Available online at www.ewijst.org

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 15 (2020) 105-115

Environment & We
An International
Journal of Science
& Technology

Assessment of Dominant Macrophytes and Paradigm for Emerging Invasion Dynamics in Okhla Bird Sanctuary

Satish Kumar[#] and Tuisem Shimrah[*]
University School of Environment Management
Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi – 110078
[#] Email: ksatishindia@gmail.com
[*] Email: tsshimrah@gmail.com

Article history:
Received 30 April2019
Received in revised form
21January 2020
Accepted 20 July2020
Available online
31 July 2020

Keywords:
Invasive alien macrophytes;
Invasion;
Vulnerability;
Environmental risk assessment;
Invasion dynamics;
Invasibility

Abstract

Macrophytes plays a critical role in habitat development and influence biogeochemical process of wetland ecosystem. Invasive alien macrophytes are recognised as one of the leading threats to biodiversity. It causes significant impact on ecosystem services and associated livelihoods. Vulnerability of wetlands to invasive alien macrophytes has described a narrow and fragmented approach under the concept of environmental risk assessment. Within this context, ecological information of invasive alien macrophytes of the vegetated urban wetland namely Okhla Bird Sanctuary (OBS) was analysed through the lens of invasion dynamics on structural components of wetland ecosystem. Vegetation study of the sanctuary described that the nearly seventy percent area of the sanctuary is infested with invasive species. *Eichhornia crassipes, Alternanthera philoxeroides*, *Typha angustata, Saccharum spontaneum* and *Pistia stratiotes* are major invasive alien species reported in dominant macrophyte communities of the sanctuary. These species observed in almost all parts of the sanctuary including both lotic and lentic habitats from densely vegetated in summer season to disperse vegetation during winter season. Invasibility via some ecosystem attributes such as water flow, depth and quality shows significant relationship with invasion mechanisms. These aggressive tropical invasive macrophytes are causing serious problem in wetland functioning. There is a need for management prescription to be developed at several levels.

Introduction

All ecosystems exhibit considerable variation in their water requirement. Presences of water throughout or parts of the year, hydric soil and plants adopted to wet condition creates wetland ecosystem. Aquatic plants grow inside or near shallow areas of wetlands referred as hydrophytes or macrophyte. According to their distribution macrophytes classified into free floating, rooted with floating leaves, submerged floating, rooted submerged and rooted emergent

plants. Macrophytes are either native species exist inside its natural distribution or alien (exotic) accidently introduced into a new habitat. Alien species become invasive when the population increase through reproduction because of no natural enemies in the new habitat. It changes ecological character of wetland particularly nutrient uptake and release. High production rate, growth in variety of hydrological condition, number of adaptive features, easily dispersed, no enemies, increase sediment deposition and cost intensive control mechanism are known features of invasive macrophytes (Walden *et al*., 2004). Adaptations in exotic plant that enable their rapid spread and growth and increase their invasive potential (Santamaria, 2002). Evangelista *et al.,* (2014) studied a temporal trend of macrophyte invasion from 1970 to 2012 at the global level indicated that 28.9% of the investigations studied focus on population dynamics, 23.9% employed an approach related to community level, 14.5% studied the economical aspect, 11.9% used an ecosystem perspective and 19.5% approach more than one level of organisation and finally 1.3% on genetics of these species.They also found that invasion studies mostly carried out in American and European continent but Asian ecosystem have rarely been addressed in published literatures.

Macrophytes considered as both exotic and invasive species, which is most likely because a majority of invasive species overcome dispersal barriers to their establishment and spread to new regions where they proliferate and are considered as exotic (Ricciardi and Cohen, 2007). The major risk concern with proportionate invasions by exotic species through colonisation and the ability to reduce the diversity of native species, compete with other macrophyte species (Mony*et al.* 2007; Sousa *et al.* 2009) and change the composition of other aquatic communities (Douglas and O'Connor 2003; Casatti *et al.* 2009). A risk assessment of the tropical wetland weed *Mimosa pigra* in northern Australia was pioneered by Walden *et al.,* (2004). They used Wetland Risk Assessment (WRA) Framework of van Dam (1999) and evaluated the threats of *Mimosa* species infestation on the wetlands of northern territory. This WRA framework further adopted by Ramsar Convention in 2000. Wetland risk assessment is a framework and methods for predicting and assessing change in ecological character (van Dam *et al.,* 1999).

In South Asia and India, the aquatic plant have rarely drawn enough attention from the ecological perspective to enable an understanding of their nature and relationship with environment variable. Detail investigations on the impacts of invasion on these variables have rarely been attempted (Gopal, 2013). Reddy (2008) reported 173 species of invasive alien plants in India. Out of these *Alternanthera Philoxeroides, Eichhornia crassipes* and *Typha angustata* macrophytes are most serious invasion characteristics species identified on wetland ecosystems. Apart from this study *Ipomoea carnea, Ipomoea pestigridis, Cyperus difformis, Echinochloa crusgalli, Melilotus alba, Ludwigia adscendens* and *Ludwigi aperennis* are reported as noxious aquatic weeds of Delhi NCR (Marnal *et al.,* 2013; Ansari *et al*., 2016). Shah and Reshi (2012) studied invasion characteristic of invasive alien macrophytes in wetlands of Kashmir valley. They also found that invasive macrophyte characteristically forms thick mat in eutrophic water whereas emergent plant are increasing because of decreasing depth of waterbodies due to siltation and sedimentation. Keller *et al.,* (2018) assessed implication of macrophyte invasion on livelihood and ecosystem service of Wular Lake. They found that the two-floating invasive macrophytes *Azolla cristata* and

Alternanthera Philoxeroides causing major degradation on ecosystem services including fish catch, fodder and flood control of the lake.
Aquatic vegetation of Okhla Bird Sanctuary was inventoried in management plan by Wildlife Institute of India in 2010. They found that the aquatic vegetation includes invasive alien species of the sanctuary is primarily dominated by three communities such as *Eichhornia – Salvinia – Spirodela* species in open water areas, *Alternantherea - Paspalum – Ipomoea* species in shallow water areas and *Phragmites – Typha – Saccharum – Arundo* species in marshy areas (WII, 2010). India's international agreements on management of invasive species in terms of number, coverage and changes in affected areas was committed to the Convention of Biological Diversity on National Biodiversity Target (2014). These targets mostly focus on the identification of invasion pathways and the eradication of invasive species from protected areas.

Material and Methods

Study sites: Okhla Bird Sanctuary is a constructed urban fresh water wetland which span about 400 hectare area of Yamuna River. This wetland is located in National Capital Region at the border of Delhi and Uttar Pradesh (Fig.1). The geographical coordinates of sanctuary is marked between $28^0$32'43.5"N to $28^0$32'56.3"N latitudes and $77^0$18'41.7"E to $77^0$18'56.6"E longitudes in lower reach of Upper Yamuna River sub basin with an elevation about 185 m above mean sea level. It consists of variety of habitats including water bodies, marshes, grasses and trees. These diverse habitats attract a large number of migratory birds throughout the year (Sharma et al., 2015).

Sanctuary was formed due to the construction of Okhla Barrage across the Yamuna River. It has declared as protected area as bird sanctuary under the sanction 18 of Wildlife Protection Act 1972 by the Government of Uttar Pradesh notification 577/14-4-82/89 dated on 1990. Okhla Bird Sanctuary (OBS) is paradise for migratory bird and variety of plant species. It has recognised as one of the Important Bird Areas (IBAs) and Asian Water bird Census (AWC) in India. The fertile flood plain and green cover of the Yamuna River ecosystem, recommended as one of the potential Ramsar Site (Urfi, 2003)

Methods: Study were carried out during pre-monsoon (May), post monsoon (October) and winter (February) in the year of 2018 -19. Study area was marked in twelve sites all along different part of the sanctuary. Sampling and field assessments were conducted in these marked places (Figure 1). Study compartmentalised in two section invasiveness and invasibility. Invasiveness described invasive potential/ reproduction and dispersal. Study choose identification and distribution criteria under invasiveness section.

An ecological assessment of invasive species ware conducted through transit walk and filed photographs. Identification of invasive species was carried out by scientific nomenclature method of taxonomic key using references of Reddy (2008). Geological information system-based information of invasive species was mapped on satellite image (Sentinal 2a) with the help of ArcMap 10.5 software. Invasibility explain about ecosystem attributes associated with susceptibility to colonisation and establishment of introduced species. Water based abiotic factor

such as flow, depth and ammonaical nitrogen were used as key attributes in relation with invasive macrophyte communities. Water flow was monitored by The Global Water Flow Probe (a xylem brand FP211) whereas depth assessed through well marked bamboo pole. Nitrogen is one of the essential nutrients of plant growth. Under this section, ammoniacal nitrogen in water sample were estimated through Kjeldahl method.

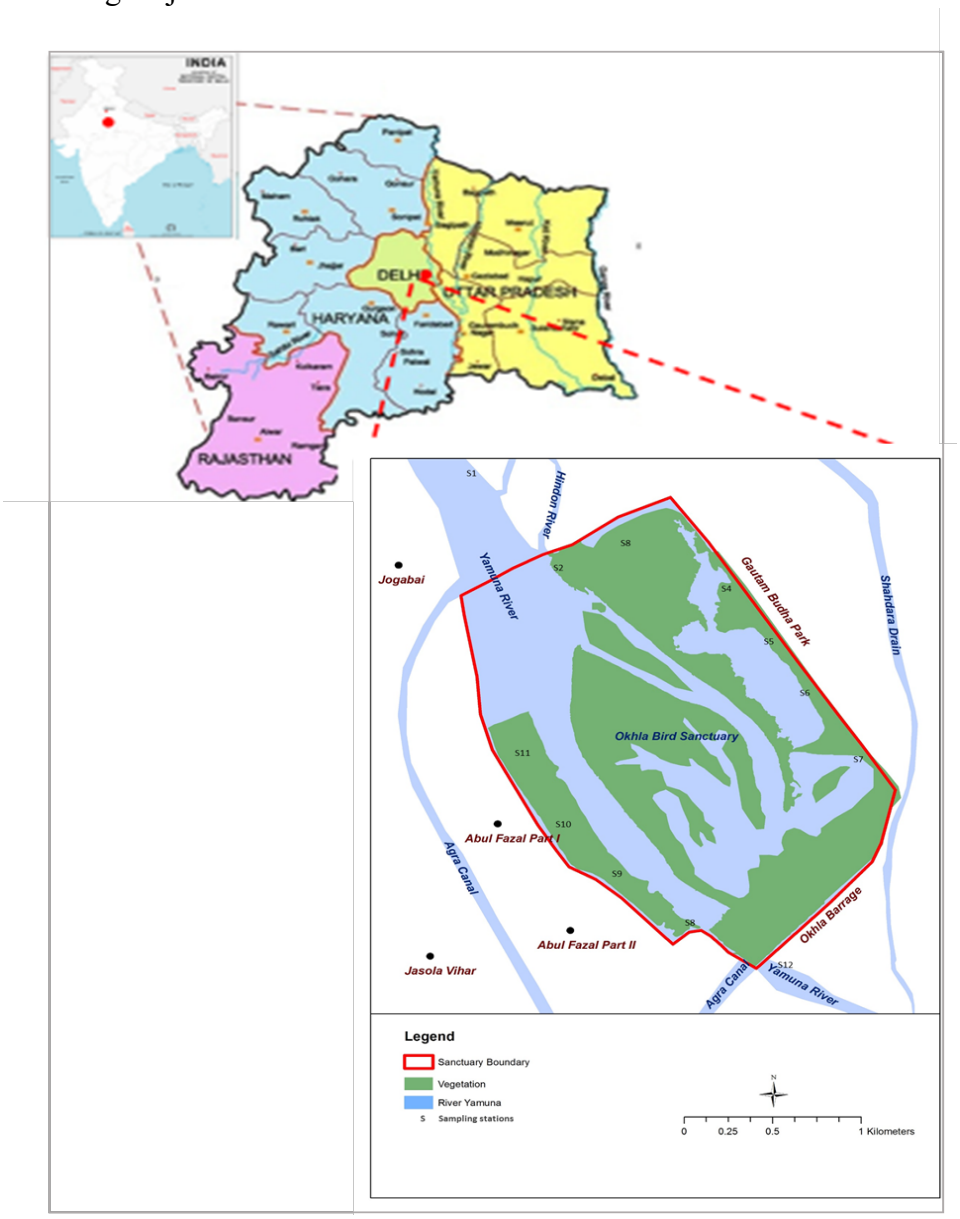


Figure 1 Location map of the Okhla Bird Sanctuary

Result and Discussion

Okhla Bird Sanctuary is characterised by number of macrophytes which covered maximum part of the water spread area (Fig.2). Study observed monospecific and polyspecific colonies of macrophytes associated with invasive alien species in each types of habitat. A total of eight invasive alien species which include five macrophytes were identified in the sanctuary. Most of these species belongs to tropical America classified as one of the worst aquatic weeds in the world by Global Invasive Species Database 2010. Detailed vegetation characteristics of these invasive species of Okhla Bird Sanctuary are provided in the table 1.

Table 1. List of invasive alien species of plants in Okhla Bird Sanctuary. (H - Herb, G – Grass, S- Shrub, Aq – Aquatic, Tr – Terrestrial)

Species	**Family**	**Habit**	**Habitat**	**Nativity**
Eichhornia crassipes	Pontederiaceae	H	Aq	Tropical America
Alternanthera philoxeroides	Amaranthaceae	H	Aq/Tr	Tropical America
Typha angustata	Typhaceae	H	Aq	Tropical America
Saccharum spontaneum	Poaceae	G	Aq/Tr	Tropical West Asia
Ipomoea carnea	Convolvulaceae	S	Aq/Tr	Tropical America
Pistia stratiotes	Araceae	H	Aq	Tropical America
Lantana camara	Verbenaceae	H	Tr	Tropical America
Parthenium hysterophorus	Asteraceae	H	Tr	Tropical North America

Community structure and species composition of invasive alien macrophytes described dense monospecific stands by high proliferation result an unorganised stratification. It is very difficult to identify different strata in floating macrophytes. Homogenous colonies of *Eichhornia spp.* And *Alternathera spp.* spread in the form of thick mat form one layered community structure in open water area. But some of the results in emergent macrophytes reveal that similar height and mixed population of reeds is not common. *Phragmites karka* and *Typha angustata* often occur together forming two layered vegetation within a habitat with height about one to five metres.

Community structure also described temporal change among invasive macrophytes where one species replacing other in different season. *Pistia stratiotes* invade during winter season after mechanical deweeding of *Eichhornia crassipes* in post monsoon. Association of invasive species with each other depend upon the invasion characteristics. *Eichhornia crassipes* and *Pistia stratiotes* do not allow the invasion by other species after forming a complete cover but may readily invade the established strand of *Alternanthera philoxeroide*.

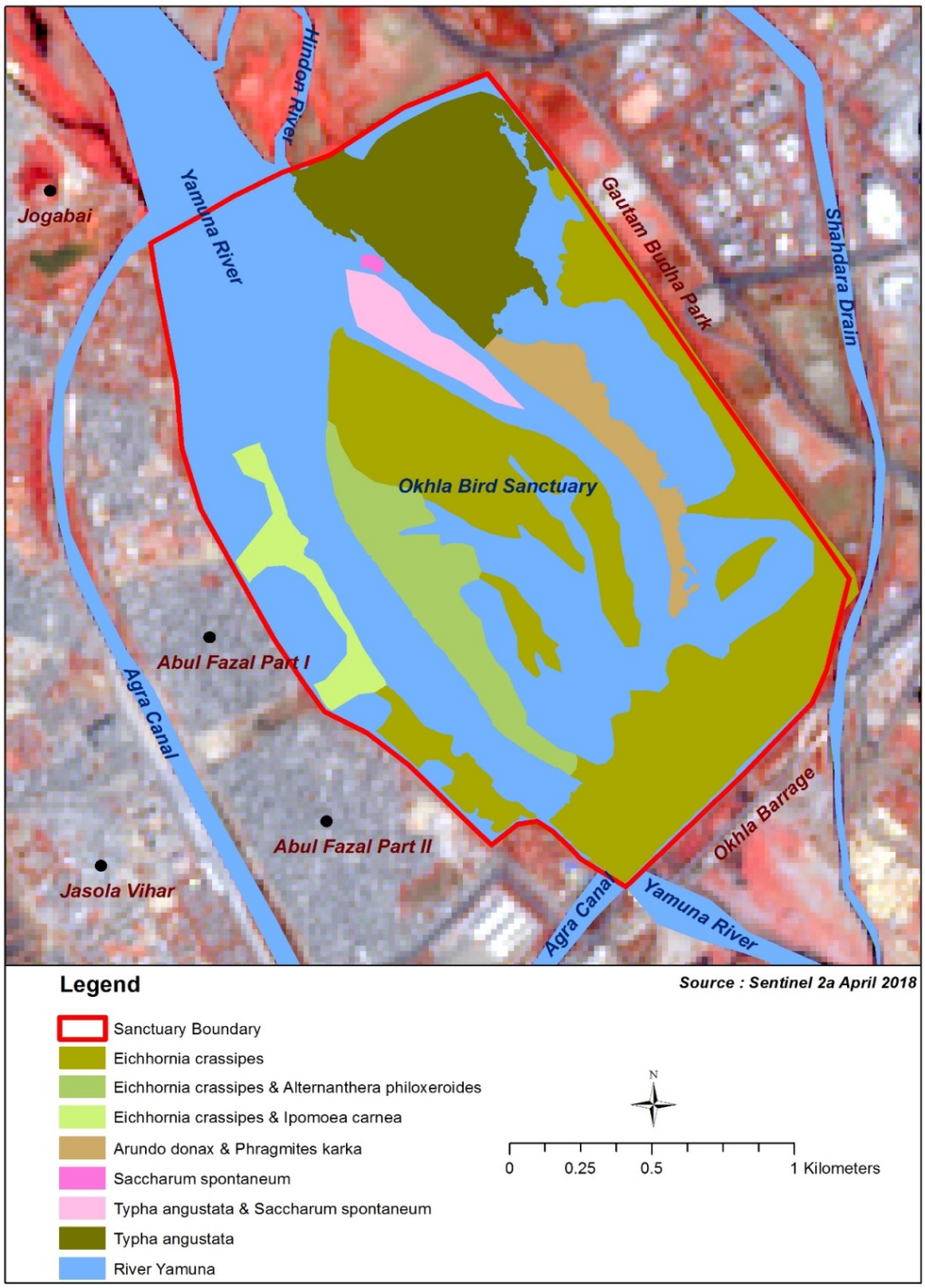
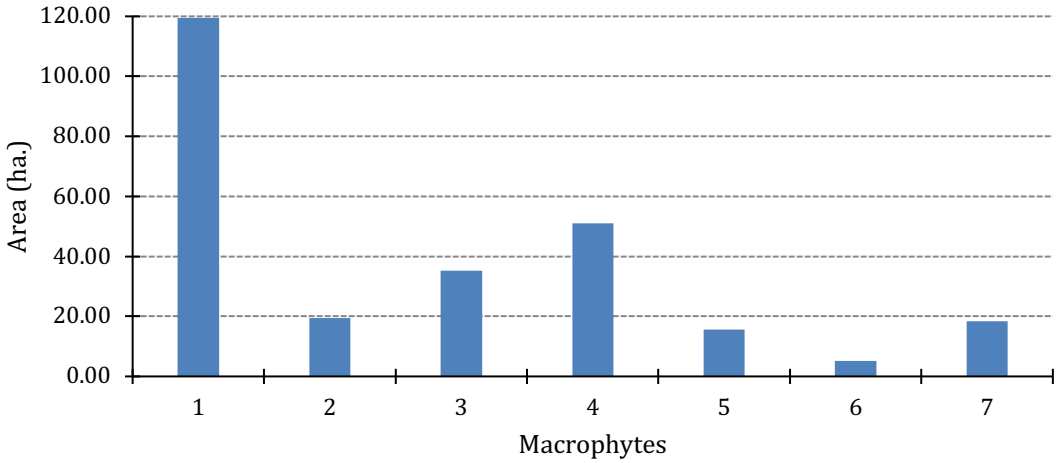


Figure 2. Distribution of dominant macrophytes in Okhla Bird Sanctuary

Nature of the habitat especially water spread areas regulated by physical structures of barrage creates conducive environment for macrophyte zonation (Fig.2). Open and free flowing water area is covered with *Eichhornia crassipes* whereas shallow water areas covered with mix colonies of *Eichhornia crassipes, Alternanthera philoxeroide* and *Pistia stratiotes.* Although free floating macrophytes do not form distinct zones but maximum accumulation of monotypic *Eichhornia spp*. reported in upstream of Okhla barrage gates. Polyspecific colonies of *Eichhornia* and associated species was found all along the spur and marginal bund of the sanctuary. Zonation in marsh vegetation recognised by long monospecific stand of *Typha angustata* in upland areas however mix colonies of *Typha spp.* noted in shallow mashes. Invasion mechanism was also assessed by the area under invasive species in different season. It was observed that the biophysical and anthropogenic factors are the key element engaged with growth of all aquatic vegetation of the sanctuary. About seventy percent area of the sanctuary is infested with monotypic and polytypic colonies of invasive macrophytes. In summer, maximum part of the open area infested with homogenous colonies of *Eichhornia*, followed by *Typha* and heterogeneous colonies *of Eicchornia–Alternanthera* species (Figure3).



Note: 1=Eichhornia sp.; 2=Eichhornia sp., Typha sp. and Ipomea sp.; 3= Eichhornia sp., Typha sp. and Alternanthera sp.; 4= Typha sp.; 5= Typha sp. and Saccharum sp.; 6= Saccharum sp.; 7= Arundo sp. and Phragmites sp

Figure 3 Area under dominant macrophytes in Okhla Bird Sanctuary

During monsoon and post monsoon large portion of macrophytes were removed through flushing and mechanical deweeding procedure. After these stagnant shallow water again invaded by *Eicchornia* and *Alternantera* species in post monsoon in contrast *Pistia stratiotes* replace previous species during winter season. The sanctuary is facing serious threats from the rapid proliferation of *Eichhornia crassipes* and *Typha angustata*, which were dominant species noted in deep water, shallow water and marshy area of the sanctuary. Invasibility considering abiotic environmental attributes influence the growth, distribution and ultimate survival aquatic life. Some of the physico-chemical attributes of water such as flow, depth and ammonical nitrogen shows significant relationship with invasive alien macrophytes. It was also observed that the degree of macrophytes invasion is directly correlate with habitat invasibility.

Water flow assessment informed lentic (standing or still water) and lotic (running water) habitats in and around the sanctuary including both inflow and outflow of Okhla Barrage (Fig.4).Construction of spur on both left and right marginal bund formed lentic zone whereas central portion of free flowing water represent lotic zone. Study found that lentic habitat susceptible for colonisation of all type of invasive macrophytes. Lotic habitat associated with monospecific colonies of *Eichhornia* species and mix population of *Eichhornia* and *Alternanthera* species. Flow assessment also described crucial environment for zone of vegetation. Free floating form of vegetation grow in both lotic and lentic environment of the sanctuary whereas emergent vegetation grows in lentic habitat with shallow marshy areas. It was also noted that inflow (S1 and S2) and outflow (S12) of barrage is deprived of all type of vegetation because of high velocity of water at these region.

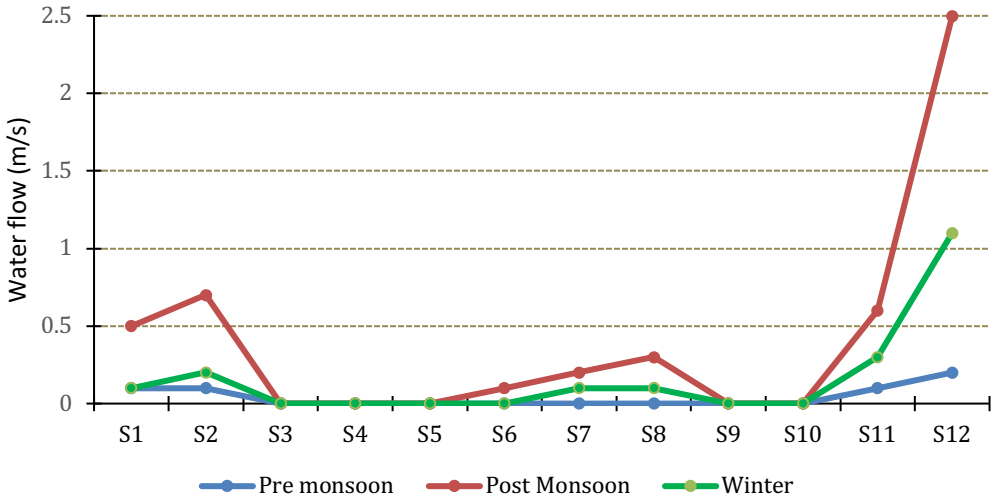


Figure 4 Water flow in different stations of Okhla Bird Sanctuary

Water depth and its seasonal changes are another key variable influencing the growth of invasive macrophytes. There are large proportion of variability in growth attributed to the changing water depth. There are large differences was noted in population of both monotypic and polytypic species, irrespective of its age. Water depth profile with respect to invasive macrophytes indicated thatthe *Eicchornia crassipes* species are more frequent in open water area with depth about more than 1.5 meters. Shallow water area about 0.5 to 1.5 meter depth was preferred by number of invasive species. This transitional zone of the sanctuary is more favourable for introduction of new species. The area is mostly infested with mix population of *Eicchornia crassipes, Typha angustata, Alternanthera philoxeroide, Pistia stratiotes* and *Ipomoea cranea*. *Typha angustata* grows on both dry upland marshes and shallow water area with depth less than 0.5 meter. Aggravated colonies of monotypic stands of *Typha angustata* was also observed in upland marshes of the sanctuary.

Study also represent distinct variation in the distribution pattern of invasion with different nutrient regimes. Nitrogen is one of the macronutrient promote luxuriant growth of macrophytes. The effect of ammoniacal nitrogen on invasive macrophytes shows significant relation on growth pattern (Fig.5). High concentration of ammoniacal nitrogen in water sample were observed in dense colonies of macrophytes. The concentration of ammoniacal nitrogen were reported high on sampling station S7 to S11 on river bank of Delhi region. Because large quantities of untreated domestic and industrial sewage discharge through maximum number of drain in this region.

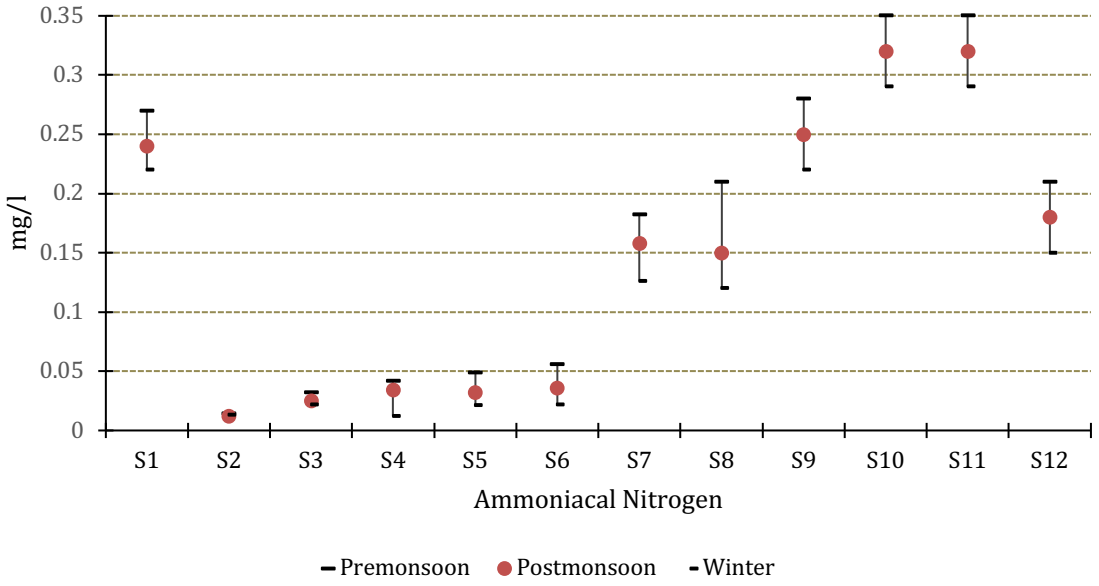


Figure 5 Ammoniacal nitrogen concentration in Okhla Bird Sanctuary

Water pollution especially in summer is believed that one of the major issues that affect the integrity of the sanctuary. High nutrient load create conducive environment for the growth of these macrophytes. Study also found that large thick mat of invasive macrophytes were established near the sampling station with more concentration of nitrogen residue dissolve in water.

Conclusion

Invasive species are an increasingly serious problem in tropical wetlands. Maximum part of the sanctuary is infested with *Typha spp. and Eichhornia spp.* Water flow and depth determine the colonisation of all invasive macrophytes. Nutrient concentration as ammoniacal nitrogen represent different growth pattern and expansion of invasive macrophytes species in both side of sanctuary. Dense and extensive stands of these invasive macrophytes on water cause sediment deposition which would aggravate the problem of flooding in surrounding areas of the sanctuary. There is a need for management prescriptions to be developed at several levels.Critically, for wetland managers and users effective strategic framework is required which provides the

necessary options for invasive macrophyte and their control effort from local to regional perspectives.The utilisation of aquatic vegetation for various household uses is one of the best approaches which can serve as a strategy for controlling noxious growth of invasive macrophytes. Medicinal use of *Pistia stratiotes* leaves with boiled coconut oil are used for cure of chronic skin disease (Tripathi *et al*., 2010). Edible parts of *Typha angustata* such as rhizomes, tender leaves and pollen are used in different parts of India. Leave of *Typha* species are woven into thick mats and also use for handicraft, basket making etc. (Dogan *et al.* 2008). Early warning capabilities with high ecological response in wetland ecosystem was addressed by Ramsar convention on comprehensive management of invasive macrophytes (Ramsar Convention, Resolution VII.10, 1999). Contracting parties of Ramsar Convention (COP) was agreed that the early detection of invasive species should be based on a systematic survey and field assessment for detection of new species. A crucial part of early detection is a contingency plan which determines the action to be taken when an alien invasive species found in wetland ecosystem.

Acknowledgement: *One of the authors (Satish Kumar) acknowledges University Grant Commission (UGC), Government of India for providing financial assistance through National Fellowship Programme. The Authors thank Forest Department of Uttar Pradesh for granting permission to carry out field work. The authors are also grateful to Wetlands International South Asia (WISA), Delhi for their continuous encouragements to do research in wetland management in India.*

Authors Contribution: *Satish Kumar(Ph.D. Scholar) performed the research work, data collection and writing of the manuscript and also the corresponding author; TuisemShimrah(Assistant Professor) has contributed in interpretation of data including the editing of manuscript.*

References

Ansari N.A., Khan A.A. and Ram J., 2016. Vascular plants of Surajpur Wetland, National Capital Region, India, *Indian Journal of Plant Sciences*, 5(1), 54 -69.

Casatti, L., de Paula Ferreira, C. and Carvalho, F. R., 2009. Grass-dominated stream sites exhibit low fish species diversity and dominance by guppies: an assessment of two tropical pasture river basins. *Hydrobiologia*, 632(1), 273-283.

Dogan, Y., Nedelcheva, A.M., Dragica, O.P. and Padure, I.M., 2008. Plants used in traditional handicrafts in several Balkan countries. *Indian Journal of Traditional Knowledge*, 7(1), 157-161

Douglas, M. M. and O'Connor, R. A., 2003. Effects of the exotic macrophyte, para grass (Urochloamutica), on benthic and epiphytic macroinvertebrates of a tropical floodplain. *Freshwater Biology*, 48(6), 962-971.

Evangelista, H., Thomaz, S.M. and Umetsu, C.A., 2014. An analysis of publications on invasive macrophytes in aquatic ecosystems. *Aquatic Invasions*, 9(4), 521-528.

Gopal, B., 2013. Future of wetlands in tropical and subtropical Asia, especially in the face of climate change. *Aquatic sciences*, 75(1), 39-61.

Keller, R.P., Masoodi, A. and Shackleton, R.T., 2018. The impact of invasive aquatic plants on ecosystem services and human well-being in Wular Lake, India. *Regional environmental change*, 18(3), 847-857.

Manral, U., Raha, A., Solanki, R., Hussain, S. A., Mohan, D., Talukdar, G. and Veeraswami, G. G. 2012. Hydrological characteristics and flood plain vegetation of human impacted wetlands: A case study from Okhla Bird Sanctuary, National Capital Region, India. *Asian Journal of Conservation Biology*, 1(2), 110-119.

Mony, C., Koschnick, T. J., Haller, W. T. and Muller, S., 2007. Competition between two invasive Hydrocharitaceae (Hydrilla verticillata (Lf) (Royle) and Egeria densa (Planch)) as influenced by sediment fertility and season. *Aquatic Botany*, 86(3), 236-242.

Ramsar Convention on Wetlands , 1999. Resolutions of the San José Conference. Resolution VII.10 on wetland risk assessment. Online at: http://archive.ramsar.org/cda/en/ramsar-documents-resol-resolution-vii-10/main/ramsar/1-31-107%5E20805_4000_0__

Reddy, C. S., 2008. Catalogue of invasive alien flora of India. *Life Science Journal*, 5(2), 84-89.

Ricciardi, A. and Cohen, J., 2007. The invasiveness of an introduced species does not predict its impact. *Biological Invasions*, 9(3), 309-315.

Santamaría, L., 2002. Why are most aquatic plants widely distributed? Dispersal, clonal growth and small- scale heterogeneity in a stressful environment. *Acta oecologica,* 23(3), 137-154.

Sharma, N., Gaur, S., Dhyani, R. and Singh, A. 2016. Challenges of small protected areas in urban cities: a case study of Okhla Bird Sanctuary, India. *Environment, development and sustainability*, 18(1), 295-310.

Shah, M.A. and Reshi, Z.A., 2011. Invasion by Alien Macrophytes in Freshwater Ecosystems of. Invasive Alien Plants. An Ecological Appraisal for the Indian Subcontinent, 1, pp.199 – 215, CABI Invasive Species Series, London, UK.

Sousa, W. T. Z., Thomaz, S. M., Murphy, K. J., Silveira, M. J. and Mormul, R. P., 2009. Environmental predictors of the occurrence of exotic Hydrilla verticillata (Lf) Royle and native Egeria najas Planch. in a sub-tropical river floodplain: the Upper River Paraná, Brazil. *Hydrobiologia*, 632(1), 65-78.

Tripathi, P., Kumar, R., Sharma, A.K., Mishra, A. and Gupta, R., 2010. Pistia stratiotes (Jalkumbhi). *Pharmacognosy reviews*, 4(8),153.

Urfi, A. J. 2003. The birds of Okhla barrage bird sanctuary, Delhi, India. *Forktail*, 39-50.

van Dam, R. A., Finlayson, C. M. and Humphrey, C. L.1999. Wetland risk assessment. Techniques for enhanced wetland inventory and monitoring, edited by Finlayson, CM and Spiers, AG, Supervising Scientist Report, 147, 83-118. Online at: https://www.environment.gov.au/system/files/resources/6be4c8f2-26c9-48e4-928e-ebec96bfa5c0/files/ssr147-web.pdf#page=89

Walden, D., van Dam, R., Finlayson, M., Storrs, M., Lowry, J. and Kriticos, D., 2004. A risk assessment of the tropical wetland weed Mimosa pigra in northern Australia. Supervising Scientist Report, 177, Supervising Scientist, Darwin NT. Online at: https://www.environment.gov.au/system/files/resources/e2c72d6a-f937-48f3-acb9-b1b58622795a/files/ssr177-print.pdf

Wildlife Institute of India 2010. Management plan for Okhla Bird Sanctuary, Dehradun, Uttarakhand, India.