

Invasive alien freshwater hydrophytes: Co-facilitating factors with emphasis on Indian scenario

Ria Ghosh, Cumali Özaskan¹ and Puja Ray*

Multitrophic Interactions and Biocontrol Research Laboratory, Department of Life Sciences,
Presidency University, 86/1 College Street, Kolkata, West Bengal 700073, India

¹Department of Plant Protection, Faculty of Agriculture, University of Dicle, 21280 Diyarbakir, Turkey

*Email: puja.ray@gmail.com

Article information

DOI: 10.5958/0974-8164.2021.00042.3

Type of article: Opinion article

Received : 18 June 2021

Revised : 22 September 2021

Accepted : 23 September 2021

KEYWORDS

Freshwater ecosystems

India

Climate change

Hydrophytes

Invasiveness

Biological adaptation

ABSTRACT

The vulnerability of the freshwater ecosystem due to the global atmospheric changes is an agonizing concern. Exacerbating greenhouse gases, the temperature and ill-considered anthropogenic activities are manifesting the disruption in the ecosystems worldwide including the freshwater ecosystem. The objective of this review work is scrutinization of the invasive, alien, and stress-tolerant aquatic plant species – how their augmentation and endurance are facilitated by myriad factors (both biotic and abiotic) with a special focus on Indian climatic condition. The groundwork is concentrated mainly on the few invasive aquatic weeds like *Eichhornia crassipes* (Mart.) Solms, *Pistia stratiotes* L., *Salvinia molesta* D.S.Mitch., and *Alternanthera philoxeroides* (Mart.) Griseb. as they are more problematic and more pernicious. However, the other less invasive ones should not be underestimated as they can also boom any time in the future due to the impact of climate change and might cause havoc. In this paper, we have tabulated 130 species of alien and invasive freshwater hydrophytes and evaluated discrete forces that might promote their invasiveness. The temperature, precipitation, wind pattern, salinity, nutrient concentration, natural calamities (like flood and drought), elevation, run-offs, habitat fragmentation, and many other elements diminishing the natural biogeochemistry of the freshwater ecosystem. The hydrophytes invasiveness undermines the society, ecologically and economically as well. There are more than one hundred freshwater invasive hydrophytes, found in India. Aquatic macrophytes rather than hydrophytes are the imperative unit of the freshwater ecosystem by providing food, oxygen, and habitat for aquatic organisms including enormous imperiled ones too and thus playing a crucial role in maintaining the food web. But the invasiveness of the alien species restrains all-embracing ecological balance, and also getting promoted due to some environmental issues like increased temperature, nutrient enrichment, humanitarian interferences. Undoubtedly, the management of invasive species is a prodigious challenge. It is candidly essential to be aware of the way and effects of climate change on the freshwater ecosystem for the better understanding and scope to implement potential management measurements - physical, mechanical, chemical, and biological to preserve the indigenous ecological aspects for the freshwater ecosystem. Such studies shall help the investigators attain better perception about these plants and will provide scope to excel in strategic management under changing climatic conditions.

Exponential population growth, and social and economic globalization are enforcing a robust badger on the earth's comprehensive environment. The human society's over exploitation of natural resources and the imprudent anthropogenic activities are a major driver for the ever increasing global pollution. The crucial aspect for the modification in the ecosphere's retaliation is the alteration in global

stressors' quality and quantity, considering the atmospheric change along with its mutability and land-use conversion (Thomas *et al.* 2008). Hydrophytes are the foundational background for aquatic ecosystems maintenance of aquatic biodiversity, gaseous exchange through photosynthesis, and energy transformation (Sushilkumar 2011). The demotion in endemic aquatic floral and

faunal heterogeneity of this ecosystem is taking place due to some pivotal menaces like contamination in various ways, incompatible baroscopic switching, eutrophication, nutrient loading, and intrusiveness of non-native species (Chambers *et al.* 2008). A huge amount of nutrients, toxic heavy metals, insecticides, and other contaminants are incorporated into the freshwater ecosystem over the last decades, in the form of domestic sewages, agricultural runoffs and industrial waste materials (Sushilkumar 2011). The excess contaminant ingredients lead to the transposition of water chemistry and encroachment of invasive alien species (IAS). The native biodiversity cannot withstand a certain level of remodeling at the habitat and the intrusiveness of non-native species occurs (**Figure 1**). The rapid growth pattern, fertile aquatic habitat, sometimes the warmer temperature, stress-tolerant physiological metabolisms, and weaker restrictions of spreading advocate the invasive nature of the alien plant species by substituting the vernacular community structure and reducing the biodiversity. The native community either prefers migrating to any other suitable habitat or extinct. Sometimes invasive species flourishment is very much profuse forming dense mats all over the water surface so that any tiny animals cannot even be immersed and will stay there (Anderson 2003). This type of invasiveness is demonstrated by their diversified asexual propagative ways and dispersal techniques supporting to adapt in severe climatic conditions (Fawad *et al.* 2013). The connectivity between the trophic status of freshwater ecosystems and their hydrophytes has been investigated since decades (Wolverton and McDonald 1978) yet it still remains an ambiguous area (Thomas *et al.* 2008).

The existence of various hydrophytes describes the eutrophic aquatic systems (Brönmark and Hanson 2001). The IAS slump the native ecological condition of the freshwater ecosystem by facilitating the deterioration of the water quality, a downturn in the biodiversity quantity, slow water regime, disrupting the food web, and food production, impairing navigation, hydro-electric power generation, increased evapotranspiration rate, flood, drought frequency, and intensity, habitat destruction, the desolation of agricultural lands and a lot more. The carriage and repository networks in different aquatic bodies and waterways are becoming congested due to the population outburst of aquatic weeds resulting in adulteration in that process (Datta 2009).

The impacts of metrological shifting and non-native, intimidating species possibly manifest adverse consequences by hindering the habitual ecological services which are economical as well and detrimental to individual well-being. Different

species-specific characters, weather conditions also differ in places showing variation in their influences. Sometimes, those situations either buttress other IAS or not and the effects can fluctuate accordingly like escalation, diminution, or no effect (Thomas *et al.* 2008). The high-water loss through evapotranspiration occurs due to aquatic invasive weeds (Mahmoud Ali and Khedr 2018). Since 1951, the mean annual freshwater convenience is alleviating for each person in India, from 5177 cubic meters to 1869 cubic meters in 2001 and it can further go down to 1341 cubic meters in 2025 and 1140 cubic meters in 2050 (Kumar 2003).

Earth is the secured place for human's subsistence and the biodiversity furnishes its environment flamboyantly awarding us with its immeasurable products like food, air, water, natural resources, trades – forestry, agriculture, fishery, materials for survival like organisms with medicinal properties, wood, diversified gene pool *etc.* The invasive ubiquitous habit of few species is challenging the presence of bio-diversities and our social security incidentally. The perseverance of biodiversity of all the ecosystems including the freshwater and well-grounded solutions are much needed. In this review, the invasive freshwater hydrophytes from India are listed along with details of their interaction and responses with the co-facilitating factor which will provide a progressing premise for prospective researchers for better freshwater eco-system management.

Freshwater ecosystem and its hydrophytes

The freshwater ecosystem occupies only approximately 0.8% of the Earth's surface (Dudgeon *et al.* 2007) despite 70% of our planet is covered with water. Freshwater ecosystems are the fecund and variegated ecosphere including all the aquatic bodies except the marine water. India contains only 4% of the world's freshwater. This planet is the low salt concentration environment of which the temperature, depth, shape depends on the location, area of flowing, seasons *etc.*, and is one of the biodiversity hotspots. The aqueous environment may be fresh, somewhat saline or brackish water in nature establishing a prime wedge of inland waters (Chandra *et al.* 2018). The different forms of freshwater regions are 1: Ponds with smaller and lesser deep regions and stagnant water; 2: Lakes with larger and deeper regions with stagnant or slow-moving water; 3: Streams and rivers – the incessantly flowing water system with or without large flowing area and specific direction respectively, and 4: Wetlands – the transitional area for both the terrestrial and aquatic ecosystems saturated or covered with a temporary or permanent

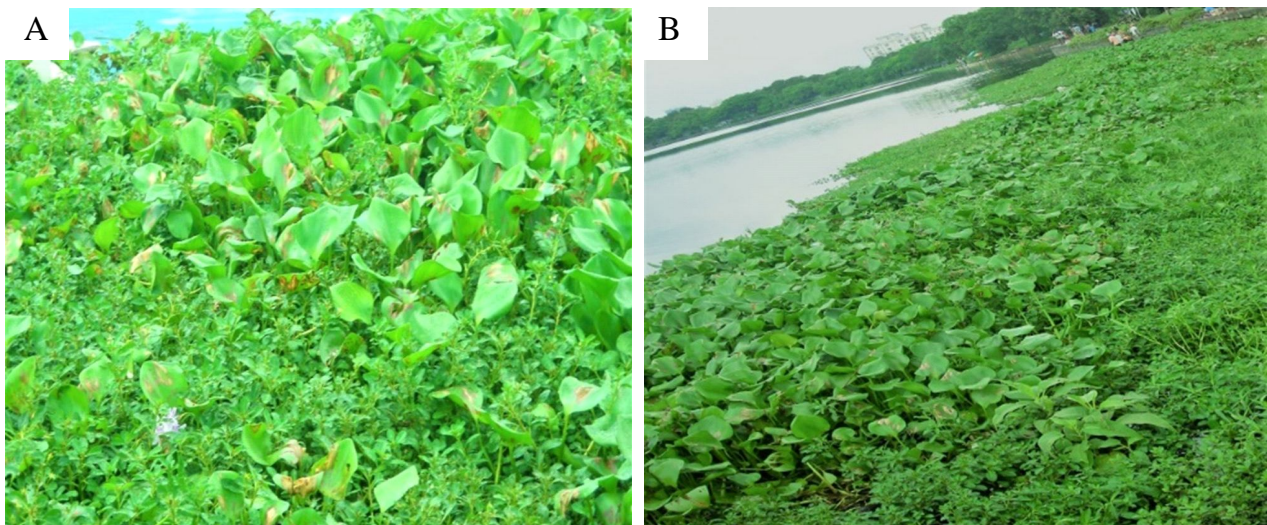


Figure 1. The fresh water invasive weeds succession - the water hyacinth getting substituted by another IAS *Ludwigia adscendens*, B – Invasion by common water hyacinth (Location: Subhas Sarober, Kolkata, West Bengal)

water level at or near the surface advocating diversified biodiversity. Besides the living existence of the water supplier for all purposes - domestic, industrial, agricultural, tourism, communication, *etc.* the freshwater ecosystem mitigates the risk of different natural issues such as flood, soil erosion and safeguards the other ecosystem by hindering the marine water infringement. It is also a great reservoir for global carbon sinking and filtration zone of excess nutrients and various pernicious elements like cadmium, lead *etc.* Sometimes, the genes from many wild bio-diversities of freshwater ecosystems are using manipulating genes to invent more germane products for society's benefit (Buchar *et al.* 1997).

'Hydro' means something related to water and 'phytes' is the group of plants. So, the vascularized plants which can be acclimatized entirely or partially to spend their life cycle and submerged in water or moist places, are called hydrophytes. These are refined with unique adaptive characteristics like having larger and broad-leaves with more stomata and narrow cuticle, lesser root quantity and mechanical tissue, higher amount of air vacuoles in the plant body, and others. Those freshwater hydrophytes can be categorized into few groups – 1. Free-floating: the floating plants on the water surface having the entire body above the water except for its roots. It is in immediate contact with both the air and water, but not the soil; 2. Suspended hydrophytes: which are completely submerged underwater in stagnant or slow-moving water and roots are also not attached with the soil at its matured condition; 3. Submerged anchored: It is the underwater, well-rooted, astomatic, aquatic vegetation growing below the motionless or flowing water; 4. Anchored with

floating shoots: The root of few hydrophytes is at the floor of the aquatic body in a well-anchored condition, but the shoots are of creeping habit along the water surface; 5. Anchored but with floating leaves only; 6. Emergent hydrophytes – Aquatic plants with well-projected aerial shoots above water, supple stem, and anchored rhizome to substratum below water. They are implied for having their amphibious nature as found in both shallow water and wetlands. The aquatic habitat includes 7.5% and 11% of dicotyledonous and monocotyledonous flora, respectively (Les and Schneider 1995).

The IAS are the non-native, dominating, sometimes stress-tolerant any kind of living organisms affecting all types of ecosystems globally both ecologically and economically. Few IAS can also be spotted among hydrophytes of the freshwater ecosystem. Among all, *Eichhornia crassipes*, *Pistia stratiotes*, *Hydrilla verticillata*, *Nelumbo nucifera*, *Ipomoea aquatic*, *Ipomoea cornea*, *Vallisneria spiralis*, *Typha angustifolia*, *Salvinia molesta* few *Nymphaeae* sp., *Alternanthera philoxeroides* are the primary concerning IAS for India now (Sushilkumar 2011).

Total 130 aquatic macrophytes and 40 families are explored associated with the invasiveness of the freshwater ecosystems in India. It is observed that the family - Pontederiaceae, Lemnaceae, Salviniaceae, Onagraceae, Hydrocharitaceae, and Alismatacae –are dominating in waters, while the wetland is ruled by, Cyperaceae and Poaceae mainly (Table 1). There, 13 free-floating, 16 rooted floating, 1 suspended, 3 anchored hydrophytes with floating leaves, 13 rooted submerged, and 84 emergent aquatic plant species are found (Table 2). So, the

Table 1. The percentage distribution of taxonomic families of freshwater ecosystems hydrophytes occurring in India

Family name	No. of available hydrophytes	Family name	No. of available hydrophytes
Alistamaceae	6	Lythraceae	1
Amaranthaceae	3	Araliaceae	1
Araceae	5	Marsileaceae	2
Asteraceae	7	Menyanthaceae	1
Butomaceae	1	Najadaceae	2
Boraginaceae	2	Nelumbonaceae	1
Brassicaceae	3	Nymphaeaceae	3
Ceratophyllaceae	1	Onagraceae	5
Martyniaceae	1	Plantaginaceae	1
Commelinaceae	1	Poaceae	9
Convolvulaceae	3	Cannaceae	1
Cabombaceae	1	Polygonaceae	5
Cyperaceae	14	Pontederiaceae	6
Fabaceae	4	Potamogetonaceae	8
Haloragaceae	2	Salviniaceae	5
Hydrocharitaceae	4	Solanaceae	3
Lamiaceae	5	Trapaceae	1
Lemnaceae	3	Typhaceae	3
Sparginiaceae	1	Orchidaceae	1
Lentibulariaceae	1	Oxalidaceae	1

Source: <https://www.invasivespeciesinfo.gov/resources>
<https://www.ncbi.nlm.nih.gov/taxonomy>
http://www.bsienvs.nic.in/database/invasive_alien_species_15896.aspx
<https://weedsdb.live-website.com/>
<http://www.theplantlist.org/>
<https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?mode=info&id=33090>

invasive suspended hydrophyte is the least and the emergent anchored is highest in terms of species richness in this ecosystem. Excluding Cyperaceae and Poaceae, Typhaceae, Polygonaceae, Asteraceae, Lamiaceae, Fabaceae, and Amaranthaceae are pre-eminent families among emergent anchored sections. It can also be noticed that the invasive and alien rooted hydrophytes with floating shoots are more than the ones rooted with floating leaves. Most of the emergent anchored hydrophytes are from the marshy swampland. The average surveillance for all those species is they all are stress-tolerant and are utilizing the supplementary nutrients and other atmospheric conditions for the flourishing within that ecosystem.

Hydrophytes status in Kolkata and surrounding area

A meticulous scrutinization is carried out regarding the chosen problem by exploring both the field studies and the published research articles and databases.

We have gathered the data of the freshwater hydrophytes' diversity and its abundance from the extensive fieldwork – a meticulous survey of the ponds, lakes, canals, wetlands, and the accessible

part of the river the Ganges for five months (January 2021 to May 2021) in Kolkata and nearby few sunburn areas of North and South-24 Parganas districts. The freshwater floral diversity and the identification of the invasive aquatic weeds were the principal goal of this survey so that we can relate the literature results with the field survey data to synthesize an accurate result. The samples of the unknown species are collected and identified later in the laboratory with the expert help of and by reviewing relevant literature - Bengal Plants. It was not possible to conclude about the freshwater floral species of India through this short survey. Hence, we have surveyed the literature to ascertain about all the freshwater invasive plants of entire India. We followed The Plant List – a synergistic perspective by the Royal Botanic Gardens, Kew, and Missouri Botanical Garden <http://www.plantlist.org/> providing a potent directory where researchers can find the floral information comfortably, about different flora. We have also consulted <https://sites.google.com/site/efloraofindia/home>. The invasive nature of the weed in India is assured through these databases - <https://weedsdb.live-website.com/> and http://www.bsienvs.nic.in/Database/Invasive_Alien_species_15896.aspx.

For building a relationship over time, we reviewed this less investigated freshwater floral weed by concentrating on the research works of the last decade mainly. We have searched for peer-reviewed journals - <http://www.aquaticinvasions.net/>, <https://www.science.org/>, <https://www.journals.elsevier.com/aquatic-botany>, <https://www.frontiersin.org/journals/plant-science> and other websites, books, conference papers through Google (<https://www.google.co.in/>), Researchgate (<https://www.researchgate.net/>), Academia (<https://www.academia.edu/>), and Google Scholar (<https://scholar.google.com/>) platforms.

Heterogenous ecological responses

The significance of the illustrations between the hydrophytes and different environmental gradients in the aquatic ecosystem has been well explained by Hutchinson (1975). The principal determinant for ecological replacement is the man-made activities right away (Vitousek *et al.* 1997). Though, the amplification of terrestrial biodiversity is developing presently (Parmesan 2006; Root *et al.* 2003, Walther *et al.* 2002), the upgraded illustrations from the watery world are also anticipating (Parmesan 2006). A significant percentage of plants of total vascular flora are gradually establishing their population in the non-native environments of any ecosystems (Pysek *et al.* 2017, 2020). Different components like temperature, water flow, *etc.* along with the escalating concentration of carbon dioxide, and

Table 2. Habitat based categorization of hydrophytes of fresh water ecosystems in India

Category	Scientific name	Common name	Family	Native range	References
Free-floating	<i>Eichhornia crassipes</i> (Mart.) Solms	Water hyacinth	Pontederiaceae	South America	Obianuju <i>et al.</i> 2020
	<i>Salvinia molesta</i> D.S.Mitch.	Kariba weed	Salviniaceae	South-eastern Brazil	Julien <i>et al.</i> 2009
	<i>Salvinia natans</i> L.	Floating water moss	Salviniaceae	Central and south eastern Europe and the major part of Asia	Polechońska <i>et al.</i> 2019
	<i>Salvinia auriculata</i> (Mitch) Syn.	Eared water moss	Salviniaceae	South and Central America	Banerjee and Matai 1990
	<i>Azolla pinnata</i> R. Br.	Mosquito fern	Salviniaceae	Africa, Asia, and parts of Australia	Mostafa <i>et al.</i> 2021
	<i>Azolla cristata</i> Kaulf.	Water velvet	Salviniaceae	North and South America	Ahad <i>et al.</i> 2012
	<i>Lemna minor</i> L.	Common duck weed	Lemnaceae	Africa, Asia, Europe, and North America	Paolacci <i>et al.</i> 2018
	<i>Lemna gibba</i> L.	Duckweed	Lemnaceae	Ireland	Paolacci <i>et al.</i> 2018
	<i>Wolffia columbiana</i> Karsten	Columbian water meal	Araceae	North America	Shah and Reshi 2012
	<i>Lemna perpusilla</i> Torr.	Duckweeds	Lemnaceae	New England	https://gobotany.nativeplanttrust.org/species/lemna/perpusilla/
	<i>Pistia stratiotes</i> L.	Water lettuce	Araceae	Uncertain, probably pantropical, first found from Africa or South America	Coelho <i>et al.</i> 2005
	<i>Spirodela polyrhiza</i> (L.) Schleid.	Common duck-meat	Araceae	Florida	https://plants.ifas.ufl.edu/plant-directory/spirodela-polyrhiza/
	<i>Wolffia globosa</i> (Roxb.) Hartog & Plas	Asian water meal	Araceae	Asia	http://www.plantsoftheworldonline.org/taxonomy:lsid:ipni.org:names:1135607-2
	Rooted-floating	<i>Potamogeton pectinatus</i> L.	Sago pond weed	Potamogetonaceae	North America
<i>Potamogeton filiformis</i> Pers.		Fine leaf pond weed	Potamogetonaceae	Temperate Northern Hemisphere, Hispaniola, Ecuador to South America	http://www.efloras.org/florataxon.aspx?flora_id=110&taxon_id=242340932
<i>Potamogeton tubitans</i> Roth		Long leaf pond weed	Potamogetonaceae	Eurasia and the Americas	Shah and Reshi 2012
Rooted-floating	<i>Nymphaea luteosa</i> Paine.	Tuberous water-lily	Nymphaeaceae	North America	Pandit <i>et al.</i> 2005
	<i>Nymphaea lotus</i> L.	Egyptian white-water lily	Nymphaeaceae	Africa and Asia	Tungmunithum <i>et al.</i> 2021
	<i>Nymphaea mexicana</i> Zucc.	Mexican water lily	Nymphaeaceae	North America/South Oklahoma to Southeast U.S.A. and Mexico	Nachtrieb <i>et al.</i> 2011
	<i>Marsilea minuta</i> L.	Dwarf water clover	Marsiliaceae	Asia, Europe	Shah and Reshi 2012
	<i>Marsilea quadrifolia</i> L.	Water clover	Marsiliaceae	Caucasia, western Siberia, Afghanistan southwest India, China, Japan, and North America	Soni and Singh 2012
	<i>Utricularia flexuosa</i> Vahl	Bladder wort	Lentibulariaceae	Northern Hemisphere	
	<i>Trapa natans bispinosa</i> (Roxb.) Makino	Water chestnut	Trapaceae	Taiwan, China, Korea, and Japan	Kak (1990)
	<i>Ipomoea aquatica</i> Forssk.	Water Morning Glory	Convolvulaceae	Southeast Asia	Austin, 2005
	<i>Ipomoea hederacea</i>	Ivy-leaved morning glory	Convolvulaceae	tropical parts of the Americas	Smith and Rausher 2006
	<i>Ludwigia parviflora</i> Roxb.	Perennial water primrose	Onagraceae	South America	Gobalakrishnan <i>et al.</i> 2020
	<i>Ludwigia peploides</i> (Kunth) P.H.Raven	Floating primrose-willow	Onagraceae	Central and South America	Mitchel and White 2013
	<i>Ludwigia palustris</i> (L.) Elliot	Marsh seed box	Onagraceae	North America and Eurasia	Dite <i>et al.</i> 2017
	<i>Ludwigia ascendens</i> (L.) H.Hara	Water primrose	Onagraceae	uncertain - Asia/ Australia/South America/Africa	http://www.plantsoftheworldonline.org/taxonomy:lsid:ipni.org:names:144324-2
	Suspended rooted-submerged	<i>Ceratophyllum demersum</i> L.	Common hornwort	Ceratophyllaceae	All continents except Antarctica
<i>Elodea canadensis</i>		American waterweed	Hydrocharitaceae	North America	USFW, 2019
<i>Vallisneria spiralis</i> L.		Eel grass	Hydrocharitaceae	Southern Europe	Soni and Singh 2012
<i>Hydrilla verticillata</i> (L. f.) Royle		Indian star-vine.	Hydrocharitaceae	Probably Africa or Europe	Alix <i>et al.</i> 2009
<i>Ottelia alismoides</i> (L.) Pers.		Duck lettuce	Hydrocharitaceae	Asia and northern Australia.	Wagutu <i>et al.</i> 2021
<i>Myriophyllum verticillatum</i> L.		Parrot feather	Haloragidaceae	Temperate Northern hemisphere	http://www.plantsoftheworldonline.org/taxonomy:lsid:ipni.org:names:430479-1
<i>Najas minor</i> All.		Brittle naiad	Najadaceae	Europe, western Asia, and northern Africa	USFW, 2018
<i>Najas marina</i> L.		Spiny Naiad	Najadaceae	Caribbean Territories, California, Hawaii, continental US, and Eurasia	USFW, 2012
<i>Potamogeton crispus</i> L.		Curly leaf pond weed	Potamogetonaceae	Eurasia	Shah and Reshi 2012
<i>Potamogeton natans</i> L.		Broad-leaved Pond weed	Potamogetonaceae	Europe	Shah and Reshi 2012
<i>Potamogeton lucens</i> L.		Shining pondweed	Potamogetonaceae	Eurasia and North Africa	
<i>Potamogeton pusillus</i> L.		Small pond weed	Potamogetonaceae	North America	Lupoae <i>et al.</i> 2015
<i>Cabomba aquatica</i> Aubl.		Gul Kabomba	Cabombaceae	South America	
<i>Heteranthera dubia</i> (Jacq.) MacMill		Water star grass	Pontederiaceae	North and Central America	Driesche <i>et al.</i> 2002
Anchored hydrophytes with floating leaves	<i>Nelumbo nucifera</i> Gaertn.	Indian lotus	Nelumbonaceae	Central and northern India	Shah and Reshi, 2012
	<i>Potamogeton nodosus</i> Poir.	Long-leaf pond weed	Potamogetonaceae	Florida	https://plants.ifas.ufl.edu/plant-directory/potamogeton-nodosus/
	<i>Sagittaria guayanensis</i> Kunth	Guyanese arrow head	Alistamaceae	Mexico, Central America, the West Indies, and much of South America, West Africa, south and southeast Asia, Sudan and Madagascar	https://indiabiodiversity.org/species/show/259147
Emergent anchored	<i>Myriophyllum indicum</i> Willd.	Water milfoil	Haloragaceae	India	http://www.plantsoftheworldonline.org/taxonomy:lsid:ipni.org:names:430420-1
	<i>Persicaria amphibia</i> (L.) Delarbre	water knot weed	Polygonaceae	Europe, Asia, North America, and parts of Africa	http://www.plantsoftheworldonline.org/taxonomy:lsid:ipni.org:names:30193627-2
	<i>Hydrocotyle umbellata</i> L.	Many flower marsh pennywort	Araliaceae	Brazil	Hamdey <i>et al.</i> 2018
	<i>Fimbristylis miliacea</i> (L.) Vahl	Grasslike fimbry	Cyperaceae	Tropical America	Schaedler <i>et al.</i> 2013

Invasive alien freshwater hydrophytes: Co-facilitating factors with emphasis on Indian scenario

Category	Scientific name	Common name	Family	Native range	References
Emergent anchored	<i>Meteranthera limosa</i> (SW) Wild	Mud plantain	Pontederiaceae	Tropical and subtropical America	Mitchell 1985
	<i>Monochoria vaginalis</i> Presl.	Heartshape false pickerel weed	Pontederiaceae	Asia and across many of the Pacific Islands	Shah and Reshi 2012
	<i>Pontederia cordata</i> L.	Pickrel weed	Pontederiaceae	American continents	https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=42620#null
	<i>Monochoria hastata</i> (L.) Solms	Arrow leaf pond weed,	Pontederiaceae	South-East Asia and Oceania	Mitchell 1985
	<i>Panicum perpurascens</i> Raddi.	Para grass	Poaceae	South America and West Africa	
	<i>Paspalum fluitans</i> Kunth	Water paspalum	Poaceae	South America, Central America, and North America	
	<i>Phragmites karka</i> (Retz.) Trin. ex Steud.	Tall Reed	Poaceae	West tropical Africa to Kenya, Tropical & Subtropical Asia to Pacific.	http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:415942-1
	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	Common reed	Poaceae	North America	Hazelton <i>et al.</i> 2014
	<i>Echinochloa colona</i> (L.) Link	Jungle rice	Poaceae	Tropical and subtropical Asia,	Ray and Chatterjee, 2017
	<i>Chloris barbata</i> Sw.	Swollen finger Grass.	Poaceae	Tropical America	https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=565064#null
	<i>Echinochloa crus-galli</i> Beauv.	Barnyard grass	Poaceae	Tropical Asia	VKM Report, 2016
	<i>Paspalum distichum</i> L.	Knot grass	Poaceae	North and South America	https://www.cabi.org/isc/datasheet/38952
	<i>Phalaris arundinacea</i> L.	Canary grass	Poaceae	Eurasia and North America	Lavergne and Molofsky, 2004
	<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	Alligator weed	Amaranthaceae	Temperate regions of South America	Pan 2017
	<i>Alternanthera sessilis</i> (L.) R.Br. ex DC	Dwarf copper leaf	Amaranthaceae	Tropical Asia.	Rao 2018
	<i>Alternanthera caracasana</i> Kunth.	Khaki weed	Amaranthaceae	South America	Iamónico and Pino 2016
	<i>Alisma gramineum</i> Lej.	Narrow water plantain	Alismataceae	Temperate Northern Hemisphere.	http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:77097302-1
	<i>Alisma lanceolatum</i> With.	Lance leaf water plantain	Alismataceae	Asia-Temperate, Europe, Northern Africa	Shah and Reshi, 2012
	<i>Alisma plantago aquatica</i> L.	American water plantain	Alismataceae	parts of Australia	Ash <i>et al.</i> 2004
	<i>Sagittaria latifolia</i> Willd.	Duck potato	Alismataceae	Southern Canada and most of the contiguous United States, as well as Mexico, Central America, Colombia, Venezuela, Ecuador, and Cuba	Shah and Reshi 2012
	<i>Sagittaria sagittifolia</i> L.	Hawaii Arrowhead	Alismataceae	Europe from Ireland and Portugal to Finland and Bulgaria, and in Russia, Ukraine, Siberia, Japan, Turkey, China, India, Australia, Vietnam and the Caucasus	USFW, 2012
	<i>Commelina benghalensis</i> L.	Benghal day flower	Commelinaceae	Tropical and subtropical Asia and Africa	Ghosh <i>et al.</i> 2019
	<i>Cyperus glomeratus</i> L.	Clustered Sedge.	Cyperaceae	Europe/Asia	Shah and Reshi, 2012
	<i>Cladium jamaicense</i> C. rantz.	Saw-grass	Cyperaceae	Caribbean Territories, America, Hawaii	https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=39878#null
	<i>Cyperus alternifolius</i> L.	Umbrella sedge	Cyperaceae	Panama, Madagascar	http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:303729-1
	<i>Carex diandra</i> Schrank	tussock-sedge	Cyperaceae	Europe and North Africa.	
	<i>Cladium mariscus</i> (L.) Pohl.	swamp sawgrass	Cyperaceae	Temperate Europe and Asia	
	<i>Eleocharis equisetoides</i> (Ell.) Torr.	Jointed spikerush	Cyperaceae	South America	
	<i>Eleocharis acicularis</i> (L.) Roem et Schlt.	Needle spike sedge	Cyperaceae	Temperate Northern Hemisphere to South America	Shah and Reshi 2012
	<i>Eleocharis parishii</i> Britton.	Parish's spike rush.	Cyperaceae	Northern Mexico, the Southwestern United States	Shah and Reshi 2012
	<i>Eleocharis pauciflora</i> Link	Few-flowered spike-rush	Cyperaceae	North America	Shah and Reshi 2012
	<i>Cyperus compressus</i> L.	Poorland flat Sedge	Cyperaceae	Tropics & Subtropics.	Shah and Reshi 2012
	<i>Cyperus rotundus</i> L.	Nut sedge	Cyperaceae	Africa, southern and central Europe (north to France and Austria), and southern Asia	Barai <i>et al.</i> 2017
<i>Cyperus iria</i> L.	Rice Flat Sedge.	Cyperaceae	Tropical Asia	Shah and Reshi 2012	
<i>Cyperus difformis</i> L.	Small flower umbrella-sedge	Cyperaceae	southern Europe, most of Africa and Asia, and Australia	Derakhshan and Gherekhloo, 2013	
<i>Lycopus europeus</i> L.	European bugleweed	Lamiaceae	Azores, Europe to China	https://nas.er.usgs.gov/queries/GreatLakes/FactSheet.aspx?Species_ID=2694	
<i>Mentha aquatica</i> L.	Water mint	Lamiaceae	Europe, northwest Africa and southwest Asia	Anca-Raluca <i>et al.</i> 2013	
<i>Mentha arvensis</i> L.	Corn mint	Lamiaceae	Temperate regions of Europe and western and central Asia, east to the Himalaya and eastern Siberia, and North America	Thawkar <i>et al.</i> 2016	
<i>Mentha piperita</i> L.	Pepper mint	Lamiaceae	Europe	Shah and Reshi 2012	
<i>Mentha spicata</i> L.	Spearmint	Lamiaceae	Europe and southern temperate Asia	https://www.gbif.org/es/species/113618163	
<i>Cassia occidentalis</i> L.	Kalkashunda	Caesalpinaceae	Tropical and subtropical regions of the America	Yadav <i>et al.</i> 2009	

Category	Scientific name	Common name	Family	Native range	References
Emergent anchored	<i>Cassia uniflora</i> Mill.	Oneleaf senna	Caesalpinaceae	Tropical South America.	Joshi 1991
	<i>Cassia tora</i> L.	Sickle senna	Caesalpinaceae	Central America	Pradhan <i>et al.</i> (2005)
	<i>Nicotiana plumbaginifolia</i> Viv.	Tex-mex tobacco	Solanaceae	Mexico, South America, and parts of the Caribbean	Knapp and Clarkson, 2004
	<i>Datura innoxia</i> Mill.	Pricklyburr	Solanaceae	Southwestern United States, Central, and South America	Cinelli and Jones 2021
	<i>Datura metel</i> L.	Stinkweed	Solanaceae	Southern China	Vadlapudi and Kaladhar 2012
	<i>Sparganium erectum</i> Huds.	Branched burreed	Sparginiaceae	North America	
	<i>Menyanthes trifoliata</i> L.	Bog bean	Menyanthaceae	Labrador to Alaska south to Wyoming, Nebraska, Missouri, Ohio, and Virginia.	http://www.plantsoftheworldonline.org/taxonomy/urn:lsid:ipni.org:names:50970102-1
	<i>Rumex aquaticus</i> L.	Willow dock	Polygonaceae	Temperate Eurasia	Shah and Reshi 2012
	<i>Rumex conglomeratus</i> Murry	Sharp dock	Polygonaceae	Europe, Asia and North Africa	Shah and Reshi 2013
	<i>Polygonum nepalensis</i> (Meisn) Gross	Nepalese smart weed	Polygonaceae	Eastern Africa, including Madagascar, and parts of Asia.	https://www.inaturalist.org/guide_taxa/122922
	<i>Polygonum lapathifolium</i> L.	Pale smart weed	Polygonaceae	North America and Eurasia	https://www2.ic.edu/prairie/pond_smartweed.htm
	<i>Polygonum barbatum</i> L.	Knot grass	Polygonaceae	Asia	CABI, 2019
	<i>Canna indica</i> L.	Indian shot	Cannaceae	Tropical America	Kumbhar <i>et al.</i> 2018
	<i>Utricularia vulgaris</i> L.	Greater bladder wort	Lentibulariaceae	Northern Europe, Asia	
	<i>Hemimium lanceum</i> (Thunb. ex Sw.) Vuijk	Chinese Lady's-Tresses	Orchidaceae	Mongolia to Tropical Asia	Raskoti <i>et al.</i> 2017
	<i>Oxalis corniculata</i> L.	Creeping woodsorrel	Oxalidaceae	probably southeast Asia	Groom <i>et al.</i> 2019
	<i>Typha angustifolia</i> L.	Narrowleaf cattail	Typhaceae	North America, Europe, and Asia.	Ciotre <i>et al.</i> 2012
	<i>Typha latifolia</i> L.	Broad-leaf cattail	Typhaceae	North and South America, Europe, Eurasia and Africa	Bansal <i>et al.</i> 2019
	<i>Typha orientalis</i> C.Presl	Cumbungi	Typhaceae	Australia, New Zealand, Malaysia, Indonesia, Japan, Korea, Mongolia, Myanmar, Philippines, China, and Russia Parts of Africa, and much of Asia, Europe	https://tropical.theferns.info/viewtropical.php?id=Typha+orientalis
	<i>Rorripa islandica</i> Borbas	Northern marshyellowcress	Brassicaceae	Eurasia, North America, and the Caribbean.	https://inaturalist.ca/taxa/64162-Rorripa-palustris
	<i>Cardamine flexuosa</i> With.	wavy bittercress	Brassicaceae	Europe and Eastern Asia	Marhold <i>et al.</i> 2016
	<i>Cardamine hirsuta</i> L.	Hairy bittercress	Brassicaceae	Western Asia	Marble <i>et al.</i> 2021
	<i>Aeschynomene aspera</i> L.	Sola pith plant	Fabaceae	Bangladesh, Bhutan, Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, and Vietnam	http://www.plantsoftheworldonline.org/taxonomy/urn:lsid:ipni.org:names:472655-1
	<i>Parthenium hysterophorus</i> L.	Whitetop weed	Asteraceae	American tropics.	Kaur <i>et al.</i> 2014
	<i>Gnaphalium polycaulon</i> Pers.	Stem cud weed	Asteraceae	Asia/Zimbabwe	http://www.plantsoftheworldonline.org/taxonomy/urn:lsid:ipni.org:names:209889-1
	<i>Grangea maderaspatana</i> (L.) Poir.	Madras carpet	Asteraceae	Asia, Africa	https://sites.google.com/site/efloraofindia/species/a---/ar/asteraceae/asteroideae/astereae/grangea/grangea-maderaspatana
	<i>Ageratum conyzoides</i> L.	Billygoat-weed	Asteraceae	Tropical America, especially Brazil	Bosi <i>et al.</i> 2013
	<i>Blumea laciniata</i> (Roxb.) DC.	Cutleaf Blumea	Asteraceae	India to New Guinea and the Solomon Islands	http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:185697-1
	<i>Bidens bittermata</i> (Lour.) Merr. & Sheriff	Spanish needles	Asteraceae	Asia	Shah and Reshi 2012
	<i>Eclipta alba</i> (L) Hassk.	False daisy	Asteraceae	Tropical America	Shah and Reshi 2012
	<i>Myosotis caespitosa</i> Schultz	Tufted forget-me-not	Boraginaceae	Europe	https://keyserver.lucidcentral.org/weeds/data/media/Html/myosotis_laxa_subsp_caespitosa.htm
	<i>Myosotis laxa</i> Lehm.	Mall-flowered forget-me-not	Boraginaceae	Africa	Swenson <i>et al.</i> 1997
<i>Martynia annua</i> L.	Cat's claw	Martyniaceae	Mexico, Central America, and the Caribbean	CABI, 2019	
<i>Lytharum salicaria</i> L.	Purple loosestrife	Lytharaceae	Europe and Asia	Shah and Reshi, 2012	
<i>Hippuris vulgaris</i> L.	Common mare's-tail	Plantaginaceae	Subarctic & Temperate regions	http://www.plantsoftheworldonline.org/taxonomy/urn:lsid:ipni.org:names:430352-1	
<i>Epilobium hirsutum</i> (L.) Gray	Cherry-pie	Onagraceae	North Africa, Europe up to southern Sweden, and Asia	Shah and Reshi, 2012	
<i>Butomus umbellatus</i> L.	Flowering-rush	Butomaceae	Africa, Asia, and Eurasia	Shah and Reshi, 2012	
<i>Colocasia esculenta</i> (L.) Schott	Wild taro	Araceae	Tropical Asia probably South-East or southern Central Asia	Shah and Reshi, 2013	
<i>Ipomoea carnea</i> Jacq.	Morning glory-bush	Convolvulaceae	South America	Chaudhuri <i>et al.</i> 1994	

greenhouse gases like methane gas, nitrous oxide in the atmosphere, the changing rainfall amount are also predominating issues for having some footprints on the endowment and distribution of aquatic invasive species (Thomas *et al.* 2008, Lamsal *et al.* 2017). An elaborate evaluation of morphological, physiological, and molecular aspects of the plant community structure and its adaptations should be explored considering all the biotic and abiotic environmental

factors (Wittingham *et al.* 2019, Dalla Vecchia *et al.* 2020). The mass production of sexual and asexual reproductive propagules and its remote dissemination helps the invasive hydrophytes across freshwater bodies and wetlands, causing both native biodiversity and provident deprivation (Richardson *et al.* 2000, Kercher and Zedler 2004). It has been estimated statistically that a great portion of our planet's ecosystem is already invaded by invasive plant

species and they are mostly seen in the economically developed countries (Rai and Singh 2020), although the impacts of the ecological and economic will be encountered globally due to this invasion.

Nutrient encroachment: Aquatic vegetation is the primary producer of freshwater ecosystems. They require many elements - light, water, and carbon dioxide to complete the photosynthesis, respiration, metabolic activities, etc. (Moss 1988). Enormous recyclable and non-recyclable products are pouring into the freshwaters every day and from different sources leading to the nutrient-enriched and violated the condition that shapes the freshwater ecosystem rather than biodiversity and its hydrology primarily or in different auxiliary ways (O'Hare *et al.* 2018). The aquatic floral world – its structure, composition, and interactions can be substituted by the prevailing inflation in carbon dioxide content (Feely *et al.* 2004) and the physiological metabolisms like reproduction, absorption, and water content are exhilarated among aquatic under-growths (Weltzin *et al.* 2003). The obnoxious species, *Hydrilla verticillata* was observed growing rapidly with a higher proportion of carbon dioxide and temperature (Chen *et al.* 1994). The amount of nutrients like nitrogen, phosphorus, becomes higher in freshwaters from varieties of sources anthropogenically (Hou *et al.* 2013). Hydrophytes, epiphytes, and planktons struggle for daylight after the nutrient loading (Hilton *et al.* 2006). Phosphorus is the moderately available and much-needed nutrient for autotrophs representing greater scope to stop the extension (Schindler *et al.* 1977). Solar radiation can't invade the condensed intrusion by IAS on the entire water surface and without light other plants can't grow. The invasive hydrophytes which are not anchored to the soil and can sail with water current exacerbate their growth with a more nutrient-loading state (Poikane *et al.* 2018, van Zuidam and Peeters 2013, Verhofstad *et al.* 2017), while higher salinity negatively provokes the standard hydrophytes growth. The inconsistency can also be seen for the fauna as nutrients, food, and higher biological and chemical oxygen demand is scarce. Those components are utilized entirely by the IAS. Aquatic organisms can't sustain in such a suffocating environment due to the prosperity in the microorganisms' community. When both the nitrogen and phosphorus are accumulated at an outrageous rate, the mushrooming can also be curbed for local hydrophytes (Anderson *et al.* 2002, Fisher *et al.* 1992).

Eutrophication is a common outcome found in the freshwater ecosystem of those ravaging. It is a serious problem for this ecosystem as a greater

amount of nutrients facilitates the speedy multiplication rate for some alien, stress-tolerant, invasive hydrophytes and toxic algal species and thus lowers the abundance of biodiversity and hampers the entire food web rather than environmental stability. Such affected aquatic bodies remind us about sustainable development for the long run on this planet (Dubey and Datta 2020). The leaves of the submerged hydrophytes become fully covered with the extravagant phytoplankton and periphyton growth giving an inappropriate amount to the light exposure and thus the community structure is controlled (O'Hare *et al.* 2018). The gradual depletion of hydrophytes occurs due to the strong pressure of invasive ones as the fight is at a greater percentage for survival (Hilton *et al.* 2006). The secretion of toxic cyanotoxins from the algal bloom may be lethal to other aquatic organisms also. A few such abundant but harmful algal species found in India include *Microcystis* sp., *Anabaena* sp., and *Gloeotrichia* sp. The water color may get altered as per the algal pigment like brownish, different greenish and other shades. Eutrophication is a universal hassle and can be observed more in highly populated areas and near the farmlands (Smith 2003). This phenomenon also depends on variation in abiotic factors like salinity, humidity, precipitation, latitude, altitude, season *etc.* (Liu *et al.* 2010). Furthermore, nutrients promote faster-growing free-floating or canopy-forming macrophyte species outcompeting slower-growing or shorter species (Poikane *et al.* 2018, van Zuidam and Peeters 2013, Verhofstad *et al.* 2017).

Temperature: The unscrupulous attitude of human society towards the environment leads to the increased level of greenhouse gases in the earth's atmosphere and causing global warming. Presently, the glaciers and icebergs are melting at a great percentage and the water temperature is higher than the normal condition affecting the aquatic ecosystem (Mooij *et al.* 2005, Woolway *et al.* 2017). It is manifested that the surface water temperature is identical to the atmospheric temperature and the warm discharges from industrial belts are also responsible for the warmer condition in the freshwater ecosystem. The warmer temperature and changes in precipitation dynamics are better catalysts than higher carbon dioxide concentration to aid for invasive hydrophytes proliferation (Ojala *et al.* 2002). For example, *Phragmites australis* advances more expeditiously at higher temperatures (Wilcox *et al.* 2003). It happens because the temperature induces the anatomical metabolisms of the hydrophytes including its reproductive nature. It was studied that the submerged hydrophytes can photosynthesize well within the range of 25 and 32°C (Barko *et al.* 1982, Santamaría and Van Vierssen 1997, Pedersen *et al.*

2013) and in India, this range is common. The average temperature remains around 25-26°C representing suitable weather for the IAS – freshwater hydrophytes. The gross photosynthetic rate is two times within the range of 10 and 30 ° C (Drew *et al.* 1979). Maximum photosynthesis, respiration, light compensation points can work 50% more during the elevation of 5 to 10°C (Hootsmans and Vermaat 1991). Warmer temperature also reduces the nutrient and stoichiometric equilibrium - the temperature-plant physiological hypothesis (Reich and Oleksyn 2004), as aquatic vegetation needs a smaller amount of alimentative for its perpetuation (Reich and Oleksyn 2004, Zhang *et al.* 2016). In the shallow freshwater area, the temperature also controls the decay and assimilation rate of organic matters (Carpenter and Adams 1979, Federle *et al.* 1982, Brock *et al.* 1983, Brock 1984). Increasing temperature and the invasiveness both instigate pronounced evapotranspiration rate and water extraction from the ecosystem resulting in habitat loss and drought conditions also. This drying effect only can be remunerated by an ample amount of rainfall (Hanseen *et al.* 2003). Otherwise, provisional bogs will be obliterated along with their paramount biodiversity reservoir (Gibbs 1993, Semlitsch *et al.* 1996, Semlitsch and Brodie 1998).

Human endeavors: It is an irrevocable issue and a broadly accepted fact that the main reason for global atmospheric changes is for inconsiderate anthropogenic activities, like exorbitant exploitation of the natural resources, burning fossil fuel, destructing greenery, restyling of natural organisms and their products *etc.* causing disruption of natural cycles in all types of ecosystems (IPCC 2021). Excessive human force from different aspects like scarcity of space for urbanization, global e-commerce *etc.* alters the environmental components like temperature and many others which ultimately ameliorates the invasive nature of the biological organisms (Bolpagni 2021). Extended warmer seasons reinforce the exorbitant biomass of freshwater ecosystems and explain the instability rate among freshwater hydrophytes including IAS according to the metrological influences (Rooney and Kalff 2000). The massive utilization of freshwater ecosystem by copious means such as for food, as a drainage basin, power generation, transportation, urbanization *etc.* is polluting this environment and shows disturbance in its common behavior (Vitousek 1994, Nelson 2005). Kolar and Lodge (2000) pointed out heterogeneous humanitarian interference and its consequences for this ecosystem along with the explanation of how the invasiveness is inspired from varied aspects: entertainment purposes, surplus food production, formation of concrete structures on waterways, and filling up the local freshwaters. The

intensified rate of population growth demands more basic commodities and advanced culture. Human society is sharing those components to improve civilization as the natural depository is fixed in its amount. The dams were constructed for hydroelectric power generation by fragmenting the aquatic body and the natural habitat as well. We extract water, its flora, and fauna from this ecosystem for miscellaneous purposes such as food, fodder, industrial usage *etc.*, and evacuating virulent detritus into it. The native freshwater communities can't hold out against contamination and increased levels of flooding, drought, altered fluvial characters surge the extinction rate as they are not getting the desirable habitat. It is denoted that any disturbed habitat rather than the undisturbed ones is more susceptible to transgression (Mack *et al.* 2000) while the simplification of such occurrence – the relationship, was described (Hobbs 2000). A greater level of chemical usage and genetic engineering for better production and quality of products is slowly degenerating rather than destroying the ecosystem. The urbanization, excess agricultural operations easing the conditions for the IAS (hydrophytes) into the freshwater ecosystem (Glassner-Shwayder 2000) leading to interruptions and unevenness to that certain ecosystem ecology (Hansen and Clevenger 2005, Mack *et al.* 2000).

Potential measures

The IAS including hydrophytes are conferring serious threat to the ecosystem rather than to the freshwaters (Enserink 1999, Kolar and Lodge 2000, Pimentel *et al.* 2000, Palumbi 2001). So, the realization, researches, and conservation is depending on the better clarity of the interrelation between the ecosystem and its various modules sharply (Hansen *et al.* 2003). Except for the mass awareness and meticulous laws, we should distribute our analysis to divergent fields. The principal focus should be the restoration and maintenance of native freshwater biodiversity in cost-effective methods before it's become too late as we already have lost enough resources. Preventive management refers to the manual removal, monitoring, and barricading technique (Sushilkumar 2011). As an instance, Jamshepur municipality, Jharkhand has applied this technique to pull out the water hyacinth from the river (Sushilkumar 2011). Mechanical procedures are also easier and more money-saving ones. The use of the net, proper drainage, harvesters, and other weed cutters can be introduced frequently. Chemical management is another approach to control the invasive freshwater hydrophytes. Different non-ecofriendly herbicides like 2,4-D, glyphosate were registered in India for managing invasive weeds and minimize their harmful effects on aquatic biodiversity.

Biological control methods are the most environment-friendly, the cheapest process, though it is time-consuming. The host-specific bio agents are incorporated into the inland water systems and the IAS can be eradicated (Sushilkumar 2011). The clogging by *Salvinia molesta* is checked by the integration of weevil into the city canals in Kerala (Jayanth 1987). The integrated measures (integration of biological and chemical approaches) can also be followed as per the requirement as used in Jabalpur, Madhya Pradesh for water hyacinth control (Sushilkumar 2011a).

Conclusion

The freshwater IAS are truly hazardous for this ecosystem and Indian climatic conditions provide congenial environment for them to flourish. Moreover, the narcissistic attitude of the human is a resentful concern of our society for this dismantlement. The growth, disadvantageous aspects and factors of the ambience by which freshwater IAS are thriving need to be re-evaluated. The excessive proliferation of hydrophytes needs to be managed (Datta 2009) by paving the path in such a way that the management of invasive hydrophytes coincides with efforts to restore the native biodiversity.

ACKNOWLEDGEMENTS

The authors express their heartfelt gratitude to the research grant provided by the Department of Biotechnology, Govt. of West Bengal (Project No.: BT (Estt) / RD 36 /2014) for undertaking this project.

REFERENCES

- Ahad B, Reshi Z, Ganaie A and Yousuf A. 2012. *Azolla cristata* in the Kashmir Himalaya. *American Fern Journal* **102**: 224–227.
- Alix M, Scribailo R and Price J. 2009. *Hydrilla verticillata* (Hydrocharitaceae): An Undesirable Addition to Indiana's Aquatic Flora. *Rhodora*, **111**: 131–136.
- Anca-Raluca A, Boz I, Zamfirache MM and Burzo I. 2013. Chemical composition of essential oils from *Mentha aquatica* L. at different moments of the ontogenetic cycle. *Journal of Medicinal Plant Research* **7**(9): 470–473.
- Anderson LW. 2003. A review of aquatic weed biology and management research conducted by the United States Department of Agriculture; Agricultural Research Service. *Pest Management Science* **59**(6 7): 801–813.
- Anderson DM, Glibert PM, and Burkholder JM. 2002. "Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences," *Estuaries* **25** (4): 704–726.
- Ash GJ, Cother EJ and Tarleton J. 2004. Variation in Lanceleaved Waterplantain (*Alisma lanceolatum*) in Southeastern Australia, *Weed Science* **52**(3): 413-417. <https://www.jstor.org/stable/4046938>.
- Austin DF. 2007. Water Spinach (*Ipomoea aquatica*, Convolvulaceae): A Food Gone Wild. *Ethnobotany Research and Applications*. 5. 10.17348/era.5.0.123-146.
- Barai M, Amin H, Barai D and Thakkar R. 2017. Motha (*Cyperus rotundus* Linn.): An Ayurvedic Perspective. *Rasamruta* **9**: 18.
- Banerjee A and Matai S. 1990. Composition of Indian aquatic plants in relation to utilization as animal forage. *Journal of Aquatic Plant Management* **28**: 69–73.
- Barko JW, Hardin DG and Matthews MS. 1982. Growth and morphology of submersed freshwater macrophytes in relation to light and temperature. *Canadian Journal of Botany* **60**: 877–887. doi: 10.1139/b82-113
- Bolpangi R. 2021. Towards global dominance of invasive alien plants in freshwater ecosystems: the dawn of the Exocene? *Hydrobiologia* **848**: 2259–2279. <https://doi.org/10.1007/s10750-020-04490-w>.
- Bansal S, Lishawa SC, Newman S *et al.* 2019. Typha (Cattail) Invasion in North American Wetlands: Biology, Regional Problems, Impacts, Ecosystem Services, and Management. *Wetlands* **39**: 645–684. <https://doi.org/10.1007/s13157-019-01174-7>
- Bosi CF, Rosa DW, Grougnet R, Lemonakis N, Halabalaki M, Skaltsounis AL and Biavatti MW. 2013. Pyrrolizidine alkaloids in medicinal tea of *Ageratum conyzoides*, *Revista Brasileira de Farmacognosia Brazilian Journal of Pharmacognosy* **23**(3): 425–432.
- Brock MA and Shiel RJ. 1983. The composition of aquatic communities in saline wetlands in Western Australia. *Hydrobiologia* **105**: 77–84.
- Brock THCM. 1984. Aspects of the decomposition of (*vmphoides peltata* (Gruel.) O. Kuntze (Menyanthaceae). *Aquatic Botany* **19**: 131–156.
- Brock MA, Nielsen DL, Shiel RJ, Green JD and Langley JD. 2003. Drought and aquatic community resilience: The role of eggs and seeds in sediments of temporary wetlands. *Freshwater Biology*, **48**: 1207–1218.
- Bucher E, Castro G and Floris V. 1997. Freshwater ecosystem conservation: Towards a comprehensive water resources management strategy. *ENV*, **114**: 1–38.
- Brönmark C and Hansson LA. 2001. *The Biology of Lakes and Ponds*. Oxford University Press, UK.
- Carpenter SR and Adams MS. 1979. Effects of nutrients and temperature on decomposition of *Myriophyllum spicatum* L. in a hard- water eutrophic lake. *Limnology and oceanography* **24**: 520–528.
- Ciotir C, Kirk H, Row JR and Freeland JR. 2012. Intercontinental dispersal of *Typha angustifolia* and *T. latifolia* between Europe and North America has implications for Typha invasions, *Biol Invasions* **15**:1377–1390. DOI 10.1007/s10530-012-0377-8.
- Chaudhuri H, Ramaprabhu T and Ramchandran V. 1994. *Ipomea cornea* Jacq. A New Aquatic Weed Problem in India, *Journal of Aquatic Plant Management* **32**: 37–38. <http://www.apms.org/japm/vol32/v32p37.pdf>.
- Coelho FF, Deboni L and Lopes FS. 2005. Density-dependent reproductive and vegetative allocation in the aquatic plant *Pistia stratiotes* (Araceae). *Revista de Biologia Tropical* **53**: 3–4.

- Chambers PA, Lacoul P, Murphy KJ and Thomaz SM 2008. Global diversity of aquatic macrophytes in freshwater. *Hydrobiologia* **595**: 9–26.
- Chandra K, Gopi Kc, Rao D, Subramanian KA and Valarmathi K. 2018. Current status of freshwater biodiversity of India: An Over View. *Zoological Survey of India*, 1-25.
- Chen DX, Coughenour MB, Eberts D. 1994. Interactive effects of CO₂ enrichment and temperature on the growth of dioecious *Hydrilla verticillata*. *Environmental and Experimental Botany* **34**: 345–353.
- Cinelli MA and Jones AD. 2021. Alkaloids of the genus datura: Review of a rich resource for natural product discovery. *Molecules* **26**(9): 2629. <https://doi.org/10.3390/molecules26092629>.
- Dalle Fratte M, Bolpagni R, Brusa G, Caccianiga M, Pierce S, Zanzottera M and Cerabolini BEL. 2019. Alien plant species invade by occupying similar functional spaces to native species. *Flora* **257**: 151419.
- Derakhshn A and Gherekhloo J. 2013. Factors affecting *Cyperus difformis* seed germination and seedling emergence, *Planta Daninha, Viçosa-MG* **31**(4):823–832. <https://www.scielo.br/j/pd/a/yRHfmvccNCsMnPjKjLvGTfb/?format=pdf&lang=en>
- Datta S. 2009. Aquatic Weeds and Their Management for Fisheries, 1-22. <http://www.scribd.com/doc/22049534/Aquatic-Weeds-and-Their-Managemnt-for-Fisheries>.
- Díť D, Eliáš P Jr., Díť Z, Šimková A. 2017. Recent distribution and phytosociological affiliation of *Ludwigia palustris* in Slovakia. *Acta Societatis Botanicorum Poloniae* **86**(1): 3544. <https://doi.org/10.5586/asbp.3544>.
- Drew, MC, Jackson MB and Gifford S. 1979. Ethylene-promoted adventitious rooting and development of cortical air spaces (aerenchyma) in roots may adaptive responses to flooding in *Zea mays* L. *Planta* **147**: 83–88.
- Driesche RV, Blossey B, Hoddle M, Lyon S and Reardon R. 2002. Biological Control Forest Health Technology Enterprise Team. *Biological Control* **1**: 424.
- Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Leveque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullian AC. 2007. “Freshwater biodiversity: importance, threats, status and conservation challenges” *Biological reviews, Cambridge Philosophical Society* **81**(2): 163–182.
- Dubey D, Dutta V. 2020. Nutrient Enrichment in Lake Ecosystem and Its Effects on Algae and Macrophytes. In: Shukla V., Kumar N. (eds) *Environmental Concerns and Sustainable Development*. Springer, Singapore. https://doi.org/10.1007/978-981-13-6358-0_5.
- Enserink M. 1999. Biological Invaders Sweep. pp. 1834–1836. In. *Science*, **285**.
- Fawad, M, Khan, H and Gul, B. 2013. Study and collection of hydrophytes of the district Swabi, Pakistan. *Pakistan Journal of Weed Science Research*, **19**(4): 513-522.
- Federle TW, McKinley VL and Vestal JR. 1982. Physical determinants of microbial colomzaun and decomposition of plant litter in an arctic lake. *Microbial Ecology* **8**: 127–138
- Feely RA, Sabine CL, Lee K et al. 2004. Impact of anthropogenic CO₂ on the CaCO₃ system in the oceans. *Science* **30**(5682): 362–366.
- Fisher TR, Peele ER, Ammerman JW, Harding LW. 1992. “Nutrient limitation of phytoplankton in Chesapeake Bay,” *Marine Ecology Progress Series* **82**: 51–63.
- Ghosh P, Dutta A, Biswas M, Biswas S, Hazra L, Nag S, Sil S and Chatterjee S. 2019. Phytomorphological, chemical and pharmacological discussions about *Commelina benghalensis* Linn. (Commelinaceae): A review. *The Phrama Innovation* **8**(6): 12–188.
- Gibb JP. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. *Wetlands* **13**: 25–31.
- Glassner-Shawdyder KM. 2000. Briefing paper: Great Lakes nonindigenous invasive species. A product of the Great Lakes nonindigenous invasive species workshop; October 20–21, 1999; sponsored by the U.S. Environmental Protection Agency, Great Lakes National Program Office. Available online at <http://www.glc.org/ans/pdf/briefpapercomplete.pdf>.
- Gobalakrishnan R, Bhuvanewari R, Rajkumar M. 2020. Natural antimicrobial and bioactive compounds from *Ludwigia parviflora* Roxb. *J Anal Pharm Res.* **9**(1):37–42. DOI: 10.15406/japlr.2020.09.00349
- Groom QJ, Straeten JVD, Hoste I. 2019. The origin of *Oxalis corniculata* L. *Peer J* **7**:e6384 DOI 10.7717/peerj.6384
- Hamdy SA, Hefnawy HME, Azzam SM and Aboutabl EA. 2018. Botanical and genetic characterization of *Hydrocotyle umbellata* L. cultivated in Egypt, *Bulletin of Faculty of Pharmacy, Cairo University* **56**(1): 46–53. <https://doi.org/10.1016/j.bfopcu.2018.03.006>.
- Hazelton E, Mozdzer T, Burdick D, Kettenring K and Whigham D. 2014. *Phragmites australis* management in the United States: 40 years of methods and outcomes. *AoB plants.* **6**: plu001; doi:10.1093/aobpla/plu001
- Hansen LJ, Biringer JL and Hoffmann JR. 2003. Buying time: a user’s manual for building resistance and resilience to climate change in natural systems. Berlin: WWF Climate Change Program, pp 245.
- Hansen MJ and Clevenger AP. 2005. The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. *Biological Conservation* **125**(2): 249–259.
- Hobbs RJ. 2000. Land use changes and invasions. In: Mooney, HA; Hobbs, RJ; eds. *Invasive species in a changing world*. Washington, DC: *Island Press*; pp. 55–64.
- Hilton J, O’Hare M, Bowes MJ, and Jones JI. 2006. How green is my river? A new paradigm of eutrophication in rivers. *Science of the Total Environment* **365**: 66–83. doi: 10.1016/j.scitotenv.2006.02.055
- Hootsman MJM and Vermaat JE. 1991. Macrophytes, a key to understanding changes caused by eutrophication in shallow freshwater ecosystems. *PQDT-Global Wageningen University and Research*.

- Hou D, He J, Lu C, Sun Y, Zhang F and Otgonbyar K. 2013. Effects of environmental factors on nutrients release at sediment-water interface and assessment of trophic status for a typical shallow lake, Northwest China. *The Scientific World Journal* **716342**: 1-16.
- Hutchinson, G.E. 1975. *A Treatise on Limnology*. Limnological Botany. John Wiley & Sons, New York, **III**: 929.
- Iamónico D. and Pino I. 2016. Taxonomic revision of the genus *Alternanthera* (Amaranthaceae) in Italy, Plant Biosystems, *An International Journal Dealing with all Aspects of Plant Biology* **150**(2): 333-342, <http://dx.doi.org/10.1080/11263504.2015.1019588>.
- Intergovernmental Panel for Climate Change IPCC (WG 1). 2021. Climate Change 2021, *The Physical Science Basis, the Summary for Policy-Makers*, Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 1-41.
- Jayanth KP. 1987. Biological control of the water fern *Salvinia molesta* infesting a lily pond in Bangalore (India) by *Cyrtobagous salviniae*. *Entomophaga* **32**: 163-165. <https://doi.org/10.1007/BF02373127>.
- Joshi S. 1991. Interference effects of *Cassia uniflora* Mill on *Parthenium hysterophorus* L. *Plant and Soil* **132**(2): 213-218. <http://www.jstor.org/stable/42936987>
- Julien MH, Hill Martin and Tipping PW. 2009. *Salvinia molesta* D. S. Mitchell (Salviniaceae). *Biological Control of Tropical Weeds Using Arthropods*. 378-407. 10.1017/CBO9780511576348.019.
- Kaur M, Aggarwal NK, Kumar V and Dhiman R. 2014. Effects and management of *Parthenium hysterophorus*: A weed of global significance, *International Scholarly Research Notices* **2014**: 1-12. <https://doi.org/10.1155/2014/368647>.
- Kercher S and Zedler JB. 2004. Multiple disturbances accelerate invasion of reed canary grass (*Phalaris arundinacea* L.) in a mesocosm study. *Oecologia* **138**: 455-464.
- Knapp S and Clarkson J. 2004. Proposal to conserve the name *Nicotiana plumbaginifolia* against *N. pusilla*, *N. humilis* and *N. tenella* (Solanaceae). *Taxon* **53**(3): 844-846.
- Kolar CS and Lodge DM. 2000. Freshwater nonindigenous species: interactions with other global changes. pp. 3-30. In: *Invasive species in a changing world*. (Eds. Mooney HA and Hobbs RJ) Washington, DC: *Island Press*.
- Kumbhar ST, Patil SP and Une HD. 2018. Phytochemical analysis of *Canna indica* L. roots and rhizomes extract, *Biochemistry and Biophysics Reports* **16**: 50-55, <https://doi.org/10.1016/j.bbrep.2018.09.002>.
- Kumar CP. 2003. *Fresh Water Resources: A perspective*. National Institute of Hydrology, Roorkee, India (Uttaranchal)
- Lamsal P, Kumar L, Atreya K. et al. Vulnerability and impacts of climate change on forest and freshwater wetland ecosystems in Nepal: A review. 2017. *Ambio* **46**: 915-930.
- Lavergne S and Molofsky J. 2004. Reed canary grass (*Phalaris arundinacea*) as a biological model in the study of plant invasions, *Critical Reviews in Plant Sciences* **23**(5): 415-429. DOI: 10.1080/07352680490505934
- Les DH, and Schneider EL. 1995. The Nymphaeales, Alismatidae, and the theory of an aquatic monocotyledon origin. pp. 23-42. In *Monocotyledons: Systematics and Evolution*. Edited by PJ Rudall, PJ Cribb, DF Cutler and CJ Humphries, Royal Botanic Gardens, Kew.
- Liu D, Keesing JK, Dong Z, Zhen Y, Di B, Shi Y, Fearn P and Shi P. 2010. Recurrence of the world's largest green-tide in 2009 in Yellow Sea, China: *Porphyra yezoensis* aquaculture rafts confirmed as nursery for macroalgal blooms. *Marine Pollution bulletin*, **60**: 1423-1432, doi: 10.1016/j.marpolbul.2010.05.015.
- Lupoaie P, Cristea V, Borda D, Mariana L, Gurău G and Dinica R. 2015. Phytochemical screening: Antioxidant and antibacterial properties of *potamogeton* species in order to obtain valuable feed additives. *Journal of Oleo Science* **64**: 10.5650/jos.ess15023.
- Mack RN, Simberloff D, Lonsdale WM et al. 2000. Biotic invasions : causes, epidemiology, global consequences, and control. *Ecological Applications* **10**(3):689-710.
- Mahmoud Ali Y and Khedr IS. 2018. Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (Case study: Rosetta Branch). *Water Science* **32**(2): 259-275.
- Marble C, Steed S, and Boyd NS. 2021. Biology and Management of Hairy Bittercress (*Cardamine hirsuta*) in Ornamental Crop Production, University of Florida, IFAS Extension. 1-5.
- Mitchell DS. 1985. African aquatic weeds and their management. The Ecology and Management of African Wetland Vegetation, 177-202. https://doi.org/10.1007/978-94-009-5504-2_7.
- Mitchel R and White. 2013. Invasive Plants and Weeds of the National Forests and Grasslands in the Southwestern Region.
- Mooij WM, Hülsmann S, Domis LNDS, Nolet BA, Bodelier PLE, Boers PCM et al. 2005. The impact of climate change on lakes in the Netherlands: a review. *Aquatic Ecology*. **39**, 381-400. doi: 10.1007/s10452-005-9008-0.
- Marhold K, Šlenker M, Kudoh H and Zozomová-Lihová J. 2016. *Cardamine occulta*, the correct species name for invasive Asian plants previously classified as *C. flexuosa*, and its occurrence in Europe. *PhytoKeys* **62**:57-72. <https://doi.org/10.3897/phytokeys.62.7865>
- Moss B. 1988. Ecology of Freshwaters Man and Medium. Oxford: Blackwell Scientific Publications.
- Mostafa AA, Hafez RM, Hegazy AK, Fattah AMAE, Mohamed NH, Mustafa YM, Gobouri AA and Azab E. 2021. Variations of structural and functional traits of *Azolla pinnata* R. Br. in response to crude oil pollution in arid regions. *Sustainability* **13**: 2142. <https://doi.org/10.3390/su13042142>.
- Nelson GC. 2005. Drivers of ecosystem change: summary chapter. pp. 73-76. In: Hassan, R; Scholes, R; Ash, N; eds. Ecosystems and human well-being. Volume I: current state and trends. Washington, DC: *Island Press*.

- Nachtrieb JG, Grodowitz MJ and Smart RM. 2011. Impact of invertebrates on three aquatic macrophytes: American pondweed, Illinois pondweed, and Mexican water lily. *Journal of Aquatic Plant Management* **1**: 49.
- Obianuju PI, Mulala DS, S'phumelele LN, Ntandoyenkosi MM and Nagendra GP. 2020. The benefits of water hyacinth (*Eichhornia crassipes*) for Southern Africa: A review. *Sustainability* **12**: 9222; doi:10.3390/su12219222.
- Ojala A, Kankaala P, and Tulonen T. 2002. Growth response of *Equisetum fluviatile* to elevated CO₂ and temperature. *Environmental and Experimental Botany* **47**(2):157–171.
- O'Hare MT, Baatrup-Pedersen A, Baumgarte I, Freeman A, Gunn IDM, Lazar AN, Sinclair R, Wade AJ and Bowes MJ. 2018. Responses of aquatic plants to eutrophication in rivers: A revised conceptual model. *Frontiers in Plant Science* **9**: 451. doi: 10.3389/fpls.2018.00451.
- Palumbi SR. 2001. Humans as the world's greatest evolutionary force. *Science* **293**: 1786–1790.
- Paolacci S, Jansen MAK and Harrison S. 2018. Competition between *Lemna minuta*, *Lemna minor*, and *Azolla filiculoides*. growing fast or being steadfast?. *Frontiers in Chemistry* **6**: 207.
- Pan XY. 2007. Invasive *Alternanthera philoxeroides*: biology, ecology and management. *Acta Phytotaxonomica Sinica* **45**: 10.1360/aps06134.
- Parmesan C. 2006. Ecological and evolutionary responses to climate change. *Annual Review of Ecology, Evolution and Systematics* **37**: 637–669.
- Pedersen O, Colmer TD and Sand-Jensen K. 2013. Underwater photosynthesis of submerged plants—recent advances and methods. *Frontiers in Plant Science* **4**: 140. doi: 10.3389/fpls.2013.00140.
- Pimentel D, Lach L, Zuniga R and Morrison D. 2000. Environmental and economic costs associated with non-indigenous species in the United States. *BioScience*, **50** (1): 53–65.
- Poikane S, Portielje R, Denys L, Elferts D, Kelly M, Kolada A, Mäemets H, Phillips G, Søndergaard M, Willby N, van den Berg MS. 2018. Macrophyte assessment in European lakes: diverse approaches but convergent views of 'good' ecological status. *Ecological Indicators*, **94**:185–197. <https://doi.org/10.1016/j.ecolind.2018.06.056>.
- Polechońska L, Agnieszka K and Ma³gorzata D. 2019. Trace element accumulation in *Salvinia natans* from areas of various land use types. *Environmental Science and Pollution Research* **26**: 10.1007/s11356-019-06189-5.
- Pysek P, Pergl J, Essl F. *et al.* 2017. Naturalized alien flora of the world: Species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. *Preslia* **89**: 203–274.
- Pysek P, Hulme PE, Simberloff D and *et al.* 2020. Scientists' warning on invasive alien species. *Biological Reviews* **95**:1511–1534. doi: <https://doi.org/10.1111/brv.12627>
- Pandit AK, Rather GH, Wani SA and Javeed JA. 2005. Current status of macrophytic vegetation in various freshwaterbodies of Kashmir Himalaya. *Journal of Research and Development* **5**: 63–69.
- Rai PK and Singh JS. 2020. Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological Indicators*. **111**: 106020.
- Rao P. 2018. Ayurvedic view of *Alternanthera sessilis* Linn. with special reference to mathsyakshi: A brief review. *Scifed Publishers* **2**(1): 1000013
- Raskoti BB, Schuiteman A, Jin W-T and Jin X-H. 2017. A taxonomic revision of *Herminium* L. (Orchidoideae, Orchidaceae), *PhytoKeys* **79**: 1–74. <https://doi.org/10.3897/phytokeys.79.11215>.
- Ray S and Chatterjee A. 2017. Nutritional and biological importance of the weed *Echinochloa colona*: A review. *International Journal of Food Science and Biotechnology* **2**(2): 31–37. doi: 10.11648/j.ijfsb.20170202.13
- Reich PB, and Oleksyn J. 2004. Global patterns of plant leaf N and P in relation to temperature and latitude. *Proceedings of the National Academy of Sciences of the United States of America* **101**: 11001–11006.
- Richardson DM, Pysek P, Rejmanek M, Barbour MG, Panetta FD, and West CJ. 2000. Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions* **6**: 93–107.
- Rooney N and Kalf J. 2000. Inter-annual variation in submerged macrophyte community biomass and distribution: the influence of temperature and lake morphometry. *Aquatic Botany* **68**: 321–335.
- Root TL, Price JT, Hall KR *et al.* 2003. Fingerprints of global warming on wild animals and plants. *Nature* **421**(6918): 57–60.
- Schindler DW. 1977. "Evolution of phosphorus limitation in lakes. 1977. Natural mechanisms compensate for deficiencies of nitrogen and carbon in eutrophied lakes," *Science* **195**(4275): 260–262.
- Semlitsch RD, and Brodie JR. 1998. Are small isolated wetlands inexpedient? *Conservation Biology* **12**:1129–1133.
- Semlitsch RD, Scott DE, Pechmann JHK, and Gibbons JW. 1996. Structure and dynamics of an amphibian community: Evidence from a 16-year study of a natural pond. pp. 217–248. In *Long-term Studies of Vertebrate Communities Academic Press*, (Eds. Cody ML and Smallwood JA), San Diego, California, USA.
- Santamaría L and Van Vierssen W. 1997. Photosynthetic temperature responses of fresh-and brackish-water macrophytes: a review. *Aquatic Botany* **58**: 135–150. doi: 10.1016/S0304-3770(97)00015-6.
- Service, United States Fish and Wildlife. 2018. Brittle water nymph (*Najas minor*) ecological risk screening summary 1 native range and status in the United States Status in the United States.
- Service, United States Fish and Wildlife. 2012. Ecological Risk Screening Summary 1 Native Range, and Status in the United States. Guppy (*Poecilia Reticulata*) Ecological Risk Screening Summary, Native Range, and Status in the United States, **1989**(2011): 1–14.
- Service United States Fish and Wildlife. 2019. Elodea (*Elodea canadensis*), Ecological Risk Screening Summary, 1-12.
- Shah MA and Reshi ZA. 2012. Invasion by alien macrophytes in freshwater ecosystems of India. *Invasive Alien Plants: An Ecological Appraisal for the Indian Subcontinent*, Chapter **16**: 199–215.; <https://doi.org/10.1079/9781845939076.0199>.
- Smith ML. 2003. Aquatic ecology in environmental impact assessment. *Environmental Impact Assessment Series, Brookvale, Australia*. 1–91.

- Smith RA and Rausher MD. 2006. Close clustering of anthers and stigma in *Ipomoea hederacea* enhances prezygotic isolation from *Ipomoea purpurea*. *New Phytologist Foundation* **173**(3): 641–647; <https://nph.onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.2006.01933.x>.
- Soni P and Singh L. 2012. *Marsilea quadrifolia* Linn. - a valuable culinary and Remedial fern in Jaduguda, Jharkhand, India. *International Journal of Life Science and Pharma Research* **2**: 99–104.
- Swenson ULF, Stuessy TF, Baeza M and Crawford DJ. 1997. New and historical plant introductions, and potential pests in the Juan Fernandez Islands, Chile, Pacific, *Science* **51**(3):233–253
- Sushilkumar. 2011. Aquatic weeds problems and management in India. *Indian Journal of Weed Science* **43**(3&4): 118–138.
- Sushilkumar. 2011a. Biological based chemical integration for early control of water hyacinth. *Indian Journal of Weed Science* **43**(3&4): 211–214.
- Thomas R, Kane A, Bierwagen BG. 2008. “*Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research*”. United States Environmental Protection Agency: pp EPA/600/R-08/014.
- Thawkar B, & Jawarkar A, Kalamkar PV, Pawar K and Kale MK. 2016. Phytochemical and pharmacological review of *Mentha arvensis*. *International Journal of Green Pharmacy* **10**(2): 71–76.
- Tungmunnithum D, Kongsawadworakul, P and Hano CA. 2021. Cosmetic perspective on the antioxidant flavonoids from *Nymphaea lotus* L. *Cosmetics* **8**:12; <https://doi.org/10.3390/cosmetics8010012>.
- U.S. Environmental Protection Agency (EPA). 2008. *Effects of Climate Change for Aquatic Invasive Species and Implications for Management and Research*. National Center for Environmental Assessment, Washington, DC; EPA/600/R-08/014. Available from the National Technical Information Service, Springfield, VA, and online at <http://www.epa.gov/ncea>.
- Vadlapudi V and Kaladhar DSVGK. 2012. Antimicrobial study of plant extracts of *Datura metel* L. against some important disease causing pathogens, *Asian Pacific Journal of Tropical Disease* **2**(1): S94–S97, [https://doi.org/10.1016/S2222-1808\(12\)60130-3](https://doi.org/10.1016/S2222-1808(12)60130-3).
- van Zuidam JP and Peeters ET 2013. Occurrence of macrophyte monocultures in drainage ditches relates to phosphorus in both sediment and water. *SpringerPlus* **2**: 564. <https://doi.org/10.1186/2193-1801-2-564>.
- Verhofstad MJJM, Alirangues Núñez MM, Reichman EP, van Donk, E, Lamers LPM, Bakker ES. 2017. Mass development of monospecific submerged macrophyte vegetation after the restoration of shallow lakes: roles of light, sediment nutrient levels, and propagule density. *Aquatic Botany* **141**: 29–38.
- Vélez-Gavilán J. 2020. *Monochoria hastata* (hastate-leaved pondweed). Invasive Species Compendium. Wallingford, UK: CABI. DOI:10.1079/ISC.52540909.20203483525
- Vierssen WV, Mathies, A and Vermaat J. 1982. Early growth characteristics of *Potamogeton pectinatus* L. pp. 135–144. In: *Lake Veluwe, a macrophyte-dominated system under eutrophication stress*, (Eds. W. van Vierssen *et al.*). Kluwer Academic Publishers, Amsterdam (1994).
- Vitousek PM, Mooney HA, Lubchenco J. 1997. Human domination of earth’s ecosystems. *Science* **277**(5325): 494–499.
- Vitousek PM. 1994. Beyond global warming: ecology and global change. *Ecology* **75**(7): 1861–1876.
- VKM. 2016. Risk assessment of cocksbur grass (*Echinochloa crus-galli*). Scientific Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food Safety, ISBN: 978-82-8259-213-0, Oslo, Norway.
- Walther GR, Post E, Convey Pet *al.* 2002. Ecological responses to recent climate change. *Nature* **416**(6879): 389–395.
- Weltzin, JF; Belote, TR; Sanders, NJ. 2003. Biological invaders in a greenhouse world: will elevated CO2 fuel plant invasions? *Frontiers in Ecology and the Environment* **1**(3): 146–153.
- Wagutu GK, Tengwer MC, Jiang W, Li W, Fukuoka G, Wang G and Chen Y. 2021. Genetic diversity and population structure of *Ottelia alismoides* (Hydrocharitaceae), a vulnerable plant in agro-ecosystems of Japan, *Global Ecology and Conservation* **28**: e01676 <https://doi.org/10.1016/j.gecco.2021.e01676>.
- Wilcox KL, Petrie SA, Maynard LA. 2003. Historical distribution and abundance of *Phragmites australis* at Long Point, Lake Erie, Ontario. *Journal of Great Lakes Research* **29**(4): 664–680.
- Wittingham SS, Moderan J and Boyer KE. 2019. Temperature and salinity effects on submerged aquatic vegetation traits and susceptibility to grazing. *Aquatic Botany* **158**: 103–119.
- Wolverton BC and McDonald RC. 1978. Water hyacinth absorption rates of Lead, Mercury and Cadmium. *Hydrobiologia* **22**: 132–135.
- Woolway RI, Dokulil MT, Marszelewski W, Schmid M, Bouffard D, and Merchant, JC. 2017. Warming of Central European lakes and their response to the 1980s climate regime shift. *Climatic Change* **142**: 505–520. doi: 10.1007/s10584-017-1966-4.
- Yadav JP, Ved A, Yadav S, Panghal M, Kumar S and Dhankhar, S. 2009. *Cassia occidentalis* L.: A review on its ethnobotany, phytochemical and pharmacological profile. *Fitoterapia*. **81**: 223–230. 10.1016/j.fitote.2009.09.008.
- Zhang P, Bakker ES, Zhang M, and Xu J. 2016. Effects of warming on *Potamogeton crispus* growth and tissue stoichiometry in the growing season. *Aquatic Botany* **128**: 13–17. doi: 10.1016/j.aquabot.2015.08.004.