepiadaceae	Shrub	Perennial	Seeds	Tropical Africa	0.70	80%
Ceratophyllum demersum L	Ceratophyllaceae	Aquatic Herb	Perennial	Rhizome, Seeds	Tropical America	0.86	100%
Chara zeylanica L	Characeae	Aquatic Herb	Perennial	Spores,rhizoides	Tropical America	0.76	100%
Chromolaena odorata (L.) King & Robinson	Asteraceae	Herb	Perennial	Seeds	Tropical America	0.91	100%
Cleome rutidosperma DC.	Cleomaceae	Herb	Annual	Seeds	Tropical America	0.55	60%
*Cleome viscosa*L.	Cleomaceae	Herb	Annual	Seeds	Tropical America	0.57	60%
Croton bonplandianum Boil.	Euphorbiaceae	Herb	Annual	Seeds	Temperate South America	0.52	60%
Cuscuta reflexa Roxb.	Cuscutaceae	Herb	Perennial	Seed	Mediterranean	0.50	60%
Cyclosorus interruptus (Willd.) H.Ito	Thelypteridaceae	Herb	Perennial	Rhizome,	Unknown	0 69	80%

Datura metel L.	Solanaceae	Shrub	Perennial	Seeds	Tropical America	0.53	60%
Dysophylla auricularia L.	Lamiaceae	Herb	Annual	Seeds		0.77	80%
Eclipta prostrata (L.) L.	Asteraceae	Herb	Perennial	Seeds	Tropical America	0.58	60%
Eichhornia crassipes (C. Martius) Solms-Loub.	Pontederiaceae	Herb	Perennial	Offset,Seeds	Tropical America	0.90	100%
Echinochloa colona L.	Poaceae	Herb	Perennial	Rhizome, Seeds	Tropical Africa	0.87	100%
Echinochloa crus-pavonis Kunth	Poaceae	Herb	Perennial	Rhizome, Seeds	Tropical Africa	0.82	100%
Euryale ferox Salisb	Nymphaeaceae	Aquatic Herb	Perennial	Rhizome, Seeds	Tropical Africa	0.55	60%
Evolvulus nummularius(L.) L	Convolvulaceae	Herb	Annual	Seeds	Tropical America	0.70	80%
Fuirena cillaris L.	Cyperaceae	Herb	Annual	Seeds	Tropical Africa	0.74	80%
Houttuynia cordata Thun	Saururaceae	Herb	Annual	Seeds	Tropical Africa	0.71	80%
Hyptis suaveolens (L.) Poit.	Lamiaceae	Herb	Perennial	Seeds	Tropical America	0.67	80%
Ipomoea carnea Jacq.	Convolvulaceae	Shrub	Perennial	Seeds	Tropical America	0.73	80%
Imperata cylindrica (L.)Raensch	Poaceae	Herb	Perennial	Seeds	Tropical America	0.68	80%
Lantana camara L.	Verbenaceae	Shrub	Perennial	Seeds	Tropical America	0.73	80%
Ludwigia adscandens (L.) Hara	Onagraceae	Herb	Annual	Seeds	Tropical America	0.66	80%
Lemna paucicostata Hegelm.	Alismataceae	Aquatic Herb	Perennial,	Seeds	Tropical Africa	0.89	100%
Limnophila chinensis Osbeck	Plantaginaceae	Aquatic Herb	Perennial,	Seeds	Tropical Africa	0.82	100%
Ludwigia octavalis (Jacq.) Raven	Onagraceae	Herb	Perennial	Seeds	Tropical Africa	0.68	80%
Merremia aegyptia (L.) Urban.	Convolvulaceae	Climber	Annual	Seeds	Tropical America	0.72	80%
Mikania micrantha Willd.	Asteraceae	Climber	Perennial	Seeds	Tropical America	0.63	80%
Mimosa pudica L.	Mimosaceae	Herb	Annual	Seeds	Brazil	0.71	80%
Monocharia vaginalis C.Presl.	Pontederiaceae	Herb	Annual	Seeds	Tropical America	0.85	100%
Nechamandra alternifolia Roxb.	Hydrocharitaceae	Herb	Annual	Seeds	Tropical Africa	0.49	60%
Neptunia prostrata Lam.	Fabaceae	Herb	Annual	Seeds	Tropical Africa	0.47	60%
Ottelia alismoides L.	Hydrocharitaceae	Aquatic Herb	Perennial	Rhizome, Seeds	Tropical Africa	0.91	100%
Oxalis corniculata L.	Oxalidaceae	Herb	Annual	Seeds	Europe	0.69	80%

Parthenium hysterophorus L.	Asteraceae	Herb	Annual	Seeds	Tropical North America	0.83	100%
Peperomia pellucida (L.) Kunth	Piperaceae	Herb	Annual	Seeds	Tropical South America	0.70	80%
Persicaria barbata L.	Polygonaceae	Herb	Annual	Seeds	Tropical America	0.69	80%
Pistia stratiotes L.	Araceae	Herb	Annual	Stolons,Seeds	Tropical America	0.88	100%
Portulaca oleracea L.	Portulaceae	Herbs	Annual	Seeds,cuttings	Trop. South America	0.72	80%
Polygonium oleracea L.	Polygonaceae	Herbs	Annual	Seeds	Tropical Africa	0.89	100%
Salvinia molesta Mitcheel.	Salvinaceae	Herb	Annual	Veg. growth and fragmentation	South Eastern Brazil	0.77	80%
Scoparia dulcis L.	Scrophulariaceae	Herb	Annual	Seeds	Tropical America	0.68	80%
Schoenoplectus tabernaemontani Palla.	Cyperaceae	Herb	Perennial	Seeds	Tropical America	0.63	80%
Saccharum spontaneum L.	Poaceae	Herb	Perennial	Rhizome, stem fragments	Trop. West Asia	0.67	80%
*Senna alata(*L.) Roxb.	Caesalpiniaceae	Shrub	Perennial	Seeds	West Indies	0.60	80%
*Senna occidentalis (*L.) Link	Caesalpiniaceae	Herb	Perennial	Seeds	Trop. South America	0.62	80%
*Senna tora(*L.) Roxb.	Caesalpiniaceae	Herb	Annual	Seeds	Trop. South America	0.71	80%
Solanum torvum Sw.	Solanaceae	Shrub	Perennial,	Seeds	West Indies	0.87	100%
Synedrella nodiflora (L.) Gaertn.	Asteraceae	Herbs	Annual	Seeds	West Indies	0.70	80%
Sparganium eurycarpum Engelm	Typhaceae	Shrub	Perennial,	Seeds	Tropical Africa	0.66	80%
Sparganium emersum Rehmann.	Typhaceae	Shrub	Perennial,	Seeds	Tropical Africa	0.63	80%
Tridax procumbens L.	Asteraceae	Herb	Perennial	Seeds	Tropical America	0.77	80%
Typha angustata Bory. & Choub.	Typhaceae	Herb	Perennial	Rhizomes	Tropical America	0.69	80%
Urena lobata L.	Malvaceae	Shrub	Perennial	Seeds	Tropical Africa	0.72	80%
Xanthium strumarium L.	Asteraceae	Herb	Perennial	Seeds	Tropical America	0.87	100%
Xyris indica L.	Xyridaceae	Herb	Annual	Seeds	Tropical Africa	0.81	100%

Table 2: Dominant families of invasive plant species

Family	Number of invasive plant species
Asteraceae	08
Poaceae	04
Convolvulaceae	03
Caesalpinaceae	03
Typhaceae	03
Fabaceae	02
Araceae	02
Zingiberaceae	02
Amaranthaceae	02
Salvinaceae	02
Asclepiadaceae	02
Cleomaceae	02
Solanaceae	02
Lamiaceae	02
Cyperaceae	02
Hydrocharitaceae	02
Onagraceae	02
Polygonaceae	02
Aponogetonaceae	01
Alismataceae	01
Papaveraceae	01
Lecythidaceae	01
Ceratophyllaceae	01
Characeae	01
Euphorbiaceae	01
Cuscutaceae	01
Thelypteridaceae	01
Pontederiaceae	01
Nymphaeaceae	01
Saururaceae	01
Verbenaceae	01
Plantaginaceae	01
Mimosaceae	01
Oxalidaceae	01
Piperaceae	01
Portulaceae	01
Scrophulariaceae	01
Malvaceae	01
Xyridaceae	01

Fig 1: Distributional pattern of total recorded plants into different families

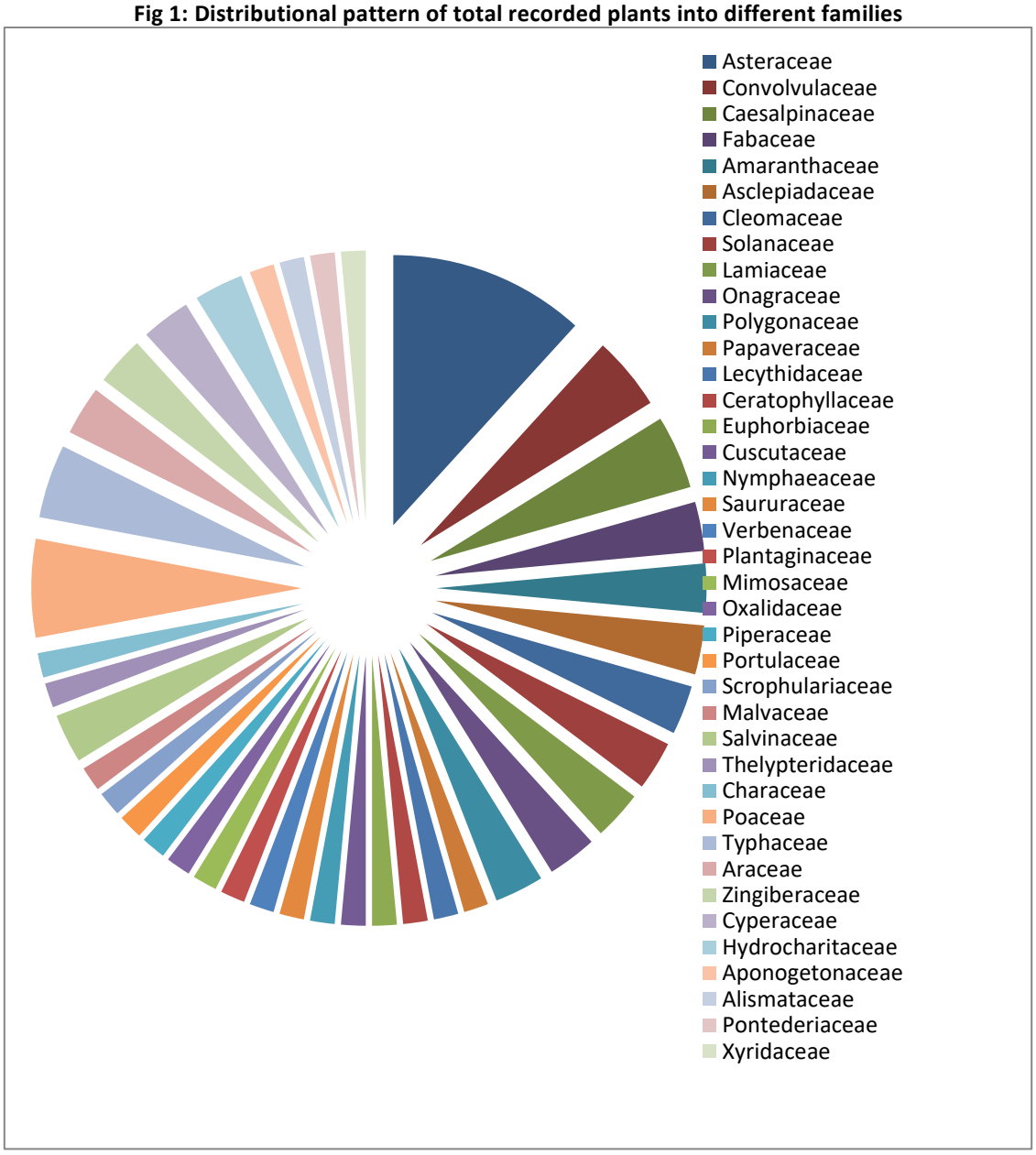

Fig 2: Distributional pattern of dicot plants into different families

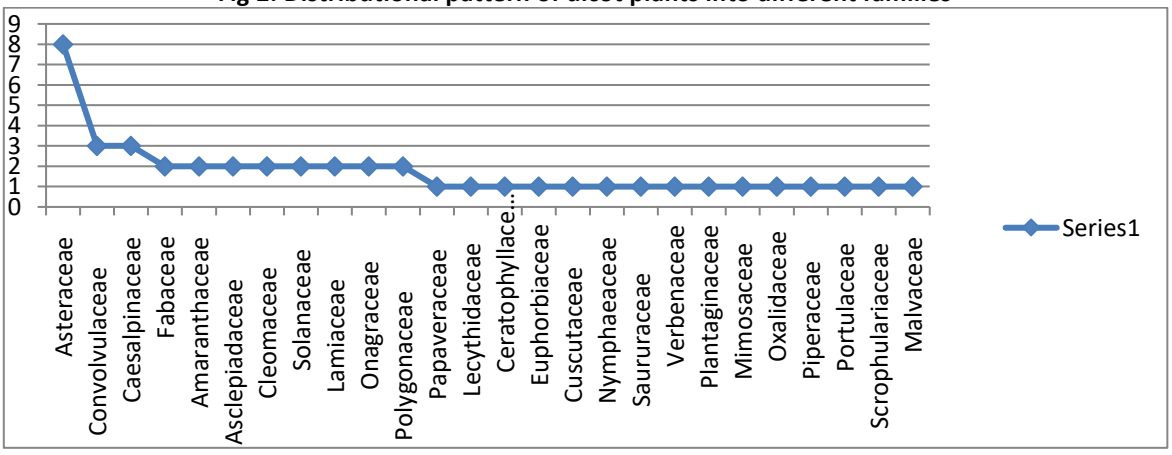

Fig 3: Distributional pattern of monocot plants into different families

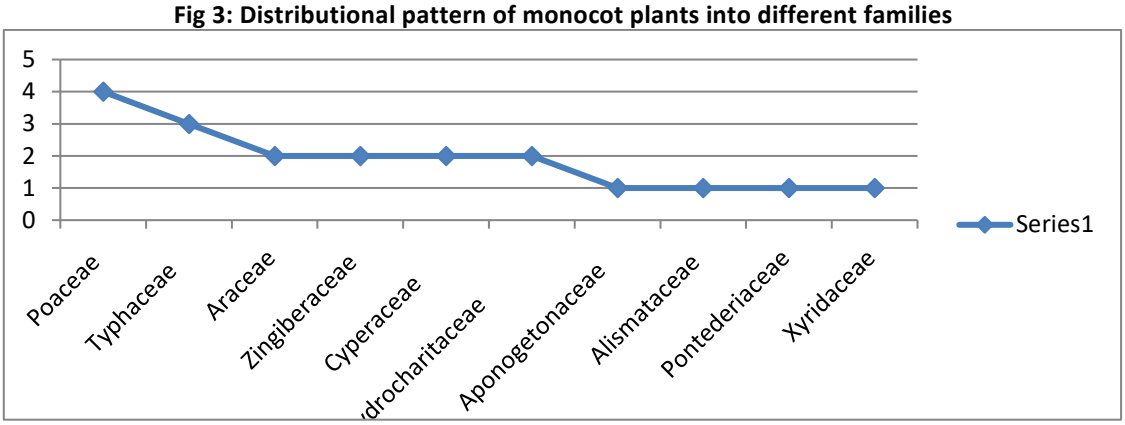

Fig 4: Distributional pattern of ferns and algae into respective families

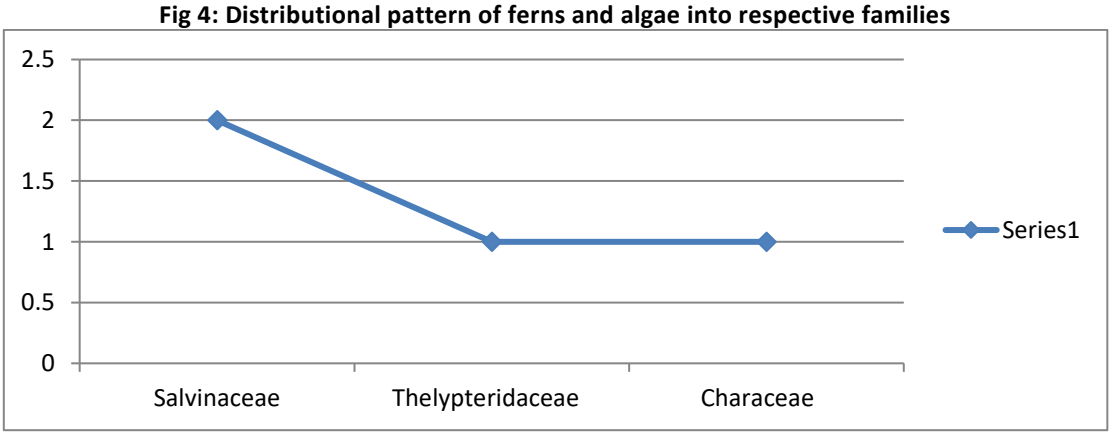

Table 3: Class frequency of invasive plant species

CLASS FREQUENCY (%)	NUMBER OF INVASIVE SPECIES
A (0 – 20)	0
B (21 – 40)	0
C (41 – 60)	9
D (61 – 80)	42
E (81 – 100)	18

The waterlogged areas, wetlands, low-lying areas and rice fields of Nalbari district had the above tabulated aquatic and ecotone plant species which were seemed to be invasive. Altogether 69 invasive plant species belonging to 40 families were recorded from the study sites occurring in different seasons of the year. These species belong to different life forms viz. herbs, aquatic herbs, shrubs, grasses, climber etc. Dominant aquatic invasive plant species of the district were *Alternanthera philoxeroides*, *Eichhornia crassipes, Ipomoea fistulosa, Ipomoea aquatica, Ludwigia octavalvis, Ottelia alismoides, Monocharia vaginalis, Cyclosorus interruptus, Salvinia molesta, Typha angustata* etc. Besides there were many dominant invasive plant species in ecotone regions viz. *Alpinia galanga, Alpinia nigra, Argemone mexicana*, *Calotropis procera*, *Senna occidentalis*, *Senna tora*, *Chromolaena odorata, Cleome viscosa*, *Croton bonplandianum*, *Cuscuta reflexa*, *Datura metel*, *Eclipta prostrata, Imperata cylindrica*, *Lantana camara*, *Mikania micrantha*, *Mimosa pudica*, *Parthenium hysterophorus*, *Urena lobata, Xanthium strumarium* etc.

Invasive aquatic plant species were introduced from different parts of the world and also from other parts of India into Nalbari district over the period of time. Geographical information in regard to the nativity of invasive aquatic plant species in studied wetlands were also shown in (table 1). Habitat destruction and anthropogenic activities by humans was responsible for rapid invasion of alien and non-native plant species into the core area of the wetlands. Blockages

of inlet and outlet feeder channels by invasive species halt nutrient flow and alter the hydrology of the water bodies and thereby initiate succession. The invasive species were fast growing and due to the long viability of seeds and their vegetative propagule, they undergo gregarious growth and multiplication due to high reproductive potential and also short life cycle, due to which within a short period of time, these species outnumbered the native species in terms of different resources such as space, nutrients and most importantly sunlight. They finally cover a large area in the wetland far beyond its native range. Moreover, the invasive species after their introduction into aquatic bodies particularly wetlands through wind, water, animal or human, proliferates at very fast rate. The invasion and infestation of invasive aquatic plants are important indicators of declining water quality and eutrophication (Gao and Li, 2004). These invasive aquatic plants not only suppress and out-compete the native species, but effectively replacing them in natural areas. Invasive aquatic and ecotone plants such as *Alpinia galanga Eichhornia crassipes, Cyclosorus interruptus*, *Pistia stratiotes* etc produces large amount of biomass leading to the depletion of nutrients both in sediment as well as in water besides causing their lateral expansion in water bodies than native counterparts. The spread of Exotic Invasive Plants (EIPs) especially *Eichhornia crassipes, Cyclosorus interruptus, Alternanthera philoxeroides, Alpinia allughas* etc depletes the natural biological richness and livelihood of inhabitants depending on wetland resources. Locals have stopped grazing their livestock's in these wetlands as the native palatable grasses such as *Hymenachne acutigluma, Hymenachne assamica*, *Hymenachne amplexicaulis, Scirpus ancistrchaetus, Scirpus flaviatilis, Eleocharis cutangula, Fimbristylis dichotoma* etc which were previously dominant are presently being replaced by the exotic invasive species especially by *Eichhornia crassipes, Ludwigia adscandens, Typha angustata, Salvinia molesta, Pistia stratiotes, Cyclosorus interruptus, Monocharia vaginalis, Ipomoea aquatica, Alternanthera philoxeroides, Alpinia allughas etc.* and this has led to decrease in quality and quantity of milk production as well reduction in the income of the villagers.

The highest value of dominance was showed by *Chromolaena odorata* (0.91) and *Ottelia alismoides* (0.91) followed by *Eichhornia crassipes* (0.90), *Polygonium oleracea* (0.89) and *Solanum nigram* L. (1.42). The minimum values were of *Neptunia prostrata* (0.47), followed by *Nechamandra alternifolia* (0.49), *Cuscuta reflexa* (0.50). The above results showed that most of the wetlands, water bodies, rice fields and water logged areas of the district had high values of dominance which indicates that the menace of invasive species were alarming in the district which in due course of time may convert these places into terrestrial ecosystem by succession. The high values of dominance indicate low species diversity in almost all the aquatic ecosystem which may cause extinction of many valuable native species.

The results of frequency class of the study sites were summarized as follows (for comparison with the normal distribution of Raunkiaer's).

A = B < C < D > E

The frequency class of the invasive plant species on the aquatic ecosystem showed that maximum frequency of species was in class D (42) followed by class E (18) and class C (9) while classes A and B do not have any species which indicates that more dominant species were in classes D and E. There was a wide divergence in most of the classes which indicates that although there is still heterogeneity in the communities but invasion was causing homogeneity as can be observed from class D where concentration of species had taken place and in classes A and B there is no species. From the above observations it can be concluded that the aquatic and ecotone communities were losing species diversity due to the invasive species.

CONCLUSION

The study of invasive aquatic and ecotone plant species is of immense interest to botanist, field researchers and conservation biologists because of their ecological impacts both at the species as well as at the ecosystem levels. The invasive species are functionally and morphologically different in their nutrient acquisition strategy which depends on their growth form and life span. The sediments and water column in the wetland act as main nutrient source for these species. The presence of native vegetation can decrease the invasion and establishment success of an alien aquatic plant species. Invasive species has the ability to colonize and grow very rapidly in the absence of a native plant community. Vegetative reproduction of many aquatic species seems to be the most important factor which influences primary distributions of these plant species.

The wetlands and water bodies of Nalbari district were invaded by alien species and the native plants and fish diversity faces a risk due to the invasion as a result many indigenous species of plants and fishes faces extinction and many of them are already extinct. Some of the native plant species have food

value and used as traditional medicines by the local people. Loss of these species results in loss of the livelihoods of many who depend on the collection and sale of different bio-resources from these wetlands. The distribution patterns of vegetation and water level fluctuations in different times of the year in wetlands brings about change in wetland habitats which invites various aquatic, terrestrial and arboreal animals. Wetlands support a wide variety of grazing and browsing animals, which includes domestic cows, buffaloes, goats, wild elephants etc. all of which act as biocatalyst in changing the native plant community and thereby invites different invasive weeds. The invasion of aquatic macrophytes in the waterlogged low-lying areas of Nalbari district of Assam can be managed by manually or mechanically eradicating them before flowering and fruiting stage is attained and burning them at the site. These species can be a source of biomass which can be converted into useful bio-products including bio-fertilizers, biogas production etc. through biotechnological intervention.

ACKNOWLEDGEMENTS

Authors are thankful to Mrs Sumangali Choudhury and Debashish Talukdar research scholar, Cotton University Assam for their help. Authors are also thankful to the people of the surveyed villages who responded enthusiastically to all the queries. Last but not the least authors are also thankful to the Department of Botany, Nalbari college for support and cooperation.

REFERENCES

1. Baker, H. G. (1974). The evolution of weeds. *Annu. Rev. Ecol. Syst. 5, 1–24*.
2. Bromilow, C.2000.Problem plants and Alien weeds of South Africa, *Briza publications, South Africa.*
3. Baruah, P., Gogoi, R., Bordoloi, S., Ahmed, S., Sharma, K., Goswami, D.C., Murthy, TVR., Shing, TS., and Garg, J.K., Wetland of Assam: A project report: Assam Remote Sensing Application Centre, Guwahati and Space Application Centre (ISRO), Ahmedabad. (1997, March)
4. Brundu, G. (2015). Plant invaders in European and Mediterranean inland waters: profiles, distribution, and threats. *Hydrobiologia* 746: 61–79, http://dx.doi.org/10.1007/s10750-014-1910-9
5. Cowardian, L.M., Carter, V., Golet, F.C., La Roe, E.T., Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. *U.S. Fish and Wildlife Service: Washington, D.C., 1979.*
6. CBD, 2002. Decision VI/23 (Annex, footnote): Alien species that threaten ecosystems, habitats and species. Document UNEP/CBD/COP/6/23. Convention on Biological Diversity Secretariat, *Montreal, Canada.* Available from https://www.cbd.int/decision/cop/id=7197,
7. Chamier, J., Schachtschneider, K., Le, Maitre D.C., Ashton, P.J., Van Wilgen, B.W. (2012). Impacts of invasive alien plants on water quality, with particular emphasis on South Africa. *Water SA* 38(2): 345–356, http://dx.doi.org/10.4314/wsa.v38i2.19
8. Darwin, C. (1859). The Origin of Species by Means of Natural Selection. *Murray, London*.
9. Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Leveque, C., *et al*. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. Rev.* 81, 163–182. doi: 10.1017/ S1464793105006950
10. Drake, J.A., H.A. Mooney., F. di Castri, R., Groves, F., Kruger, M., Rejmanek, & M. Williamson (eds.). (1989). Biological Invasions: A Global Perspective. *John Wiley and Sons, New York.*
11. Gao, L., and Li, B., (2004). The study of a specious invasive plant, water hyacinth (*Eichhornia crassipes*): achievements and challenges. *Chinese Journal of Plant Ecology* 28(6): 735–752, http://dx.doi.org/10.17521/cjpe.2004.0097
12. Kalita, G., 2009. An Ecological study of Wetlands of Kamrup district of Assam. *Ph.D. Thesis, Gauhati University*.
13. Kanjilal, UN., *et. al*. (1934-1940): *Flora of Assam*, Vol. I-IV. Calcatta
14. Kar D, Barbhuiya M, Studies on the aquatic macrophytes of Chatla Haor floodplain wetlandin Cachar district in Assam. *Indian Science Congress, New Delhi*. 2000.
15. Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Application* 10: 689–710, http: //dx.doi.org /10.1890/1051-0761(2000)010 [0689: BICEGC] 2.0.CO;2
16. Madsen JD (1997) Methods for management of nonindigenous aquatic plants. In: Luken JQ, Thieret JW (eds), Assessment and management of plant invasions. *Springer, pp* 145–171, http://dx.doi.org/10.1007/978-1-4612-1926-2_13
17. Malakar NC, The Systematic studies on the Aquatic Angiosperms of Cachar District of Assam: G.C. College. *Ph.D. thesis. Gauhati University, Assam,* 1995.
18. Milligan, H., Deinet, S., Mcrae, L., and Freeman, R. (2014). Protecting Species: Status and Trends of the Earth's ProtectedAreas.UK: *Zoological Society of London*.
19. Mooney, H.A. & J.A. Drake. (1987). "The Ecology of Biological Invasions." *Environment* 29(5):12.
20. Panetta F. D. & Scanlan J. C. (1995) Human involvement in the spread of noxious weeds: what plants should be declared and when should control be enforced? *Pl. Prot. Quart*. 10, 69–74.
21. Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien invasive species in the United States.

Ecological Economics 52: 273–288, http://dx.doi.org/10.1016/j.ecolecon.2004.10.002

22. Pyšek P, Richardson DM, Rejmanek M, Webster GL, Williamson M, Kirchner J (2004) Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. *Taxon* 53: 131–143, http://dx.doi.org/10.2307/4135498
23. Richardson D. M., Allsopp N., D'Antonio C., Milton S. J. & Rejmánek M. (2000) Plant invasions – the role of mutualisms. *Biol. Rev.* 75, 65–93.
24. Sandilyan, S. Thiyagesan, K. and Nagarajan, R. 2012. Wetlands- A boon to humanity, *Science India* 15(2): 41-45.
25. Satya Narayan, G. (1963): Hydrophytic vegetation of Jalukbari beel. *Bull.Bot. Surv.India.*4:217-218
26. S. Sandilyan. 2016. Occurrence of ornamental fishes: a looming danger for inland fish diversity of India. Current Science.,110 (11): 2099-2104. Sharma P, Geo Ecological Study of Beels and Swamps in Nagaon and Morigaon Districts, Assam: *Ph.D. thesis. Gauhati University, Assam, 1993.*
27. Strayer, D. L. (2010). Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. *Freshw. Biol.* 55, 152–174. doi:10.1111/j.1365-2427.2009. 02380.x
28. Verma DM, Cyperaceae of Assam and Neighbouring areas: *Ph.D. Thesis. Gauhati University, Guwahati, Assam, 1971.*
29. Vilà M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE, DAISIE partners (2010) How well do we understand the impact of alien species on ecosystem services? *A Pan-European, cross-tax assessment. Frontier in Ecology and the Environment 8(3)*: 135–144, http://dx.doi.org/10.1890/080083
30. Xu HG, Qiang S (2011) China's invasive alien species. *Science Press, Beijing*
31. Zedler JB, Kercher S (2004) Causes and consequences of invasive plants in wetlands: Opportunities, opportunists, and outcomes. *Critical Reviews in Plant Science* 23(5): 431–452, http://dx.doi. org/10.1080/07352680490514673