A Review on Impacts of Invasive Alien Species on Indian Inland Aquatic Ecosystems

Centre for Biodiversity Policy and Law
National Biodiversity Authority

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I. Introduction

An Invasive Alien Species (IAS) is defined by Convention on Biological Diversity (sixth Conference of Parties; Decision VI / 23) as "an alien species is a species, sub-species or lower taxon, introduced outside its natural past or present distribution, which includes any part, gametes, seeds, eggs or propagules of such species that might survive and subsequently reproduce" (CBD, 2002).

The introduction of aquatic organisms from their native environments range into new areas is expanding, primarily for the purpose of aquaculture promotion, sport fishing, control of disease vectors and trade of ornamental species of flora and fauna. Some of the exotic species introduced outside their natural range may turn invasive and cause huge loss to local diversity and economy. Invasive alien species have been emerging as the second biggest threat factor to global biodiversity after habitat destruction, and it is expected to soon surpass the damage caused by habit destruction and fragmentation factor (De Milliano *et al*., 2010; Zhang and Chen, 2011; Surendra *et al*., 2013). Global Invasive Species Program (GISP) stated that invasive species has the potential to affect the ecosystems in several ways including changing the density, diversity and distribution pattern of the native species. Further, some of the invasive alien species can indirectly and directly affects the human health and also damage the livelihood of the native / regional community and ultimately destabilize the regional economy (Anil *et al*., 2002; Surendra *et al*., 2013; Sandilyan, 2016). Moreover, it is predicted that intensive invasion can cause deleterious ecological changes, which can alter the natural nutrient cycles of the ecosystems which can also leads to global climate change (Hellmann *et al*., 2008; Schweiger *et al*., 2010).

Globally wetlands support unique aquatic and terrestrial species of plants and animals, and most of which are endemic to that habitat/region (Sandilyan *et al*., 2009). Due to their biodiversity richness wetlands are considered as "biological supermarkets" (Lu. 2001, 2002; Sandilyan *et al*., 2009). In addition, wetlands also provide unique values continuously to the society (e.g. economic, aesthetic) (Mistch and Gosselink, 1986; Heimlich *et al*., 1998; Sandilyan *et al*., 2009).

India has diverse topography and different climatic zones, which support diverse wetland habitats throughout the subcontinent. Wetlands in India cover 58.2 million hectares, including areas under paddy cultivation (Prasad *et al*., 2002). From biodiversity point of view Indian wetlands support vast group of species. They are remarkably rich in diversity and harbour unique taxonomic groups (Deepa and Ramachandra, 1999).

The introduction of invasive alien flora and fauna is considered to be a major cause for species endangerment and extinction in aquatic ecosystems including inland wetlands (Figure 1,2) (Claudi and Leach, 1999; Harrison and Stiassny, 1999; Sala *et al*., 2000; Sandilyan, 2016). Aquatic invasive species pose major ecological and economic threats to rivers, lakes and waterways worldwide through displacement of native species, alteration of hydrological cycles, affecting nutrient cycles and altering food web dynamics, introducing new diseases and parasites and hybridization with native species (Bartley *et al*., 2005; Poulos *et al*., 2012). Besides impacts on ecosystems and biodiversity by invasion results in large economic loss too (Pimentel *et al*., 2000), and cultural costs (Lockwood *et al*., 2007).

In India number of studies highlighted the occurrence of several invasive flora and fauna in inland ecosystems and also reported the consequences of the invasion in a regional scale (e.g. Gopal and Sharma, 1981; Biju Kumar, 2000; Abhilash, 2005; Singh and Lakra, 2006; Patel, 2012; EEA, 2012; Paliwal and Bhandarkar, 2014; Sandilyan, 2016).

Figure 1. Harvested Suckermouth catfish in a traditional village ponds in Anandathandavapuram, village near Mayiladuthurai, Tamilnadu.

Photo by : Sandilyan

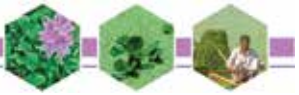
This report to NBA (National Biodiversity Authority) addresses the impacts of invasive speices on Indian inland aquatic ecosystems (ponds, rivers and lakes). Case studies are also provided to illustrate the intensity of the impacts. It also address knowledge gaps and suggest recommendations for better management and prevention.

Figure 2. *Pistia stratiotes L* in a village pond near Mayiladuthurai. Photo by : S. Sandilyan

II. Wetlands

Wetlands are defined as the lands transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface or the land covered by shallow water (Mitch and Gosselink, 1986). Wetlands are considered as one of the important environmental resources of a region. They are recognised as the kidney of the earth because they pool water and sequester pollutants. Moreover, wetlands can stabilize the regional water supply, purify the sewage and recharge the ground water and act as a local and global climate stabilizers (Mistch and Gosselink, 2000; Sandilyan *et al*., 2009). Wetlands are considered as "Biological supermarkets" because they support a large and complex food web and rich in biodiversity, provide unique habitat for large number of wildlife and loaded with immeasurable genetic wealth (Lu, 2001, 2002; Sandilyan *et al*., 2009). Mostly wetlands support unique aquatic and terrestrial species of plants and animals, many of which are endemic to that habitat/region (Sandilyan *et al*., 2009).

Apparently wetlands have also been shown to enhance a variety of ecological, biological and hydrological functions, which provide economic, aesthetic, recreational, educational and other values to society continuously i.e., ecosystem services (Mistch and Gosselink, 1986, Heimlich *et al*., 1998; Sandilyan *et al*., 2009). Therefore, devastation of a wetland results in several socio economical problems and instantly reflects on the GDP (Gross Domestic Product) of a nation. Due to the aforesaid reasons wetland conservation in India is essential.



Wetlands of India

India has a unique geographical diversity and different climatic zones, which support diverse wetland habitats throughout the subcontinent (Appendix A). Wetlands in India cover 58.2 million hectares, including areas under paddy cultivation (Prasad *et al.,* 2002). Earlier, the Indian wetlands were classified into two major groups *viz.,* Natural and Man-made. The natural wetlands in India consist of the high altitude Himalayan lakes, followed by wetlands situated in the flood plains of the major river ecosystems, saline and temporary wetlands of the arid and semi-arid regions and coastal wetlands such as lagoons, backwaters, estuaries, mangrove swamps and coral reefs (Prasad *et al.,* 2002, Deepa and Ramachandra 1999; Sandilyan *et al.,* 2009). The man-made wetlands include inland lakes (*e.g.* Veeranam, Vaduvoor lakes of Tamilnadu) and traditional village ponds. The man made wetlands in our country are about 1.8 times higher than the natural wetlands (MoEF, 1995; Sandilyan *et al.,* 2009).

Recently, National Wetland Inventory and Assessment project funded by Ministry of Environment, Forest and Climate Change (MoEF&CC) assessed the Indian wetland and suggested a new classification (MoEF, 2011). To accomplish the mission, researchers used advanced techniques like satellite remote sensing and Geographic Information System (GIS). The results of the category-wise wetland are provided in Appendix B (MoEF, 2011).

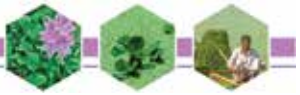
III. Biodiversity of Indian inland wetlands

Indian wetlands harbour unique species of flora and fauna. It is estimated that, freshwater wetlands of India alone support 20 percent of the known range of biodiversity and harbour almost all taxonomic groups (Deepa and Ramachandra, 1999). The floral diversity supported by inland wetlands of India range from unicellular algae, bryophytes, mosses and ferns to woody angiosperms. As per a conservative estimate, the number of plant species within Indian wetlands is nearly 1,200. According to Zoological Survey of India, the inland wetlands support 17,853 (19.9%) of known Indian fauna i.e. One-fifth of known faunal species of India (MoEF&CC & GIZ. 2014).

Among the Indian inland wetlands, rivers are the richest in biodiversity. The river system is identified as one of the last global frontiers of freshwater diversity, which supports several IUCN threatend category of species (Anon, 2012).

Nearly 50% of the aquatic plants of the world are recorded from the Indian subcontinent. However, only a handful of species have been studied in detail (Anon, 2012). With reference to the Indian inland aquatic fauna, most studies available on fishes. India is eighth in the world and third in Asia pertaining to fish diversity (Biju Kumar, 2000). The total species includes 2319 finfish *i.e.,* 838 freshwater, 113 brackish and 1368 marine (Kapoor *et al.*, 2002; Lakra *et al.,* 2009).

The Western Ghats hotspot is globally a significant centre of diversity and endemism for freshwater species where close to 16% of the 1,146 freshwater taxa assessed are threatened, 1.9% were near threatened. While in the Eastern Himalaya, nearly 31% studied are data deficient (Anon, 2012). The



above observation establish the importance and need of inland aquatic conservation.

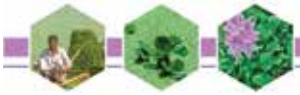
Aquatic Invasion

A number of studies disclosed that invasive species has emerged as a great threat to endemic and threatend species in several vital ecosystems of the world including the biological hotspots (e.g. Denslow, 2007; Raghavan *et al.,* 2008).

International Union for Conservation of Nature (IUCN) highlighted that, invasive species are widely distributed in all kinds of ecosystems throughout the world and harbour all major taxonomic groups including viruses, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals (Rejmanek and Richerdson, 2000; Sujay *et al.,* 2010). In wetlands, aquatic plants, ornamental and commercially important fishes and some species of shell fishes are identified as a worst invaisves (*e.g.* Biju Kumar, 2000; Sandilyan, 2016).

Worldwide aquatic invasive species pose major ecological and economic threats to rivers, lakes and waterways through the displacement of native species and the alteration of hydrologic cycles, affecting nutrient cycles, altering food web dynamics, introducing diseases and parasites and hybridization with native species (Bartley *et al.,* 2005; Poulos *et al.,* 2012). Impacts on ecosystems and biodiversity, the invaders pose a serious threat to regional economy and livelihood of native people (Pimentel *et al.,* 2000), and their cultural costs (Lockwood *et al.,* 2007).

Sala *et al*. (2000) observed that biological invasions are more important drivers of biodiversity change in freshwater systems than in terrestrial systems. Earlier studies suggest that invasive species are one of important driver of regional biodiversity changes in the lakes over the century. For

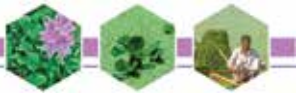


example, the introduction of Nile perch in Lake Victoria, Tanzania is a good example of the adverse impacts of invasion in wetlands (Appendix C).

Studies confirmed that intensity of the invasion in a wetland is always correlated with the pattern of human settlement around the lakes and other traditional aquatic systems (SBSTTA, 2003). Besides, it is worth to mention here that our livelihood and cultures are interlaced with inland waters. Globally, huge population settled near the large inland aquatic system making them extremely vulnerable to invasion. To support this, studies established that inland wetlands which are away from human settlements were lesser invasive species than the wetlands surrounded by human settlements (Drake *et al.,* 1989; UNEP/CBD/SBSTTA, 2003).

Management of invasive species in aquatic ecosystems is a global challenge (Chandra and Gerhardt, 2008) and therefore considered with special attention in Strategic Plan for Biodiversity for 2011-2020 by The Convention on Biological Diversity (CBD). Target 9 (which is listed under Goal B) of this plan deals specifically with invasive alien species and mentions: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment." Further the United Nations' Sustainable Development Goals set for 2030 also corroborate this plan and highlight the needs for protecting life under water and management of invasive alien species.

Across the world there are a serveral policies, legislations management approaches and awareness campaigns involving citizens to deal with invasive alien species (Piria *et al.,* 2017). In India, there is no comprehensive plan to tackle the growing menace of invasive alien species, especially aquatic invasive species.



Pathways of Introduction

The introduction, establishment and invasion of alien species into inland water ecosystems depend on a number of socio-economic, political, cultural, and ecological factors of the region (UNEP/CBD/SBSTTA, 2003). Inevitably human migration has long served as a source of species introduction. From the time immemorial, people used to bring and introduce ornamental and commercially important plants and animals to their new/old residence (UNEP/CBD/SBSTTA, 2003). On the other hand demand for food resources increases the introduction of commercially important exotic agriculture and aquaculture species. In due course of time, some of the introduced species managed to escape to wild and evolved as an Invasive (UNEP/CBD/SBSTTA., 2003; Sandilyan, 2016). Other important pathways include ornamental trade, unscientific aquaculture practice, sport fishing, mosquito control, natural disaster and ballast water (Anil *et al*., 2002; Biju Kumar, 2000; Raghubanshi *et al.*, 2005; Sandilyan, 2016). Recent studies also state that construction of dams and river linking projects also pave way for the introduction of invasive species. For instance, *Badis badis* (Blue perch or Badis), *Pethia gelius* (Golden barb), *Osteobrama cotio* (Cotio) and *Lepidocephalus guntea* (Gutum) have invaded in to Chennai lakes only after the river-linking project (SBSTTA, 2003; Daniel *et al*., 2004; Knight and Balasubramanian, 2015).

However, the ornamental trade has been identified as the vital pathway for the entry of invasive species, particularly fish and plant species (SBSTTA, 2003; Sandilyan, 2016). The occurrences and impacts of invasive ornamental fish species are poorly documented in India (SBSTTA, 2003; Sandilyan, 2016).

Entry through ornamental trade

The ever-increasing global trade on ornamental species is one of the most important and yet poorly documented pathways for aquatic invasion throughout the world including India (Ruiz *et al*.,1997; Rixon *et al*., 2005; Raghavan *et al*.,

2013; Sandilyan, 2016). Unfortunately, till date it has received little attention from the researchers and policy makers in several parts of the world (Padilla and Williams, 2004). Recent studies have clearly stated that ornamental trade (conventional and online) plays a crucial role on introduction exotic species (plant and animals) in to new aquatic systems (Padilla, and Williams, 2004; Soundarajan *et al*., 2015; Sandilyan, 2016). It is worth to mention here that for the past few decades the aquarium and ornamental species trade is growing by 14% annually worldwide, and the major contribution was from the developing countries (Fig 3) (Padilla and Williams, 2004; Rani *et al*., 2014).

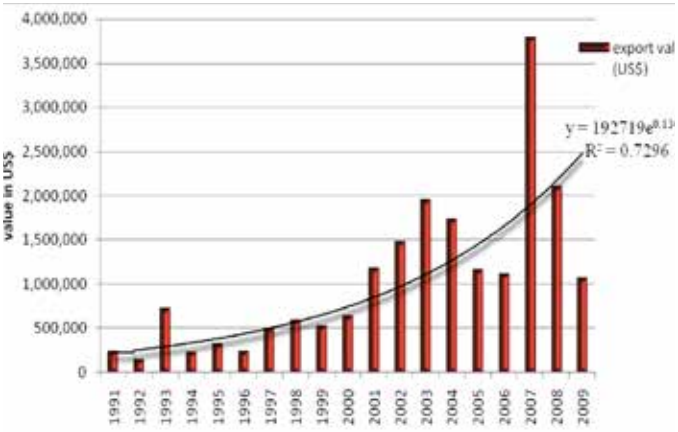


Fig 3: Ornamental fish exports from trend in India during 1991-2009 (Source - Rani *et al*., 2014)

In India, a recent study at Madurai Kamaraj University of Tamil Nadu, revealed that 19 states and Union Territories support on-line shops to market several ornamental organisms including exotic ornamental fishes, aquatic plants (Figure 1,3,4) and other small pet animal. Most of the traders are exclusively trading selected group of species. Separate shops are there for marine and fresh water exotic plants and animals (Soundararajan *et al*., 2015). Further the study pointed out that Andhra Pradesh, Chandigarh, Gujarat, Karnataka,

Kerala, Maharashtra, New Delhi, Tamil Nadu and West Bengal are pioneer in this trade (Soundararajan *et al*., 2015).

More than 3000 terrestrial ornamental plants, including herbs, shrubs and trees and 65 genera of freshwater fishes and 66 genera of marine fishes are available in on-line shopping websites of India (Soundararajan *et al*., 2015).

Most of the time the invasive species manage to escape to the wild from the hobbyist and traders and evolved as an invasive species and caused irreparable damage to Indian aquatic diversity (Sandilyan, 2016). So far, more than 10 ornamental fish species established a good breeding population in Indian inland aquatic systems (Sandilyan, 2016). The list of such exotic ornamental species reported in the aquatic systems is placed in Table 1. Five exotic ornamental fishes *viz., Gambusia affinis, Oreochromis mossambicus, Osphronemus goramy, Poecilia reticulata, Xiphophorus maculatus* were reported from Chalakudy River in the Western Ghats, a biodiversity hotspot which harbours 16 endangered and 4 critically endangered species. Further, the study highlighted that *Poecilia reticulate* species have established a breeding population in this hotspot (Raghavan *et al.,* 2008). However, there is no report about the impacts of the species in this biodiversity hotspot.

Figure 4. Flowerhorn fish in local aquarium

Table 1. Exotic ornamental fish species have been reported from different inland water bodies of India.

S. No	Species name	Common Name	Breedi population in the wild
1	*Amphilophus trimaculatus*	Three Spot/ Point Cichlid	
2	*Badis badis*	Blue perch or Badis	
3	Barbonymus gonionotus	Silver barb	
4	*Carassius auratus auratus*	Gold fish	√
5	*Carassius carassius*	Crucian carp	√
6	*Cichlasoma trimaculatum*	Three spot cichlid	
7	*Cyprinus carpio*	Common carp	√
8	*Gambusia affinis*	Western Mosquito fish	√
9	*Gambusia holbrooki*	Eastern Mosquito fish	
10	*Lepidocephalus guntea*	Gutum	
11	*Macropodus opercularis*	Paradise fish	
12	*Oreochromis mossambicus*	Mozambique tilapia	√
13	*Osphronemus goramy*	Giant gourami	
14	*Osteobrama cotio*	Cotio	
15	*Pethia gelius*	Golden barb	
16	*Pethia phutunio*	Spotted sail barb	
17	*Piaractus brachypomus*	Red-bellied pacu	
18	*Poecilia reticulata*	Guppy	√
19	*Pterygoplichthys disjunctivus*	Vermiculated sailfin catfish	√
20	*Pterygoplichthys ultiradiatus*	Sucker mouth armored catfish	√
21	*Pterygoplichthys pardalis*	Amazon sailfin catfish	√
22	*Pygocentrus natterei*	Red Piranha	
23	*Tinca tinca*	Tench	√
24	*Trichogaster trichopterus*	Three-spot gourami	√
25	*Trichopsis vittata*	Croaking gourami	√
26	*Xiphophorus hellerii*	Green swordtail	√
27	*Xiphophorus maculatus*	Platy	

Sources – Bijukumar, 2000; Rema Devi and Indra 2003; Daniels and Rajagopal 2004; Tripathi 2013; Knight, and Balasubramanian 2015.

Aquaculture practice

A number of commercially important exotic fishes are introduced in several parts of the world in order to improve the local fishery potential besides sports fishing (Bomford, 2008). India is also one of the countries which introduced several commercially important exotic fish species and some of them manage to escape to the wild from their confined area and caused several damage to native species (e.g. African cat fish) (Singh and Lakra, 2006; Lakra *et al.,* 2008). A study by Singh *et al.,* (2013) in Uttar Pradesh exposed the occurrence of several commercially important aquatic species in the major rivers of the state (Table 2).

Throughout India, more than 30 exotic species which are introduced for different purpose (*e.g.* food fish, game fish, larvicidal) were reported in the wild and the list of such exotic aquaculture species are provided in Table 3.

Figure 5. School of African cat fish in a inland water body

Table 2. Exotic fish species reported in Uttar Pradesh major rivers

S. No	Species Name	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	T
1	*Carassius auratus auratus* Gold fish	×	√	×	×	×	×	×	×	×	×	×	×	×	×	1
2	*Cyprinus carpio nudus* Common carp	×	√	×	×	×	×	×	×	×	×	×	×	×	×	1
3	*Pangasianodon hypophthalmus* Striped Catfish	×	×	×	×	×	√	×	×	×	×	×	×	×	×	1
4	*Cyprinus carpio communis* Scale carp	√	√	×	×	×	×	×	×	×	×	×	×	×	×	2
5	Cyprinus carpio specularis	√	√	×	×	×	×	×	×	×	×	×	×	×	×	2
6	*Oreochromis mossambicus* Mozambique Tilapia	√	√	×	×	×	×	×	×	×	×	×	×	×	×	2
7	*Gambusia affinis* Mosquito fish	√	√	×	×	×	×	×	×	×	√	×	×	×	×	3
8	*Cyprinus carpio* Common carp	×	√	√	√	√	√	√	√	×	×	×	×	×	√	8
9	*Oreochromis niloticus* Nile tilapia	√	√	√	√	√	√	√	×	×	×	×	√	×	×	8
10	*Hypophthalmichthys molitrix* Silver carp	√	√	√	√	√	√	√	√	×	×	×	√	×	×	9
11	*Aristichthys nobilis* Bighead carp	√	√	√	√	√	√	√	√	×	×	×	√	×	√	10
12	*Ctenopharyngodon idella* Grass carp	√	√	√	√	√	√	√	√	×	×	×	√	×	√	10
13	*Clarias gariepinus* African catfish	√	√	√	√	√	√	√	√	√	√	√	√	√	√	14
Total exotic species in individual rivers		9	12	6	6	6	7	6	5	1	2	1	5	1	4	

Source – Singh *et al* (2013b) - √ Indicate the presence, × absence
R1 – Ganga, R2- Yamuna, R3-Ramganga, R4- Gomti, R5-Sai, R6-Tamsa, R7-Sone,
R8- Baigul, R9-Nakita, R10-Hindon, R11-Kali, R12-Gerua, R13-Sharda, R14-Dewa ,
T – Total (The African catfish *Clarias gariepinus* reported in all the rivers of the study area).

Table.3. Commercially important exotic aquaculture species reported in the wild

S. No	Scientific name	Common name	Invasion status
Food fishes			
1	*Ctenopharyngodon idella*	Grass carp	I
2	*Cyprinus carpio var. nudus/communis/ specularis*	Common carp	I
3	*Hypophthalmichthys molitrix*	Silver carp	I
4	*Orecohromis mossambicus*	Tilapia	NA
5	*Pangasianodon hypophthalmus*	Pangus	NA
6	*Piaractus brachypomus*	Pacu	NA
7	*Barbonymus gonionotus*	Silver barb	NA
8	*Carassius carassius*	Golden Carp	NA
9	*Osphronemus goramy*	Gourmi	NA
10	*Puntius brevis*	Tawes	NA
11	*Tinca tinca*	Tench	NA
Unauthorised introduction for aquaculture			
1	*Hypophthalmichthys nobilis*	Bighead carp	NA
2	*Clarias gariepinus*	African catfish	NA
3	*Oreochromis niloticus*	Nile tilapia	I
4	*Coptodon zillii*	Red belly tilapia	NA
5	*Ictalurus punctatus*	Channel catfish	NA
6	*Mylopharyngodon piceus*	Black carp	NA
7	*Oreochromis sp.*	Red tilapia	NA
8	*Pygocentrus nattereri*	Red piranha	NA
Larvicidal fishes			
1	*Gambusia affinis*	Topminnow	I
2	*Poecilia reticulata*	Guppy	I
Game fishes			
1	*Salmo trutta*	Brown Trout	NA
2	*Salmo levensis*	LochLeven Trout	NA
3	*Salmo gairdneri*	Rainbow Trout	NA
4	*Salvelinus fontinalis*	Eastern Brook	NA
5	*Salvelinus namaycush*	Lake Trout	NA
6	*Oncorhynchus nerka*	Sockeye Salmon	NA
7	*Salmo salar*	Atlantic Salmon	NA

I -Invasion, NA –Not assessed
Cyprinus carpio var. nudus Common carp, *Cyprinus carpio* var. specularis Mirror and *Cyprinus carpio* var. communis Scale carp varieties have been and listed in India

IV. Impacts of invasive alien species on Indian inland wetlands

This report is formulated based on the available/accessible literature in national and international peer reviewed journals and reports collected from other unpublished dissertations from various universities and research organizations. Invariably all findings unanimously admitted that the Indian inland ecosystems and biodiversity are constantly degraded due to invasion of several exotic flora and fauna. On the other hand, most of the studies unfortunately failed to quantify the degree of loss due to such invasions.

Impacts of Water hyacinth on Indian wetlands

Water hyacinth (*Eichhornia crassipes*) was introduced as an ornamental plant in several regions of the world including India. In most of the habitats of Africa and India, this species is still spreading even after century of its initial introduction (Navarro and Phir, 2000). Recently water hyacinth has also been labelled as the world's worst weed and has garnered increasing international attention (Zhang *et al.,* 2010).

In Deepor Beel, a freshwater lake formed by the Brahmaputra River is heavily infested by water hyacinth and it has been identified causing heavy siltation in the wetland (Patel, 2012).

Besides, navigationinthe Brahmaputra river has been severely affected by water hyacinth, it has also blocked irrigation channels and obstructed the flow of water to crop fields (Figure 6) (Patel, 2012). It slows water flow by 40 to 95% in irrigation channels was also reported in several parts of India (Jones, 2009).

In West Bengal, water hyacinth causes huge annual loss of paddy by directly suppressing the crop, inhibiting rice germination and interfering with harvesting (Patel, 2012; EEA, 2012). Besides, the dense growth entangles with boat propellers and hampering fishing (Figure 7) (Patel, 2012). It also pollute the water and changes the water chemistry by decreasing the dissolved oxygen level. In Kerala, the inland water transport along the inland backwaters has been severely hampered by the invasive water hyacinth.

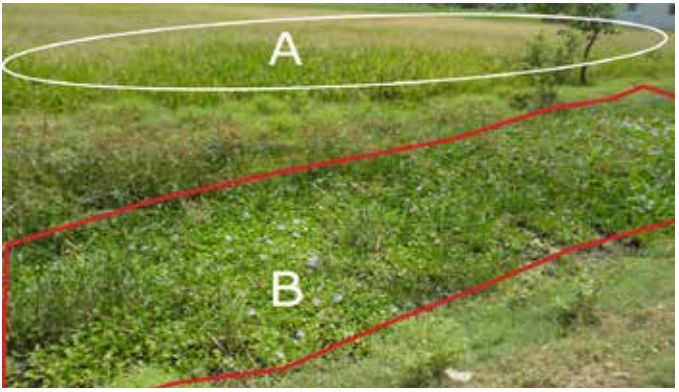
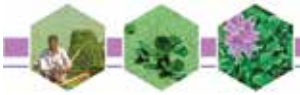


Figure 6. Invasion of *Eichhornia crassipes* in an irrigational canal obstruced the flow of water to paddy crop fields. A- Paddy field, B- Invasion in the canal. Photo by : S. Sandilyan

Figure 7. Water hyacinth clogging a canal in Chidambaram town, Cuddalore District of Tamil Nadu. More details of the species is available in Appendix. Photo by : S. Sandilyan



Impacts of exotic fishes on Indian inland wetlands

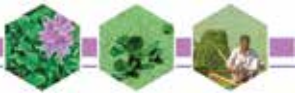
Several fish species are introduced into India for ornamental, aquaculture and other purposes. In due course of time few of the species managed to escape into wild and turned as invasive to the system. Here we discussed some of the invasive fish species which caused huge damage to the Indian biodiversity and its regional economy.

Impacts of common carp Cyprinus carpio

Common carp *Cyprinus carpio* was introduced into India during 1939 and 1957 in order to increase the aquaculture production and now it contributes 7.17% of inland production (Dey *et al.,* 2005; Singh and Lakra, 2006). Gradually this species was introduced from cultured ponds to reservoirs and lakes and later it was escaped to several India Rivers and turned as an invasive (Singh and Lakra, 2006; Singh *et al.,* 2013). Successive observations in local catches of the inland system clearly indicate the constant biomass increase. Further, it has emerged as a threat to native species and also cause pollution (e.g. Ganges system by Singh *et al.,* 2013). Around the year different age group of this species was reported in the river Ganga, which indicates the invasion potential of these species. On the other hand the local fisherman are getting low price for this species in the market (Singh *et al*., 2010).

From biodiversity point of view, *C. carpio* leads to the decline of endemic species *Osteobrama belangeri* in Loktak lake of Manipur and Schizothoracids in northern riverine system (Singh *et al.,* 2013). Further, *C. carpio* is expected to dilute the genetic diversity and species diversity of river Ganga (Singh *et al.,* 2010).

In Kerala, this species is reported as invasive in reservoirs such as Kundala Dam, Mattupetti Dam, Kallarkutty Dam, Shengulam Dam, Lower Periyar Dam, Anayirankal Dam, and all the tributaries of Periyar river. In Aruvikkara and



Kulathoopuzha regions, where the indigenous fish Mahseer is considered as sacred and fed by the devotees, the introduced carp has established effective populations, thereby replacing the indigenous species at places. Besides, the invasive carps destroy aquatic macrophytes directly by uprooting or consuming the plants, or indirectly by increasing turbidity and thereby reducing light for photosynthesis. They also compete with indigenous species for food and space and displace the indigenous species (Biju Kumar, unpublished data).

Impacts of African catfish Clarias gariepinus

African catfish *Clarias gariepinus*, was introduced into India from Bangladesh with the aquaculture species tag. Initially this species was introduced in West Bengal, Assam and Andhra Pradesh. Later during 1993 and 1994 *C.gariepinus* entered in to Kerala and largely cultured by the farmers (Thakur, 1998; Middendorp, 1998; Baruah *et al*., 1999; Krishnakumar *et al*., 2011).

The low operational costs and high profits derived from African catfish led to farming intensification of the species in several Indian states (Krishnakumar *et al*., 2011). Initially in several parts, framers cultured *C.gariepinus* with the native carp which resulted in to huge loss. In due course of time farmers prefered the monoculture of *C.gariepinus* due its high growth rate and commercial benefits (Middendorp, 1998; Thakur, 1998; Baruah *et al*., 1999). In general, Indian farmers used to stock very high densities of *C.gariepinus* in their ponds. This resulted in periodical large scale escape of the species to the neighbouring wild habitats (Pascal *et al*., 2009). Earlier studies clearly mentioned that *C.gariepinus* is known for its behaviour of slowly crawl on the land with the aid of their strong pectoral fins and enter in to adjacent wetlands during monsoon (Burgess, 1989). *C.gariepinus*

isan omnivorous predatory fish, feeds on a variety of food items from microscopic zooplankton to large fishes.

The occurrence of *C.gariepinus* has been reported from several inland system of India including the mighty rivers like Ganga, Yamuna, Sutlej, Godavari, Periyar River and the lakes like Vembanad Lake. Moreover, regional fishers in several parts of India have reported the occurrence of the species in streams, ponds and pools. *C.gariepinus* is emerging as a challenge to the unique gene pool and sustainable regional fisheries of India (Krishnakumar *et al.,* 2011; Singh, 2014).

It was reported that this African catfish can prey on native fish into half of its length (de Graff and Jansen, 1996). It was also reported that this species also devour on small reptiles, amphibians and birds (de Moor & Bruton, 1988). Studies from Vembanad Lake disclosed that *C.gariepinus* pose a threat to native cichlids like Perlspot cichlid *Etroplus suratensis* and orange chromide *Etroplus maculatus* (Krishnakumar *et al.,* 2011). Analysis on fish catch composition in several inland wetlands of India shows the dominant catch of *C.gariepinus* rather than the native species in wild (e.g. Krishnakumar *et al*., 2011; Singh, 2014). A study in Uttar Pradesh reported the occurrence of the species in 14 major rivers of the state (Table 2). Studies from Kerala confirmed the occurrence of this species from Periyar lake, Mattupetti Dam, Kundala Dam, Anayirankal Dam, Kainakarry Canal and Deviyar River and in all the tributaries of Periyar River of Idukki District (Biju Kumar, unpublished data). This fish species was reported in number of temple ponds/tanks of Kerala and they have replaced the native catfish *Clarias dussumieri*, which has become a rare fish in many water bodies and in many aquatic habitats of Kerala (Figure 8) (Biju Kumar, unpublished).

Figure 8. School of African cat fish in a Temple pond in Kerala (Photo by Biju Kumar)

Based on several scientific studies, in 1997, the National Committee for the introduction of species for India officially banned the rearing of *C.gariepinus* (Gopi and Radhakrishnan, 2002). However, until now there is no data in India about the impacts of this species in each trophic level as well as exact loss caused by the species to aquatic system.

Impacts of invasive ornamental fishes

In case of ornamental fishes, very poor literature are available and they too state only about the occurrence of the list of species in Indian inland aquatic system (Sandilyan, 2016). It is the need of the hour to concentrate our research on the role of exotic ornamental fishes in our native system, because it was reported that one-third of the world's worst aquatic invasive species are exotic ornamental fishes which is identified as a major source of ecological destruction in the introduced area (Padilla and Williams, 2004; Liang *et al.,* 2006).

A number of studies concluded that ornamental alien fishes frequently alter the aquatic ecology by changing water chemistry e.g., increase nitrogen and phosphorus concentration, damage the aquatic vegetation and exploit the

food resources and also cause the extinction of native fishes by predation destroying the eggs, larvae, sub adult and adult (Pimentel, 2001; Husen, 2014; Biju Kumar *et al*., 2015). Besides, number of ornamental alien fish species also hybridize with native species in wild and diluting the wild genetic stock leading to long-term introgression of gene pools (Pimentel, 2001).

Impacts of suckermouth armoured catfish

Suckermouth cat fish has been identified as a great threat to global freshwater diversity (Figure 9). Occurrence of the species in the wild is reported to alter the entire system and species have the ability to changes the physicochemical nature of water. Furthermore, it will outcompete the native algae consumers and aggressively drive them away from the system (Hoover *et al*., 2004). It also creates serious negative impacts on periphyton feeding and bottom spawning fishes. Besides, it consumes the eggs of the native species and leads to the local extinction of indigenous varieties (Hoover *et al*., 2004). In addition, the suckermouth catfishes are also found to affect other biota in the aquatic system. For instance, the availability of physical cover and food for the aquatic insects are destroyed by the sucker mouth fish. The strong dorsal and pectoral fins of the catfish caused death to the piscivorous birds such as brown pelicans (Pelecanus occidentalis) (Bunkley-Williams *et al*., 1994; Hoover *et al*., 2004). Furthermore, the bottom ploughing behaviour of the suckermoth damages the aquatic vegetation composition (Figure 10 - 13) (Hoover *et al*., 2004). Moreover the nesting behaviour of this species will lead to small scale bank/bund erosion (Hoover *et al*., 2004). Apart from the above said interactions, the suckermouth is also known to cause economic loss by damaging the fishing gears, cast and gill nets (Krishnakumar *et al*., 2009; Tripathi, 2015).

Biju Kumar *et al*. (2015) reported that a constant decline trend in native fishes in the drainages of Thiruvananthapuram city, Kerala due to high invasion of

suckermouth Pterygoplichthys species The number of fishes collected by the cast net every time varied from 3-27 throughout the study period which indicate the dominant biomass of the species in the system (Biju Kumar *et al*., 2015).

Figure 9. Harvested sucker mouth cat fish from Thiruvananthapuram drainage. Photo by A. Biju Kumar

Figure 10. Construction of burrows (arieal view) in river banks in USA

Figure 11. Construction of burrows (side view) in river banks in USA
Courtesy: Oliver Van Den Ende

Figure 12. The holes dug by Sailfin Catfish (*Ptergoplichthys* spp.) in stream banks at Thiruvananthapuram, Kerala (Photo: Biju Kumar)

Figure 13. Sailfin Catfish (*Ptergoplichthys* spp.) digging holes in stream banks at Thiruvananthapuram, Kerala (Photo: Biju Kumar)

Another species of suckermouth catfish *Pterygoplichthys pardalis* was reported to cause huge damage to the native species diversity of Vandiyur Lake, Madurai, Southern India. The biomass of *P. pardalis* was significantly higher compared to the indigenous varieties which clearly shows the negative impacts of this exotic aquarium fish on inland aquaculture in terms of diminished production of edible fishes (Soundararajan *et al.,* 2015). Further, *P. pardalis* does not hold any market / edible value, due to this, after the harvest people discarded the species on the banks of the lake where it is not even scavenged (Soundararajan *et al.,* 2015).

Figure 14. Discarded *P. pardalis* on the banks of Vandiyur Lake, Madurai, Tamilnadu Courtesy - Dr. S. Chandrasekaran

A study was carried out in the tributaries of Cauvery River, Thiruvengadu, region of Nagai District, Tamilnadu reported the occurrence of the species in the wild as well as in the aquaculture ponds (Meena *et al.,* 2016).

Based on the above studies, CEBPOL, NBA carried out a survey in the traditional village ponds of Anandathandavapuram, near Mayiladuthurai, Tamilnadu. During observation different age groups of this species was caught from the same pond by the local farmers, which indicate the year round breeding habit as well as the invasion potential of the species (Figure 15). The discussion with the local farmers revealed that for the past four years the biomass of the species in their catches increased gradually and they also register their concern about the nonavailability of their traditional varieties in their ponds. The aforesaid studies clearly indicate the invasion potential of sucker mouth catfishes in inland water bodies of India.

Different age groups of Suckermouth catfish harvested in a traditional village ponds in Anandathandavapuram, village near Mayiladuthurai, Tamilnadu (Photo by Sandilyan)

The other major invasive species and its impacts, diagnostic characters, reproduction, invasiveness and negative impacts and management are provided in Appendix D.

V. Impacts of the exotic species on major rivers of India

Indian rivers have been well recognised for their rich biodiversity. Besides, the system is identified as one of the last global frontiers of rich freshwater diversity and supports several IUCN threatened category species (Anon, 2012). But in the recent days researchers repeatedly reported the occurrence of the exotic ornamental and commercially important aquatic fish species in several major rivers. Especially, ornamental fishes emerging as a single strong factor which drives out our native fishes and cause immeasurable loss to Indian riverine biodiversity (Anon, 2012; Singh et al., 2013, 2014; Sandilyan, 2016). Pertaining to research in this aspect, more investigations/studies are carried out in Northern part of India rather than other parts. On the other hand, there were no detailed/complete study (i.e. impacts on trophic structure, diversity, ecosystem services and functions/economic loss etc.) of exotic fish species in Indian system.

Impacts of exotic species on river Ganga

The river Ganga is one of the trans-boundary rivers of Asia (India, Nepal and Bangladesh) and the Ganga basin is the largest river basin in India in terms of catchment area, constituting 26% of the country's land mass (8,61,404 Sq. km) and supporting about 43% of its population (approx., 448.3 million) (MoEF&CC, 2009). Among the three countries (India, Nepal and Bangladesh), India, harbours 79% area of Ganga basin. The river run across over 11 Indian states viz., Bihar, Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Jharkhand, Madhya Pradesh., Rajasthan, Uttarakhand, Uttar Pradesh and West Bengal (MOEF, 2009).

River Ganga is known for its fish diversity, 140 fish species have been documented so far (Sinha, 2006; Lakra *et al*., 2010), among them 34 species are considered as commercially important which, includes Gangetic Carps, Large Catfishes, Featherbacks and Murrels (Rao, 2001; Singh *et al.,* 2010). Besides, large scale commercial fishing activity is mainly happening in parts of the three Indian states (Uttar Pradesh, Bihar and West Bengal) (Vass *et al.,* 2010). A recent study by Singh *et al.* (2013) in-between Kanpur to Ballia region disclosed an increased yield of alien species in Ganga basin (Figure 16-17). The highest yield of alien species was found 384.27 kg km−1 between Allahabad to Varanasi. The occurrence of *Cyprinus carpio, Oreochromis niloticus, Aristichthys nobilis, Ctenopharyngodon idella, Hypophthalmichthys molitrix and Clarias gariepinus* are the predominant invasive alien species in this region and the propagule pressure is also spiralling every year. The study concluded that, there was a declining trend in the availability (catches) of local/native variety especially the Indian major carps due to the invasion of exotic species. The other impacts of the invasive speices in Ganga is placed in Table 4.

Table 4. Impacts of exotic species on native varieties of Ganga River

S. No	Name of the Exotic species	Identified and expected impacts
1	*Aristichthys nobilis* Bighead Carp	Led to decline of *Catla catla,* and high chance of hybridization
2	*Cyprinus carpio* Common Carp	led to decline of Indian major carps
3	*Oreochromis niloticus* Nile tilapia	Naturalized population of tilapia declined
4	*Clarias gariepinus* African Catfish	The carnivorous habit leads to the decline of small animals and directly and indirectly leads loss to biodiversity.
5	*Hypophthalmichthys molitrix* Silver Carp	Competing with *Catla catla* for all resources
6	*Gambusia affinis* Mosquito fish	Large scale consumption of natural zooplankton leads to food scarcity for the local fish species

Source: Singh *et al.,* 2013

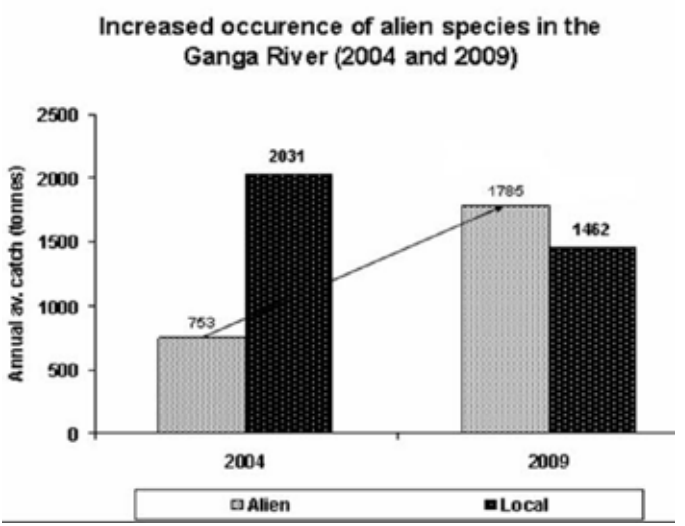


Figure 16. Increased occurence of invasive fish speices in river Ganga

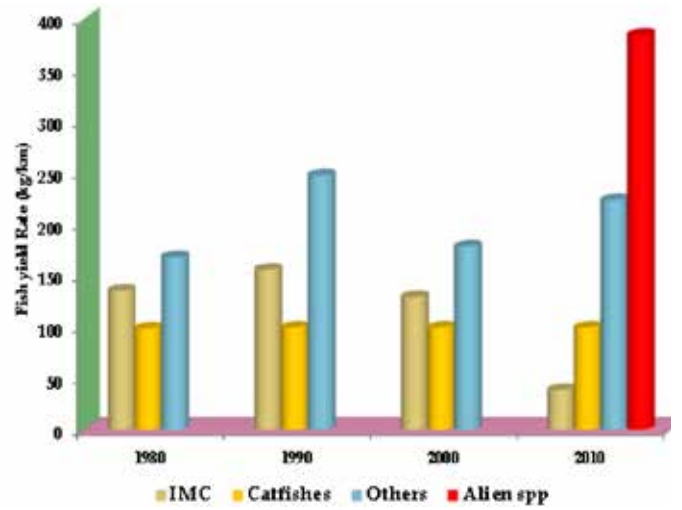


Figure 17. Fish yield rate (kg km−1) in the middle stretch of the Ganga River between 1980 and 2010 (IMC = Indian major carps). **Courtesy:** A.K. Singh

VI. Impacts of exotic species on Indian lakes

India supports relatively poor number of natural lakes and most of them are lie in the Himalayan region, flood plains of Indus, Ganga and Brahmaputra. All the natural lakes of India support dynamic ecosystem (MoEF&CC, 2010). The functions of the lakes as ecosystem provides immeasurable goods and services to the native community. Besides, the lakes also provides many socio cultural and recreational benefits and some of which are translated into direct economic benefits through tourism. Invariably all the Himalayan lakes are of great socio cultural values (MoEF&CC, 2010). Especially, the fresh water lakes of Kashmir Himalaya have been playing a great role in the sociocultural and economic status of the valley since ancient times. All the lakes have been identified as an important source of fish, fodder and a variety of economically important aquatic plants besides being a source tourism revenue (Ahmad *et al.,* 2015). However, recent investigations on the ecology of these lakes revealed that most of the lakes in this region are severely affected by several anthropogenic pressures due to unplanned urbanization, encroachments, soil erosion, deforestation, uncontrolled use of pesticides for agriculture and horticulture. The aforesaid activities directly affects the ecological services and biodiversity wealth of the lakes (Ahmad *et al.,* 2015). It is merit to mention here that aquatic habitats, especially lakes are highly vulnerable to invasion of exotic flora and fauna. Ironically, studies in this aspect are almost ignored in India (Zedler and Kercher, 2004; Shah and Reshi, 2012). However considerable studies are available about the occurrence and impacts of aquatic invasive plants of Kashmir lakes (e.g. Khuroo *et al.,* 2007; Reshi *et al.,* 2008; Shah *et al.,* 2011; Shah and Reshi,

2014). A recent study by Reshi *et al*. (2008) highlighted the common impacts of invasive species in Kashmir lakes (Table 5). It has also been identified that the lakes are the backbone of Kashmir Himalaya, however, cumulative effects of invasions have disproportionately transformed most of lake ecosystems (Reshi *et al.,* 2008).

Table 5. Common Impacts of invasive species at Kashmir lakes

Kind of Impacts	Consequences
Economic Impacts	Productivity reduction in agricultural, livestock sector and land values Imbalance in the ecosystem services Hampering of transportation
Social Impacts	Poor revenue through recreation (tourism) Health impacts
Environmental Impacts	**Ecosystem functions** Impairment of water quality Alteration in nutrient cycling Change in habitat morphology Reduction in water flow **Ecosystem structure** Local/ regional native species xtinctions Loss of biodiversity Reduced ecosystem stability

Source : Reshi *et al*., 2008.

A recent study by Shah and Reshi (2014), disclosed that occurrence of 128 alien aquatic plant species belonging to 68 genera and 42 families (Appendix E). Moreover, the study documented alien aquatic plants comprise about 40% of the total aquatic flora of Kashmir Himalaya, which is relatively more than the proportion of aliens (29%) in the terrestrial Kashmir Himalayan flora (Khuroo *et al.,* 2007). However there is no detail report on the impacts of the aquatic plants in the lakes of Kashmir. Some of the studies identified about the decline of some native aquatic plant species. For instance Khan *et al*. (2004) documented the constant decline of *Nelumbo nucifera* (lotus) in few traditional water bodies.

Impact of invasive aquatic plants in Manasbal Lake in Jammu and Kashmir

Manasbal the deepest lake (13 m depth), is located in Ganderbal district of the State of Jammu and Kashmir has altitude position of about 1551 above mean sea level and covers a catchment of 22 km^2 provides water for irrigation and domestic use to Yangoora and Safapora towns. The anthropogenic activities like agriculture and stone quarrying is reported in the slopes ranging from 15-30 degrees. The biodiversity of the lake is commendable with good number of water bird species (Rashid *et al.,* 2012).

Recent survey of CEBPOL (May 2016;Nov 2017) to Manasbal Lake disclosed the occurrence of several invasive alien species including *Azolla cristata, Ceratophyllum demersum, Myriophyllum aquaticum, Nymphide peltatum, Phragmites communis, Potamogeton lucens, Ranunculus lingua*. However the invasion of coontail (*Ceratophyllum demersum)* is highly visible than the rest. This invasive plant cause a huge menace to the lake, which covers one-third of lake surface area (Figure 18-21). Park authority collected/ removed the weed with the help of local people and heaped on the bunds of the lake. Even though, The invasion continuously diminish the aesthetic value of the lake which negatively affect tourism revenue. There is no detailed study about the other impacts of the species in this Lake.

Survey carried out in Dal Lake (2017) is also confirmed the occurence of the species in a large scale (Figure 22,23).

Figure 18. Ceratophyllum demersum near the bank of the Manasbal lake kashmir
Photo by : S. Sandilyan

Figure 19. Ceratophyllum demersum near the bank of the Manasbal lake kashmir
Photo by : S. Sandilyan

Figure 20. Removal of *Ceratophyllum demersum* by Manasbal lake authorities with the help of native people. Photo by : S. Sandilyan

Figure 21. Removal of *Ceratophyllum demersum* dumped on the banks of Manasbal lake Photo by : S. Sandilyan

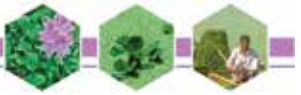
Figure 22. Mechanical removal of Ceratophyllum demersum from Dal Lake of Kashmir by Lake Authority. Photo by : S. Sandilyan

Figure 23. Ceratophyllum demersum collected from Dal Lake of Kashmir by Lake Authority. Photo by : S. Sandilyan

VI. Conclusion and Recommendtion

Knowledge gaps

1. Overall, a little / poor knowledge is available about the biodiversity of Indian wetlands before and after the bioinvasion
2. Non-availability of complete studies (i.e. ecosystem, genetic, species and socioeconomic level, invasion ecology, invasive species population dynamics) even for a single inland aquatic invasive species.
3. Occurrence of hybridization with native species is one the commonest impacts of invasive fish species (e.g. carp and tilapia strains– SBSTTA, 2003). However, such studies are lacking from India.
4. Apart from fishes, the other major possible invasive taxonomic groups includes microorganisms, plankton, aquatic insects, molluscs, pathogens and parasites, etc. To these groups there is no major documentation available in India.
5. No comprehensive report on economic impacts of aquatic bioinvasion in India.
6. Modelling and mapping of invasive species is also not attempted in the case of aquatic invasive species
7. SBSTTA 2003, pointed out some of the important areas to be addressed by the CBD signatories involved with inland invasion
    a. patterns and processes characterize the distribution and spread of invasive alien micro organisms in wetlands
    b. How do genetic traits and hybridization affect the livelihood of a species becoming invasive?



c. What are the key factors driving ecosystem resistance to invasions and the capacity to recover from invasions?

d. What are the high priority taxonomic difficulties that should be addressed first?

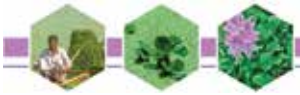
e. How can we predict invasion potential of a aquatic species?

f. How can the impacts of invasive alien species be distinguished from the consequences of other stresses such as loss of habitat and hydrological connectivity, flow regulation, loss of riparian functions and water pollution?

Eventhough as a signatory of CBD, till date India is lacking to implement/ address in the aforesaid SBSTTA recommendations. These gaps in the knowledge is a real threat to the diversity of Indian inland wetlands. Further, SBSTTA (2003) recommended for developing useful conceptual models to undertake an experimental research, prevention, management, monitoring and control of invasive alien species in wetland ecosystem but till date there is no progress in those aspects. Aforesaid are the important knowledge gaps pertaining to Indian aquatic invasive species management.

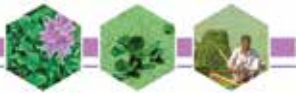
Recommendations

1. Till date, there has been no detailed and in-depth study in India to quantify the economic and biodiversity loss due to aquatic invasion in inland waters. On the other hand, several developed countries contribute major research and legal frame work in order to prevent the biological invasions of aquatic species, especially fishes (Miller, 2004). For instance, in England, the Salmon and Freshwater Fisheries Act of 1975 clearly states that transport of native and non native fishes within the political boundaries without proper procedure is illegal (Tripathi, 2015).



Further, the European Union (EU) has banned the trade, possession and transport of 37 (likely to extend to 350) invasive species. People who export or possess invasive species such as grey squirrels, ruddy ducks and water hyacinth in the EU face penalty (Sandilyan, 2016). India should adopt such a practice to minimize the further risk of invasive speices.

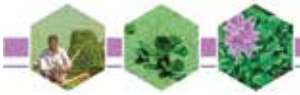
2. The National Committee on Introduction of Aquatic Species is entitled to screen the entry of exotic aquatic species before they are introduced into India. Besides, the Ministry of Agriculture, Government of India has enacted guidelines for the import of ornamental fishes, which clearly states the importance of pre-quarantine certificate from the competent authority of the exporting countries. Moreover, the guidelines also point out the post-quarantine follow-up (Tripathi, 2015). However, traders and hobbyists frequently breach the rules in India and introduce several ornamental fish species, including the notorious carnivorous piranha (Biju Kumar, 2000). Stringent measures should be taken to monitor this.
3. India is highly prone to additional invasion of ornamental fishes and their pathogens and other parasites in the future (Tripathi, 2015). Unless stringent measures are taken to monitor the aquarium fish trade and accidental release of exotic species into inland waters, which soon emerge as breeding grounds for exotic ornamental fishes which will eventually drive out India's native, indigenous freshwater fishes (Sreekantha and Ramachandra, 2005). To resolve these issues, strict implementation of the guidelines of CBD 2014X II/16 and immediate investigation related to the management/eradication of the invaded exotic ornamental fishes in the wild should be carried out (Krishnakumar *et al.,* 2009).
4. International and regional databases on successful eradications as well as reasons of failures in inland invasion should be developed and disseminated among the stakeholders/managers/policy makers.



5 Globally it was accepted that inland water ecosystems have fewer control methods compared to terrestrial ecosystems. It is mainly due to the dispersed nature of the system. Mechanical, chemical and biological control have their own issue. However the experts have identified biological control as highly cost effective, permanent, and self-sustaining (SBSTTA, 2003). In Indian context, analyse are needed before practicing the aforesaid, mechanical removal and frequent and adequate monitoring are the essential requirement in many of the aquatic invasive species.

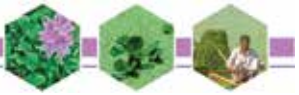
6. Continuous monitoring is needed to ensure the long-term success of control and eradication of invasive alien species in any given ecosystem. The public, especially the native community can play an important role in both control and monitoring. To achieve this a clear understanding is need about the benefits/costs of invasive alien species in the inland aquatic system. Information-sharing and collaborative programmes are important domestically, regionally and internationally in order to reduce the further spread of invasive alien species. Baseline surveys and monitoring are essential, as well as crucial for early detection and rapid response (SBSTTA, 2003).

7. Number of tools and international guidelines are available and these could be employed before introducing an exotic species (e.g., Turner, 1988). In addition the FAO Code of Conduct on Responsible Fisheries, which includes the guidelines for responsible inland fisheries and aquaculture; extensive guidance available through the Global Invasive Species Programme; and related guidance available through the Ramsar Convention on Wetlands, including the Wise Use resource centre (http://www.ramsar.org/wurc_index.htm). So stakeholders/managers and concern India department should strictly adhere the aforesaid to avoid further invasion risk.



8. Internationally exclusive tools are available to predict whether a species will become an invasive speices. Say for example genetic algorithm for rules prediction based on environmental factors (Kolar and Lodge, 2002). Such kind of tools should be prepared based on Indian condition, or researchers should be motivated to design based on region and site specific tools.
9. We need to establish a regulatory authority to deal with invasive speices issues under MoEF&CC. Further, establishment of a national institute with special branches for invasive speices management is also needed. Such an institute should concentrate on adherence to the guidelines by traders and other stakeholders, creating awareness among public and policy makers, and encouraging research in the management aspects (Sandilyan, 2016). Besides, launching of a database on Invasive Alien Species of India, promoting research on invasion ecology and economic impacts of selected invasive species as case studies to document the impacts. Creating specific awareness programmes on invasive species among the school and college students it should be included in their curriculum. In addition that to create awareness among the public on invasive species awareness day/week should be accelerated and the events can be coordinated by NBA. Besides, preparing a comprehensive management plan for the invasive speices, and establishing a cell for monitoring the impacts of invasive species at the NBA in war foot.

The aforesaid recommendation will highly helpful for a long term management.



Conclusion

Several studies conclude that inland wetlands face major losses of biodiversity, mainly due to biological invasion, besides a wide array of ecological and economic issues. Invasive species are reckoned as one of the main drivers of Inland biodiversity loss. Researchers and policy makers have identified the major pathways for the entry of invasive speices into aquatic ecosystems and shared their concern about the inadequate regulation/control measures. Introduction of species for aquaculture, aquarium trade, and ballast water are the leading pathways of entry of invasive species , which means that the drivers for this are the commercial interests. On the other hand invasive species play the deleterious role on destabilising the natural system which native communities depends for their livelihood (SBSTTA, 2003). Pertaining to a developing country like India, exotic species are considered as an easy option for commercially important agriculture, forestry and fisheries related activities. This warrants the need for developing appropriate policies and action plans to manage the invasive species in order to reduce the possible impacts on indigenous species and ecosystems. Further, there is a inevitable need to develop a national level data base on invasive species and engage researchers to work on identified knowledge gap areas.

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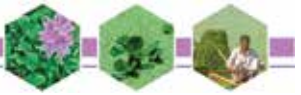

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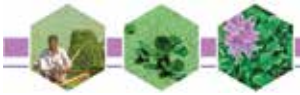

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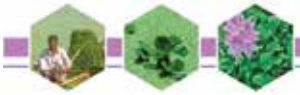

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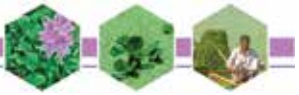

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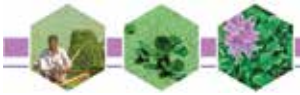

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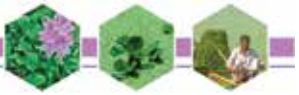

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Annexure A

Appendix A

Kinds of wetlands and its area in India subcontinent

S. No.	Type of wetlands	Million ha / Km
1	Area under paddy cultivation	40.9 million ha
2	Area suitable for fish culture	3.6 million ha
3	Area under capture fisheries (brackish and freshwater)	2.9 million ha
4	Mangroves	0.4 million ha
5	Estuaries	3.9 million ha
6	Backwater	3.5 million ha
7	Man-made impoundments	3.0 million ha
8	Rivers, including main tributaries	28,000 km
9	Canals and irrigation channels	113,000 km
Total Area of Wetlands (Excluding Rivers)		**58.2 million ha**

Source: Prasad *et al*, 2002

Appendix B

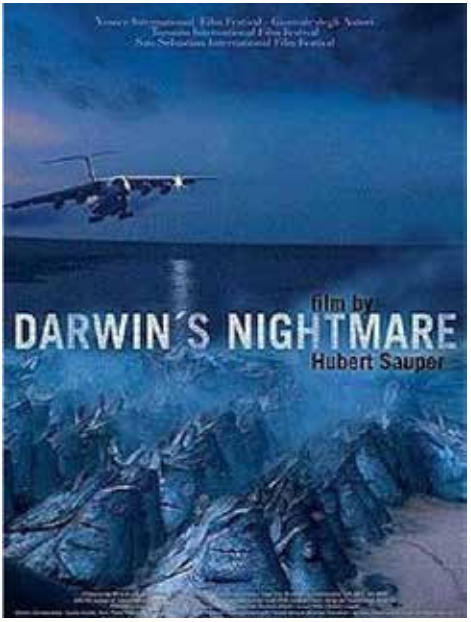
Category-wise wetland distribution based on satellite and GIS data

S. No	Wetland category	Total wetland area (ha)	% of wetland area
1.	Inland Wetlands -Natural	6623067	43.40
2.	Inland Wetlands -Man-made	3941832	25.83
Total - Inland		10564899	69.22
3.	Coastal Wetlands -Natural	3703971	24.27
4.	Coastal Wetlands -Man-made	436145	2.86
Total - Coastal		4140116	27.13
5.	Wetlands (< 2.25 ha)	555557	3.64
Total		15260572	100

Nymphide peltatum invasion in Wular lake, Kashmir Photo by : S. Sandilyan

Appendix C

Nile perch *Lates niloticus* the non-native fish species was introduced in to the Lake Victoria, Tanzania around 1950s in order to increase the fisheries yield. After a decade, it was identified that the introduced Nile perch evolved as an invasive and has completely changes the native species diversity and density of the lake. Well-designed studies clearly stated that, hundreds of smaller species have gone extinct after the invasion of Nile perch. Most of the native fish species such as tilapias, cyprinids are vanished from the lake. Recent survey exposed the occurrence of this invasive species in all part of the lake except some region. Obviously the invasion of nile perch cause a huge biodiversity loss as well as alter the socio economic status of the indigenous community in and around the lake. Based on the real incidents, **Hubert Sauper** took a documentary film called "***Darwin's Nightmare"*** in 2004. The documentary film exposed the environmental and social effects of the fishing industry around Lake. It also portrayed how the indigenous people lost their basic sanitations and how the children turned to drugs and prostitution. The film bagged several international awards. The Boston Globe called it "the year's best documentary about the animal world." This documentary film can be freely viewed in (http://topdocumentaryfilms.com/darwins-nightmare/). Till date it is one of the best studies to know about the impact of aquatic Invasion.



Appendix D

SELECTED INVASIVE SPECIES IN KERALA AND THEIR MANAGEMENT

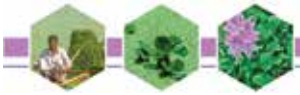
Courtesy: Department of Aquatic Biology and Fisheries, University of Kerala and Kerala Forest Research Institute

1. GIANT SALVINIA OR KARIBA WEED

Salvinia molesta D. Mitch.

Classification			
Kingdom	Plantae	Class	Filicopsida
Phylum	Pteridophyta	Order	Hydropteridales
Family		Salviniaceae	

Photo by : S. Sandilyan



Native Range: A free-floating aquatic plant native to south-eastern Brazil.

Habitat: Occurs most commonly in freshwater lakes, rivers, swamps, streams, ditches and water tanks. It is quickly killed by sea water, but can tolerate lower concentrations of salt.

Diagnostic characters: Perennial, heterosporous herbs, free floating, with microspores and megaspores produced on the same plant, green, up to 30 cm long, 5 cm wide, mat-forming, mat to 2.5 cm thick; roots absent; stems irregularly branched, pubescent. Leaves: short petiolate, in whorls of three. Sporocarps, when present, pubescent, sessile to long-stalked, globose to ovoid, rounded to apiculate at apex.

Reproduction: It produces egg-shaped, slender-tipped sporocarps that develop in elongated chains along the submersed fronds. Sporocarps contain numerous sporangia (which are usually empty or contain only a few deformed spore remnants). Because the plant is pentaploid (contains five sets of chromosomes) it cannot produce viable spores (due to an unequal division of chromosomes during meiosis). As a consequence it is sterile and can only reproduce asexually. The plant propagates by vegetative growth and sporadic fragmentation, resulting in small vegetative propagules that are dispersed by water currents.

Economic value: Used as ornamental plant, for producing biogas and for removing pollutants from aquatic ecosystems.

Invasiveness and Negative Impacts: This species spreads within an aquatic system by the movement of plants by wind, water currents, floods and animals. Birds and other animals and human-mediated transport intentionally (as ornamentals) and unintentionally as a hitchhiker may also aid their invasion. It is a pest of rice paddies in India, where it competes for water, nutrients and space, resulting in poor crop production. Thick mats of Salvinia cut off light to

submerged plants, often outcompeting rooted and submerged native plants and reducing vascular plant diversity. The formation of mats also lowers dissolved O_2 and pH, whilst simultaneously increasing CO_2 and H_2S, in waters beneath them. Benthic fauna usually decrease under well-established mats. As plants in the mat die and sink to the bottom, benthic fish can be impacted by changes in O_2 concentrations and water depth as material accumulates. In India, this species has invaded wetlands and reportedly replaced native flora. Infestations of this plant also contribute to human health problems as they serve as host plants for vectors and reduces the aesthetics of the habitat. The heavy infestation may also become asocial problem infestations can severely impede transport by water as well as commercial and recreational fishing, reduces the supply of freshwater, besides polluting water.

Management: Both chemical, physical and biological methods have been tried with varying amounts of success to control this noxious weed. Control strategies must address both watershed management (to reduce nutrient supply) and direct weed control (eg: by introduction of biological control agents and mechanical removal). Bans on the spreading, selling, relocation, and transportation may also help in the prevention of further spreading.

Photo by : S. Sandilyan

2. WATER HYACINTH

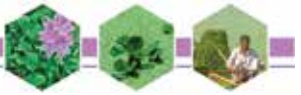
***Eichhornia crassipes* (Mart.) Solms**

Classification			
Kingdom	Plantae	Class	Monocotyledonae
Phylum	Spermatophyta	Order	Pontederiales
Family		Pontederiaceae	

Native Range: A free-floating perennial aquatic plant (or hydrophyte) native to tropical and sub-tropical South America.

Habitat: Occurs most commonly in freshwater lakes, rivers, swamps, streams, ditches and water tanks. Its habitat ranges from tropical desert to subtropical or warm temperate desert to rainforest zones. Water hyacinths do not grow when the average salinity is greater than 15% that of sea water.

Diagnostic characters: With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. They have



long, spongy and bulbous stalks. The feathery, freely hanging roots are purple-black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals.

Reproduction: One of the fastest growing plants known, water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant additionally can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years. This is a vigorous grower, known to double their population in two weeks.

Economic value: Used as ornamental plant. Used for bioremediation.

Invasiveness and Negative Impacts: This plant is believed to be introduced in India unintentionally. One of the most noxious weeds in the world, it forms thick mats that cover rice paddies, clog irrigation channels, impede navigation, halt fishing, sweep away buildings during floods and foster breeding by disease-transmitting mosquitoes. In Kerala presence of this species have considerably affected water transport, fisheries, freshwater availability and aesthetics of aquatic ecosystems, causing heavy economic losses to the government. Environmental problems associated with the water hyacinth are exuberated in warm areas where the weed grows throughout the year and develops into dense large, free-floating, monospecific islands or mats which compete with other aquatic species for light, nutrients and oxygen. Mats also deposit large amounts of organic matter which increases the organic content of sediments and greatly accelerates succession patterns, allowing emergent and riparian vegetation to colonise.

Management: Both chemical, physical and biological methods have been tried with varying amounts of success to control this noxious weed. A combination of these methods and frequent removal and reuse of the weed may help in the management. Bans on the spreading, selling, relocation, and transportation may help in the prevention of further spreading. The existing biomass may be utilized effectively for making a wide variety of by-products, and for other uses including energy generation. The reduction of nutrient pollution of water bodies, wherever it is at all feasible, should be a high-priority approach. Redistribution of excess nutrient, as an alternative to its prevention, should be considered in some situations.

3. CABOMBA/ CAROLINA FANWORT

Cabomba caroliniana Gray

Classification			
Kingdom	Plantae	Class	Dicotyledona
Phylum	Spermatophyta	Order	Nymphaeales
Family		Cabombaceae	

Native Range: Aquatic perennial herbaceous plant native to to North and South America.

Habitat: It grows rooted in the mud of stagnant to slow flowing water including streams, and smaller rivers. It also grows in ponds, lakes, reservoirs, and canals.

Diagnostic characters: This species grow fully submerged except for occasional floating leaves and emergent flowers. The roots grow on the bottom of water bodies and the stems can reach the surface. Parts of the plant can survive free-floating for six to eight weeks. It is a perennial, growing from short rhizomes with fibrous roots. The branched stems can grow up to 10m long and are scattered with white or reddish-brown hairs. The underwater leaves are divided into fine branches, resulting in a feathery fan-like appearance. These leaves are about 5cm across and secrete a gelatinous

mucous which covers the submerged parts of the plant. The solitary flowers are less than 2cm across and range in colour from white to pale yellow and may also include a pink or purplish tinge. The flowers emerge on stalks from the tips of the stems.

Reproduction: A herbaceous perennial that spreads primarily by stem fragments or rhizomes; rhizomes are fragile and easily broken, facilitating vegetative spread and transport to new water bodies. The seeds of this self-pollinating plant readily germinate.

Economic value: Used in tropical aquariums.

Invasiveness and Negative Impacts: An extremely persistent and competitive plant, under suitable environmental conditions it forms dense stands and crowds out previously well-established plants. Once established, this plant can clog drainage canals and freshwater streams interfering with recreational, agricultural, and aesthetic uses. Cabomba grows quickly and produces a large amount of plant material. It can significantly reduce water storage capacity and taint drinking water supplies. When this vegetation dies off, decomposition causes dramatic oxygen reductions and foul smelling water. Recently they have established in large quantities in many regions of Pamba river in Kerala.

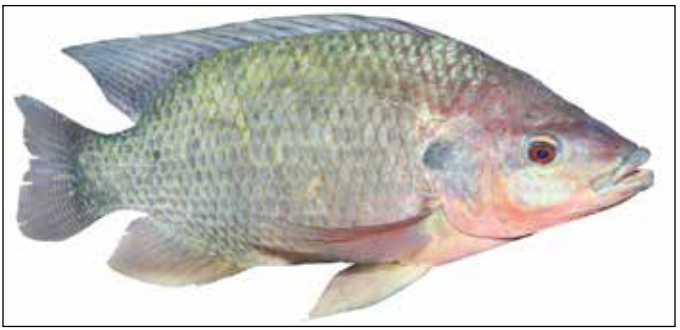
Management: Strict hygiene regulations and mechanical control (involving cutting and removing plants and ensuring fragments are not spread) are recommended to manage this species at the initial phase. Because cabomba requires direct sunlight, shading has been used to kill it in small areas.

4. MOZAMBIQUE TILAPIA

***Oreochromis mossambicus* (Peters, 1852)**

Etymology: Oreochromis: Latin, aurum = gold + chromis = a fish; mossambica describes the geographic area, Mozambique, to which the species is native.

Classification			
Kingdom	Metazoa	Class	Actinopterygii
Phylum	Chordata	Order	Perciformes
Family		Cichlidae	



Maximum length: 39 cm Standard Length

Native Range: Native to coastal regions and the lower reaches of rivers in southern Africa, from the Zambezi River delta to Bushman River in the eastern Cape.

Habitat: Generally live in rivers and lagoons, but can adapt to any water body, including salt water. Opportunistic omnivores and will feed on algae, plant matter, organic particles, small invertebrates and other fish.

Diagnostic characters: Laterally compressed deep body with long dorsal fins, the front part of which have spines; dorsal spines XV-XVII; total dorsal rays 26-29; 30-32 lateral line scales; anal spines III, lower outer gill rakers 14-20. Breeding males black in natural populations with white lower parts on head;

red dorsal and caudal fin margins; remnants of striped and barred pattern often visible in females, juveniles and non-breeding makes, as a series of mid-lateral and dorsal blotches; jaws of adult males greatly enlarged, concave dorsal head profile.

Reproduction : Male builds spawning bowers. Up to 1775 ripe eggs in one female. Hatching after 3-5 days; fry released 10-14 days after spawning. Males mouthbrooded for about another week. More than one brood per season.

Economic Importance: Popular food fish and a preferred candidate for aquaculture.

Invasiveness and Negative Impacts: Introduction in India for promoting aquaculture. Now one of the most common fish in both freshwater and brackishwater habitats. Reported as a threat to native species through competition for food and habitats, especially for the popular pearl spot, *Etroplus suratensis.* Juveniles have been documented to feed on other fish. Tilapia are now generally considered to be pests.

Management: Particularly hardy, resistant to wide varieties of water salinity oxygen and pollution levels, and can migrate long distances. They occupy a wide range of habitats, and reproduce rapidly and successfully. Removal from natural water resources where they have established may be impossible. The most effective management is complete isolation of individuals from natural waters to prevent introductions. Established populations may require intensive fishing to prevent overpopulations from affecting native populations. Promotion of culture of indigenous food fish and risk assessment of tilapia invasion are recommended.

5. NILE TILAPIA

Oreochromis niloticus (Linnaeus, 1758)

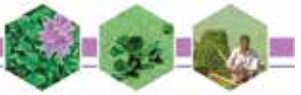
Etymology: Oreochromis: Latin, aurum = gold + chromis = a fish; niloticus describes the geographic area, Nile river to which the species is native.

Classification			
Kingdom	Metazoa	Class	Actinopterygii
Phylum	Chordata	Order	Perciformes
Family		Cichlidae	

Maximum length: 60 cm Standard Length

Native Range: Native to the Nile River basin; the south-western Middle East; the Niger, Benue, Volta and Senegal rivers, and the lakes Chad, Tanganyika, Albert, Edward, and Kivu.

Habitat: Generally live in rivers and lakes. Benthopelagic and migrate within freshwater (potamodromous). Feed mainly on phytoplankton or benthic algae. They may also feed on aquatic insects and crustaceans and fish eggs.



Diagnostic characters: Laterally compressed deep body with long dorsal fins, the front part of which have spines; Dorsal spines (total): 15 - 18; Dorsal soft rays (total): 11-13; Anal spines: 3; Anal soft rays: 9 – 11. Jaws of mature male not greatly; genital papilla of breeding male not tessellated. Distinguished easily from Mozambique tilapia by the presence of regular vertical stripes throughout depth of caudal fin.

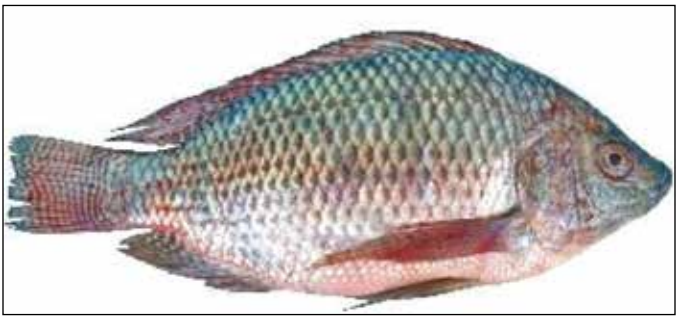
Reproduction: Sexual maturity is reached at 3-6 months depending on temperature, and reproduction occurs only when temperatures are over 20°C. Several yearly spawnings every 30 days. Females incubate eggs inside their mouths for about a week. Spawns in firm sand in shallow waters.

Economic Importance: Popular food fish and one of the most preferred candidate for aquaculture. Several strains and genetically improved forms such as Genetically Improved Farmed Tilapia (GIFT tilapia) are extensively used in aquaculture.

Invasiveness and Negative Impacts: Introduced globally for promoting aquaculture and for augmenting capture fisheries. Because tilapias reproduce at such a rapid rate, they overcrowd and out-compete native species. This loss of biodiversity leads to genetic erosion and greater susceptibility to disease. Considered as a potential pest. In India this species is introduced and cultured illegally and now is common in many rivers and reservoirs.

Management: Particularly hardy, resistant to wide varieties of water salinity oxygen and pollution levels. They occupy a wide range of habitats, and reproduce rapidly and successfully. Removal from natural water resources where they have established may be impossible. The most effective management is complete isolation of individuals from natural waters to prevent introductions. Established populations may require intensive fishing to prevent overpopulations from affecting native

populations. Promotion of culture of indigenous food fish and risk assessment of tilapia invasion are recommended.



6. SUCKER FISH OR SAILFIN ARMOURED CATFISH

Pterygoplichthys spp.

Etymology: Pterygoplichthys is derived from the Greek *pteryg*, meaning "wing",and *ichthys* meaning "fish".

Classification			
Kingdom	Animalia	Class	Actinopterygii
Phylum	Chordata	Order	Siluriformes
Family		Loricariidae	

Maximum length: 70 cm Total Length

Native Range: Native to the streams, floodplain lakes and marshes of South America. This genus has a specialized (enlarged) stomach which appear to function as accessory respiratory organs, hence can survive in poorly-oxygenated waters and can survive outside water up to 30 hours!

Habitat: Most common in sluggish streams, floodplain lakes, and marshes. Demersal. Their primary food is plant matter. Their diet consists of algae, detritus, general plant matter and possibly carrion. They may also consume worms, insect larvae, fish eggs and other bottom-dwellers. Basically they are grazing animals or scavengers.

Diagnostic characters: Differentiated from most other fishes of the family due to their large dorsal fins with 9 or more (usually 10) dorsal fin rays, which gives them their common name "sailfin catfish". These fish have rows of armour plating covering the body; the abdomen is almost completely covered in small plates. They also have an underslung suckermouth assisting them in feeding on algae, hence the name "suckermouth" catfish. Several species and their hybrids have invaded water bodies of India, and the species differentiation is based on the colour patterns in abdomen and nature of arrangement of scales and body plates. Color pattern is generally dark brown with either darker spots or lighter spots or vermiculations.

Reproduction: Reproduce sexually and have high fecundity. Males construct horizontal burrows in banks or water bodies, which are used as nesting tunnels. Eggs are guarded by males until the free-swimming larvae leave. Females may lay between 500-3,000 eggs.

Economic Importance: Popular in aquaria as sucker fish and imported through ornamental fish trade.

Invasiveness and Negative Impacts: Main source of introduction in India is through ornamental fish trade. Common now in many larger rivers in India and have established extensive populations. Potential effects include alteration of bank structure and erosion, disruption of aquatic food chains, competition with native species, changes in aquatic plant communities, and damage to fishing gear and industry.

Management: Removal of larger fish by intensive fishing may be effective in smaller habitats and this could be used to support commercial fish market. They can also be removed in large numbers and used for large scale production of fish manures or fish meal. Intense egg collection from the breeding burrows could reduce their abundance in such habitats. There should also be restrictions and ban on import. Educating the public, especially aquarists, to avoid releasing their unwanted fishes into open waters may reduce their introductions. More risk assessment studies are required in India to find out the full environmental implications of this species.

7. COMMON CARP

***Cyprinus carpio Linnaeus,* 1758**

Etymology: Cyprinus: Latin, *cyprinus* = carp*; carpio:* carpio latinized form of carp

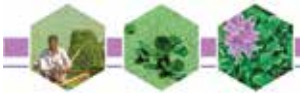
Classification			
Kingdom	Animalia	Class	Actinopterygii
Phylum	Chordata	Order	Cyprinodontiformes
Family		Cyprinidae	

Maximum length: 120 cm Total Length

Native Range: Europe to Asia: Black, Caspian and Aral Sea basins

Habitat: Inhabit warm, deep, slow-flowing and still waters such as lowland rivers and large, well vegetated lakes. Feed on a variety of benthic organisms and plant material.

Diagnostic characters: The colour of carp varies; in the wild, they are usually olive green to bronze or silvery in colour with a paler underside. Two pairs of barbels; dorsal fin with 15-20½ branched rays; caudal fin deeply emarginated.



Pharyngeal teeth 1, 1, 3:3, 1,1, robust, molar-like with crown flattened or somewhat furrowed. Scales large and thick. `Body 1:3.2-4.8 in standard length. Very variable in form, proportions, squamation, development of fins, and colour. Caudal fin with 3 spines and 17-19 rays. Last simple anal ray bony and serrated posteriorly; 4 barbels; 17-20 branched dorsal rays; body grey to bronzegravid spot located on the posterior abdomen above the rear of the anal fin.

Reproduction: Spawn in marginal, shallow, weed-infested areas. A polytypic plastic species with a marked tendency to produce `varieties' and `races' in response to selective breeding and environmental influences. Carp is polygamous. In tropics they breed throughout the year. Individual females spawn with a few males in dense vegetation. The sticky eggs are attached to water plants or other submerged objects. A typical adult female can lay 300,000 eggs in a single spawn.

Economic Importance: Topmost fish in aquaculture production. Koi carp is an ornamental strain of this species and this popular aquarium fish is brightly coloured.

Invasiveness and Negative Impacts: Introduced in India for promoting aquaculture. On every continent where it has been introduced it has reduced water quality and degraded aquatic habitats. They also compete with indigenous species for food and space and displacement of indigenous species have been reported due to the invasion of this species.

Management: The use of potentially invasive alien species for aquaculture and their accidental release/or escape can have negative impacts on native biodiversity and ecosystems should be prevented. Potential carp control techniques practiced in the west include harvesting, barriers, biomanipulation, exclusion with screens or barriers, poisoning, biological control, bioacoustics, bubble barriers, immunocontraception and genetic manipulation. Research is needed to realise the full environmental implications of this species in India.

8. NORTH AFRICAN CATFISH

***Clarias gariepinus* (Burchell, 1822)**

Etymology: Clarias: Greek, chlaros = lively, in reference to the ability of the fish to live for a long time out of water; *gariepinus*: Named after its type locality, the Gariep river, , South Africa

Classification			
Kingdom	Animalia	Class	Actinopterygii
Phylum	Chordata	Order	Siluriformes
Family		Clariidae	

Maximum length: 170 cm Total Length

Native Range: Found throughout Africa and the Middle East.

Habitat: Live in freshwater lakes, rivers, and swamps, as well as man-made habitats, such as oxidation ponds or even urban sewage systems. Bottom dwellers and obligate air breathers. Nocturnal fish. It feeds on living, as well as dead, animal matter. Because of its wide mouth, it is able to swallow relatively large prey whole. It has been known to take large waterbirds such

as the common moorhen. It is also able to crawl on dry ground to escape drying pools.

Diagnostic characters: North African catfish are elongate with fairly long dorsal and anal fins. The dorsal fin has 61-80 soft rays and the anal fin has 45-65 soft rays. They have strong pectoral fins with spines that are serrated on the outer side. They possess nasal and maxiallary barbels and somewhat smallish eyes. The head is large, depressed, and heavily boned. The mouth is quite large and subterminal. Colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey while the underside is a pale cream to white.

Reproduction: Known to breed after the rainy season. Vast numbers migrate to flooded shallow grassy verges of rivers and lakes. Shoals of the fish migrate upstream or to the shores of still water bodies prior to breeding. Eggs usually adhere to submerged vegetation. Hatching occurs soon after spawning and no parental care of the young. Average fecundity around 50,000. Growth is very rapid, with males reaching an ultimately larger size than females.

Economic Importance: Good food source for humans and farmed extensively all over Asia.

Invasiveness and Negative Impacts: Extensively translocated round the world by aquaculturists, farmers, anglers, etc. In India this fish is introduced illegally. The species is large and highly predatory, thus posing serious potential to impact on the native fish fauna. They may hybridize with native catfish species and may also bring in parasites and pathogens.

Management: Various factors make this species very difficult to control: omnivorous diet, direct air-breathing, ability to crawl on land, burrowing capabilities and ability to hide in vegetation. Now common in many larger water bodies of India. Since the introduction of this fish is illegal, their

culture should not be promoted. Extensive populations should be removed mechanically from the critical ecosystems such as Periyar lake in Kerala. Report illegal culture and presence on natural water bodies. Make the people aware of the negative impacts of this species.

9. GUPPY

Poecilia reticulata Peters, 1859

Etymology: Poecilia: Greek, poikilos = with a lot of colours; reticulata refers to the patterns on tail.

Classification			
Kingdom	Animalia	Class	Actinopterygii
Phylum	Chordata	Order	Cyprinodontiformes
Family		Poeciliidae	

Maximum length: 5.0 cm Standard Length

Native Range: Native to Antigua and Barbuda, Barbados, Brazil, Guyana, Jamaica, the Netherlands Antilles, Trinidad and Tobago, the U.S. Virgin Islands, and Venezuela

Habitat: Freshwater and brackishwater ecosystems, including irrigation and sewage canals; benthopelagic. Feed on a variety of food sources, including benthic algae and aquatic insect larvae. Guppies are used as a model organism in the field of ecology, evolution, and behavioural studies.

Diagnostic characters: Guppies exhibit sexual dimorphism. While wild-type females are grey in body colour, males have splashes, spots, or stripes with wide variety of colours. Aquarium breeders have developed a wide variety of forms.

Reproduction: Viviparous (Females are live bearers, giving birth to young ones). The gestation period of a guppy is typically 21–30 days, varying considerably. Reproduction typically continues through the year, and the female becomes ready for conception again quickly after parturition. Once inseminated, female guppies can store sperm in their ovaries and gonoducts, which can continue to fertilize ova up to eight months. Reproductive rates vary based on food availability and other environmental parameters.

Economic Importance: Common popular aquarium fish and used widely for controlling mosquitoes, though measurable effects due to introduction have not been reported.

Invasiveness and Negative Impacts: Considered a hazard to native fishes like cyprinids and it has been implicated in the decline of native fishes in many parts of the world. It is also believed to carry parasitic nematodes and tapeworms. In some parts of the world introduction of guppy implicated in the decline of native damselflies.

Management: Introductions may have resulted from escapes or releases from aquaria or outdoor breeding ponds. Educating the public, especially aquarists, to avoid releasing their unwanted fishes into open waters may reduce their introductions. More risk assessment studies are required in India to find out the full environmental implications of this species.

10. MOSQUITOFISH

Gambusia affinis (Baird & Girard, 1853)

Etymology: Gambusia: Cuban term Gambusino, which means “nothing”; affinis: Latin which means related

Classification			
Kingdom	Animalia	Class	Actinopterygii
Phylum	Chordata	Order	Cyprinodontiformes
Family		Poeciliidae	

Maximum length: 5.1 cm Standard Length

Native Range: North America, Atlantic and Gulf Slope drainages from southern New Jersey to Mexico; Mississippi River basin from central Indiana and Illinois south to Gulf.

Habitat: Freshwater and brackishwater rivers, springs, pools and canals. Benthopelagic. Voracious feeder, feeds primarily on zooplankton and invertebrate prey and often young fishes at the top of the water column.

Diagnostic characters: The back is a greenish olive to brownish, the sides grey with a bluish sheen, and the belly a silvery white. A well-defined black spot on the upper rear abdomen is surrounded by a golden patch above and behind the vent. Its body is short, its head flattened, and its mouth pointed upward for surface feeding. Origin of dorsal fin opposite 7th anal ray. The characteristic net-like scale pattern and the poster origin of the dorsal fin relative to the anal fin are typically sufficient to distinguish Gambusia from the co-occurring poeciliids. Eight horizontal scale rows between back and abdomen. The species is sexually dimorphic, with adult males being considerably smaller than females and also possessing a gonopodium-an elongated anal fin that functions as an intromittent organ for sperm transfer during mating. Mature females have a distinct gravid spot located on the posterior abdomen above the rear of the anal fin.

Reproduction: Viviparous (Females are live bearers, giving birth to young ones). Reproduction typically continues through the year, and the female becomes ready for conception again quickly after parturition. For male mosquitofish, sexual maturity is reached in about 43 to 62 days and females reach sexual maturity in about 21 to 28 days.

Economic Importance: Used as live food for carnivorous aquarium fishes and also used as mosquito control.

Invasiveness and Negative Impacts: Introduced in India for mosquito control. Mosquito fish are a remarkably hardy species, surviving in waters with little oxygen, in high salinities and temperatures. Adult fishes are extremely aggressive and attack other fish, and feed on the small-sized fishes and young ones. There are reports of elimination of native species thorugh predation, competition for space and food. They may also serve as potential hosts of helminth parasites, which may be transmitted to native fishes.

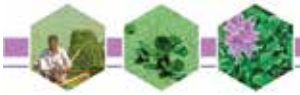
Management: Rather difficult to control because of their small size and fast reproduction rates. The poison Rotenone, which works by inducing hypoxia in fish, may be used to eliminate mosquito fish from small areas of permanent water, without much native indigenous species. More risk assessment studies are required in India to find out the full environmental implications of this species.

Appendix E

Some of the alien aquatic plant species documented in inland wetlands of India

S.No.	*Species Name*	Common Name
1)	*Alisma gramineum Lej.*	Narrow leaf water plantain
2)	*Alisma lanceolatum With.*	Lance-leaf water plantain
3)	*Alternanthera caracasana Kunth*	Mat chaff-flower
4)	*Alternanthera philoxeroides (Mart.) Griseb.*	Alligator weed
5)	*Azolla cristata Kaulf.*	Water fern
6)	*Bidens biternata (Lour.) Merr. & Sherff*	Cutleaf water -parsnip
7)	*Blumea laciniata (Wall. ex Roxb.) DC.*	Cutleaf false ox -tongue
8)	*Butomus umbellatus L.*	Flowering rush
9)	*Cabomba aquatica Aubl.*	Gul kabomba
10)	*Cardamine flexuosa With.*	Woodland bittercress
11)	*Carex diandra Schrank*	Lesser- tussock sedge
12)	*Cladium mariscus subsp. jamaicense (Crantz) Kük.*	Jamaica swamp saw-grass
13)	*Cladium mariscus (L.) Pohl*	Saw-grass
14)	*Colocasia esculenta (L.) Schott*	Wild taro
15)	*Cyperus alternifolius (L.)*	Flat sedge
16)	*Cyperus glomeratus L.*	Souchet Jaune
17)	*Eclipta prostrata (L.) L.*	False daisy
18)	*Eichhornia crassipes (Mart.) Solms*	Water hyacinth
19)	*Eleocharis acicularis (L.) Roem. & Schult.*	Needle spikerush
20)	*Eleocharis equisetoides (Elliott) Torr.*	Jointed spike -sedge

21)	*Eleocharis parishii Britton*	Parish's spikerush
22)	*Eleocharis pauciflora (Lightf.) Link*	Few-flowered spik-erush
23)	*Epilobium hirsutum (L)Gray*	Great willow herb
24)	*Eriocaulon sieboldianum Siebold & Zucc.ex Steud.*	Hatpins
25)	*Hippuris vulgaris L.*	Mare's tail
26)	*Ipomoea carnea Jacq.*	Pink morning glory
27)	*Ludwigia peploides (Kunth) P.H.Ra-ven*	Creeping water prim-rose
28)	*Lemna perpusilla Torr.*	Minute duckweed
29)	*Ludwigia palustris (L.) Elliott.*	Marsh purslane
30)	*Ludwigia parviflora Roxb.*	Kattugrampu
31)	*Lycopus europaeus L.*	Gypsywort
32)	*Lythrum salicaria L.*	Purple loosestrife
33)	*Marsilea quadrifolia L.*	European water-clover
34)	*Marsilea vestita Hook. & Grev.*	Hairy waterclover
35)	*Martynia annua L.*	Devil's claw
36)	*Mentha×piperita L.*	White peppermint
37)	*Mentha aquatica L.*	Water mint
38)	*Mentha arvensis L.*	Corn mint
39)	*Mentha spicata L.*	Spearmint
40)	*Menyanthes trifoliata L.*	Bogbean
41)	*Monochoria vaginalis (Burm.f.) C.Presl*	Oval-leaf-pondweed
42)	*Myosotis laxa Lehm.*	Tufted forget-me-not
43)	*Myosotis scorpioides L.*	Water forget-me-not
44)	*Myriophyllum aquaticum (Vell.) Verdc.*	Parrot's feather
45)	*Nicotiana plumbaginifolia Viv.*	Tex-mex tobacco
46)	*Nymphaea lotus L.*	Egyptian lotus
47)	*Nymphaea mexicana Zucc.*	Mexican water lily



48)	*Nymphaea odorata subsp. tuberosa (Paine) Wiersema & Hellq.*	Syn: Nymphaea tuberosa Paine.
49)	*Paspalum distichum L.*	Water couch
50)	*Phalaris arundinacea L.*	Reed Canary grass
51)	*Potamogeton berchtoldii Fieber*	Small pondweed
52)	*Stuckenia filiformis (Pers.) Börner*	Syn: Potamogeton filiformis Pers.
53)	*Potamogeton × fluitans Roth*	Vlottendfonteinkruid
54)	*Potamogeton lucens L.*	Shining pondweed
55)	*Potamogeton pusillus L.*	Lesser pondweed
56)	*Potamogeton trichoides Cham.&Schltdl.*	Hair like pondweed
57)	*Potamogeton compressus L.*	Flat stem pondweed
58)	*Rorippa islandica (Oeder)Borbás*	Marsh cress
59)	*Rumex aquaticus L.*	Water dock
60)	*Rumex conglomeratus Murray*	Sharp dock
61)	*Sagittaria latifolia Willd.*	Common arrowhead
62)	*Sagittaria sagittifolia L.*	Arrowhead
63)	*Salvinia auriculata Aubl*	Butterfly fern
64)	*Sparganium erectum L.*	Branched bur-reed
65)	*Herminium lanceum (Thunb. ex Sw.) Vuijk*	Syn: Spiranthes lancea Thunb. ex Sw.
66)	*Typha angustifolia L.*	Lesser bulrush
67)	*Utricularia vulgaris L.*	Greater Bladderwort
68)	*Vallisneria americana Michx.*	American eelgrass
69)	*Vallisneria spiralis L.*	Coiled vallisneria
70)	*Wolffia columbiana H.Karst.*	Watermeal

About CEBPOL

Government of India in collaboration with the Norwegian Government has established "Centre for Biodiversity Policy and Law (CEBPOL)" at the National Biodiversity Authority (NBA), an autonomous and statutory body of the Ministry of Environment Forest and Climate Change towards strengthening of expertise in Biodiversity Policy and Law in India. This programme is executed by the NBA in collaboration with Norwegian Environment Agency through the Royal Norwegian Embassy, New Delhi, India.

The Centre aims to provide advice and support to the Government of India and Norway on Biodiversity Policy and Law related issues including complex negotiations on Access and Benefit Sharing and Traditional knowledge as well as governance issues relating to biodiversity at the National and International level. The Centre proposes to help NBA in the effective implementation of International agreements on conservation, sustainable use and the associated access and benefit sharing components of it.

CEBPOL is set up as a specialized Centre of Excellence in Biodiversity Policy and Law to network, organize and consolidate expertise on issues of Biodiversity Policy and Law in India and Norway. The Centre, located at NBA, would function as an independent think tank on Biodiversity Policy and Law. In addition, CEBPOL aims to contribute to the effective implementation of the Biological Diversity Act 2002 and Rules 2004.

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