

Exotic Fish Diversity, Invasion and Its Impacts on Aquatic Biodiversity and Ecosystems in Uttar Pradesh

**A.K. Singh*, Sharad C. Srivastava, Dinesh Kumar, Abubakar Ansari,
Rita Verma and Pankaj Verma**

National Bureau of Fish Genetic Resources
Canal Ring Road, P.O.Dilkusha, Lucknow-226002 (Uttar Pradesh)
*Email: aksingh56@rediffmail.com

Introduction

Uttar Pradesh is one of the largest states in India, located between 23°52'-31°28'N latitude and 77°04'-84°38'E longitude. The state has vast aquatic bio-resources and offers considerable scope of inland fisheries development and aquaculture. Fishery resources are available in the form of rivers and their tributaries, reservoirs, wetlands, lakes, ponds and tanks. However, these aquatic bio-resources are experiencing serious threats to both biodiversity and ecosystem stability and a number of fishes are disappearing due to several anthropogenic factors and invasion of exotic fish (Singh and Lakra, 2011; Sarkar *et al.* 2012).

Exotic fishes have been introduced in Uttar Pradesh illegally or intentionally with a variety of motives such as ornamental, improvement of wild stocks, aquaculture, biological control and recreational purposes (Singh and Lakra, 2011). In many cases, fish introductions were carried out for more than once for the same species or for different species. The qualities of these introduced species were a short life span, rapid growth, rapid sexual maturity, high fecundity, euryoecious (ability to colonize a wide range of habitat types), eurytopic (wide range of physiological tolerances), gregarious behaviour, wide genetic variability and phylogenetic plasticity. These exotic species have broad range of diet

and ability to survive in disturbed habitats competing with local fishes. In this study, we have generated information from the field studies and attempted to give an over-all scenario on the different exotic fish species available in the state, their distribution, dispersal and invasiveness and also the impacts particularly on the riverine fish diversity and ecosystem.

Exotic fishes in aquaculture

11 alien fish species and 3 exotic hybrids have been recorded from grow out farms (>500 in number) from 38 districts of Uttar Pradesh. Chinese carps which included grass carp and silver carp as well as common carp were found to contribute substantially to commercial aquaculture in Uttar Pradesh. In addition, *Oreochromis niloticus* (Nile tilapia), *Oreochromis mossambicus* (Mossambique tilapia), *Pangasianodon hypophthalmus* (Sutchi catfish also known as pangas), *Clarias gariepinus* (African catfish), *Mylopharyngodon piceus* (Black carp), *Barbonymus gonionotus* (Java barb) and *Piaractus brachipomus* (Pacu) have also been found to be commonly cultured. Many of these species were illegally introduced during the last few years to supplement fish production.

Recent culture of exotic Pacu and Pangas is gearing up as commercial aquaculture across the State of Uttar



Barbonymus gonionotus



Piaractus brachipomus



Oreochromis niloticus



Oreochromis mossambicus



Hypophthalmichthys molitrix



Aristichthys nobilis



Cyprinus carpio



Pangasianodon hypophthalmus

Commonly cultured exotic fish species in Uttar Pradesh

Pradesh. In comparison to other aquaculture species, pacu and pangas can be stocked at high densities in ponds under monoculture. The most important aquaculture attributes of these species were rapid growth and resistance to poor water quality. It was estimated that exotic fishes contributed around 28% of total aquaculture production in Uttar Pradesh.

Exotic fishes in fish markets

Data on contribution of different exotic fish in various fish markets of Uttar Pradesh was generated through bench mark survey in 41 districts. The considerable contribution of exotic fishes in various markets were Pangas, African catfish, common carp and tilapia. These fishes were either from aquaculture or riverine catch or from transport across the state. The relative contribution and over all presence of exotic fishes in different fish markets is presented (figure 1).

Occurrence and spread of exotics in natural aquatic bodies

Many introduced fishes are now available in

different river stretches, reservoirs, lakes and wetlands. Data generated from 14 river stretches of Uttar Pradesh has revealed that there are occurrences of **14 different exotic species** in different aquatic bodies (table 1). The species recorded from different river stretches were *Cyprinus carpio specularis*, *Cyprinus carpio nudus*, *Cyprinus carpio communis*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, *Aristichthys nobilis*, *Oreochromis mossambicus*, *O. niloticus*, *Clarias gariepinus*, *Pterygoplichthys perdis*, *P. disjunctivus*, *Barbonymus gonionotus*, *Gambusia affinis*, *Poecilia reticulata*.

Abundance index of alien species was calculated in the Yamuna River (Saharanpur to Allahabad and the Ganga River (Allahabad to Ballia). Risks associated with culture and spread of common carp, tilapia and African catfish was identified. The loss to the local fish species particularly Indian major carps was quantified in the Yamuna and the Ganga Rivers. Data on general contribution of exotic fish species in the fishery of different river stretches was generated for the year 2011 and 2012 and the same are presented (Figure 2).

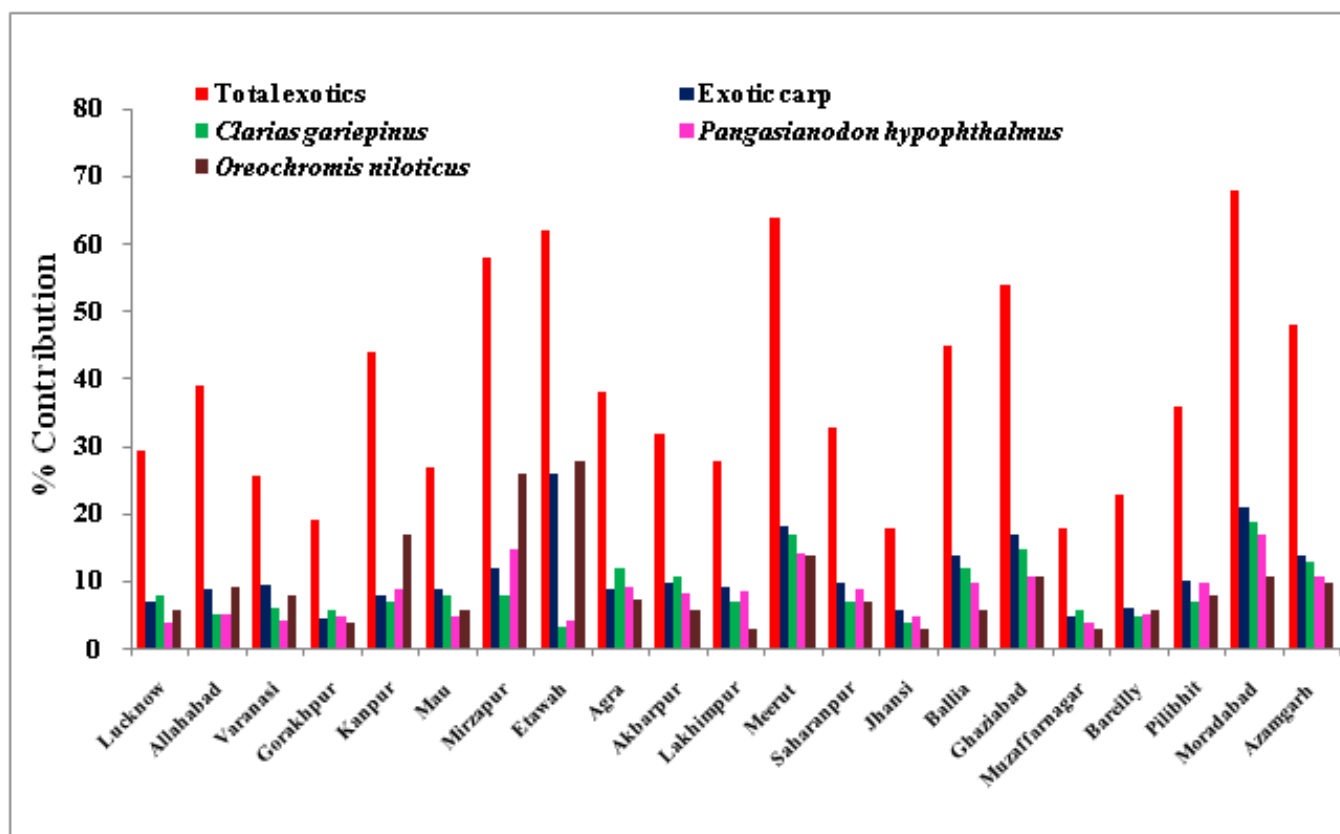


Figure 1: Market contribution of total and different exotic fishes in Uttar Pradesh.

Table 1: Occurrences of Exotic fishes in different River stretches of Uttar Pradesh

| Rivers | Exotic fishes |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ganga | <i>Cyprinus carpio communis</i> , <i>Cyprinus carpio specularis</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Gambusia affinis</i> , <i>Clarias gariepinus</i> , <i>Oreochromis mossambicus</i> , <i>Oreochromis niloticus</i> |
| Yamuna | <i>Cyprinus carpio communis</i> , <i>Cyprinus carpio specularis</i> , <i>Cyprinus carpio nudus</i> , <i>Carassius auratus auratus</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Gambusia affinis</i> , <i>Clarias gariepinus</i> , <i>Oreochromis mossambicus</i> , <i>Oreochromis niloticus</i> |
| Ramganga | <i>Cyprinus carpio</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Gomti | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus Carpio</i> , <i>Oreochromis niloticus</i> , <i>Clarias gariepinus</i> |
| Sai | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Tamasa | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Pangasianodon hypophthalmus</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |

| Rivers | Exotic fishes |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sone | <i>Cyprinus carpio</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharygodon idella</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Baigul | <i>Hypophthalmichthys molitrix</i> , <i>Cyprinus carpio</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharygodon idella</i> , <i>Clarias gariepinus</i> |
| Nakatia | <i>Clarias gariepinus</i> |
| Hindon | <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Gambusia affinis</i> |
| Kali | <i>Clarias gariepinus</i> |
| Gerua | <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> , <i>Cyprinus carpio</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharygodon idella</i> , <i>Hypophthalmichthys molitrix</i> |
| Sharda | <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> |
| Dewa | <i>Ctenopharygodon idella</i> , <i>Hypophthalmichthys molitrix</i> , <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Aristichthys nobilis</i> |

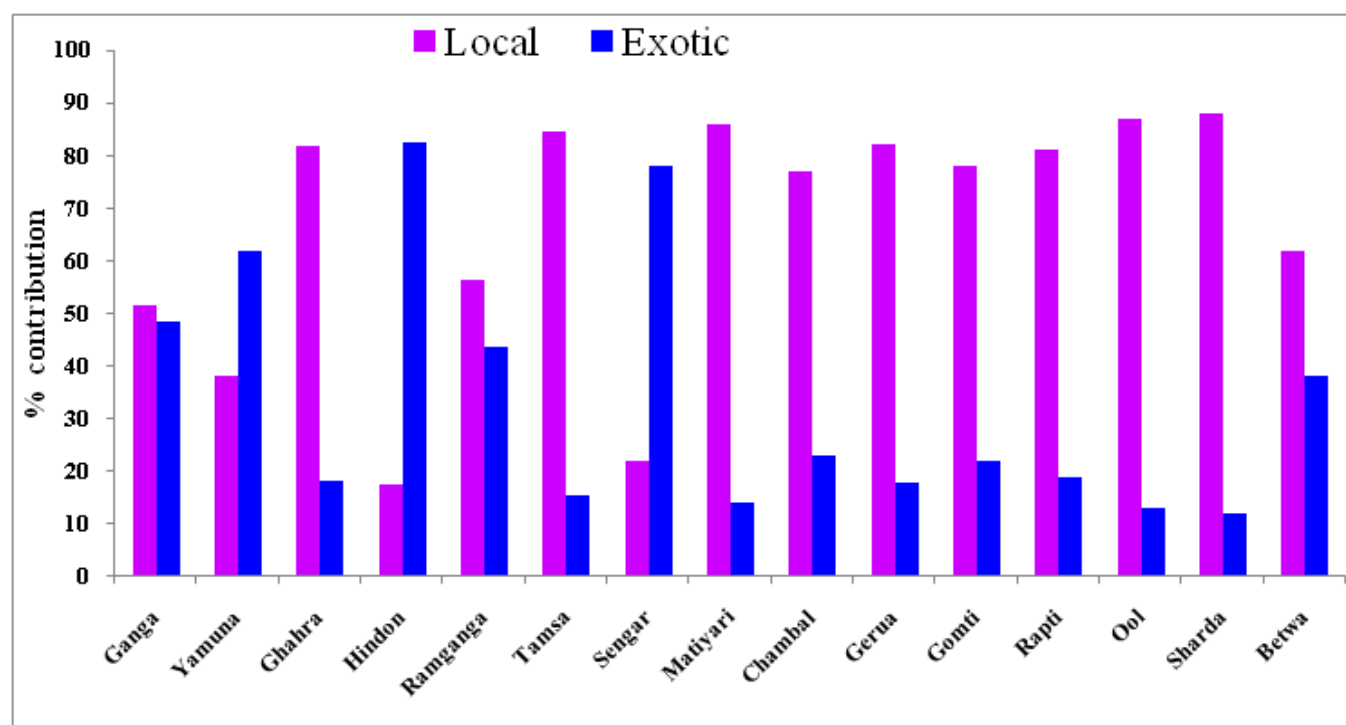


Figure 2: General Contribution of exotic fish species in the fishery of different river stretches

Figure 2: Occurrences and contribution of exotic fishes in different river stretches in Uttar Pradesh.



Captured exotic fishes (**A**-*Oreochromis niloticus*) from Yamuna river, (**B**-*Cyprinus carpio*) from Ganga river, (**C**-*Clarias gariepinus*) from Ganga river and (**D**-*Aristichthys nobilis*) from Raipur lake, Lakhimpur Kheri.

Presence of exotic fish species was also recorded from reservoirs, lakes and wetlands. We have recorded presence of seven species namely *Hypophthalmichthys molitrix*, *Aristichthys nobilis*, *Ctenopharyngodon idella*,

Cyprinus carpio, *Clarias gariepinus*, *Oreochromis niloticus*, *Barbonymus gonionotus*. In addition we also registered the presence of Koi (*Cyprinus carpio*). The generated data was tabulated for each water body (Table2).

Table 2: Exotic fishes in some natural lakes and reservoirs of Uttar Pradesh

| Waterbody | Exotic fishes |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Kartarniaghat | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Derwn lake | <i>Ctenophayrigodon idella</i> , <i>Cyprinus carpio</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> |
| Surhatal | <i>Clarias gariepinus</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Hypophthalmichthys molitrix</i> |
| Hasanpur lake | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |

| Water body | Exotic fishes |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gujartal | <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> |
| Nawabganj | <i>Hypophthalmichthys molitrix</i> , <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Ahrora | <i>Clarias gariepinus</i> |
| Rihand | <i>Ctenopharyngodon idella</i> , <i>Cyprinus carpio</i> , <i>Aristichthys nobilis</i> , <i>Clarias gariepinus</i> , <i>Oreochromis niloticus</i> |
| Dhandhrol | <i>Clarias gariepinus</i> , <i>Cyprinus carpio</i> , <i>Aristichthys nobilis</i> |
| Ramgarh tal | <i>Cyprinus carpio</i> , <i>Cyprinus carpio</i> (Koi Carp), <i>Aristichthys nobilis</i> , <i>Ctenopharyngodon idella</i> , <i>Barbonymus gonionotus</i> |
| Raipur lake | <i>Aristichthys nobilis</i> , <i>Hypophthalmichthys molitrix</i> |

Exotic Ornamental Fishes

Many exotic fish species are now available at several aquarium shops throughout the year. We enlisted the presence of 82 varieties of 52 exotic fish species in Uttar Pradesh. These exotic fishes are small, mostly tropical and flourishing aquarium trade. The most commonly occurring aquarium fishes having popularity and demand were guppy, molly, platy, gold fish, barbs, angel,

loaches, pacu, piranha, sucker mouth catfish and stripped catfish (Table 3). Some of these ornamental fish species such as piranha, sucker mouth catfish, guppy and gambusia were identified as invasive and were recorded from natural aquatic bodies. *Pterygoplichthys pardalis* and *P. disjunctivus* were captured from Ganga and Gomti rivers while guppy and gambusia were recorded from Yamuna and Hindon rivers.

Photographs of some exotic ornamental fishes in Uttar Pradesh



Labeotropheus fuelleborni



Gymnocorymbus ternetzi



Heros severus



Parrot fish



Trichogaster trichopterus



Balantiocheilus melanopterus



Myxocyprinus asiaticus asiaticus



Carassius auratus auratus

Photographs of some invasive ornamental fishes in Uttar Pradesh



Pterygoplichthys pardalis



Pygocentrus nattereri



Gambusia affinis



Poecilia latipinna



Xiphophorus maculatus

Table 3: Exotic ornamental fish species recorded from Uttar Pradesh

| Sl. No. | Scientific Name | Common Name | Native range | Availability | Invasion risk | IUCN Red List Status |
|---------|----------------------------------|---------------------------------------|--------------------|--------------|---------------|----------------------|
| 1. | <i>Aequidens rivulatus</i> | Green terror | South America | ++ | High | NE |
| 2. | <i>Amatitlania nigrofasciata</i> | 2 Varieties of Banded Convict Cichlis | Central America | + | Medium | NE |
| 3. | <i>Amphilophus labiatus</i> | Red Devil | Central America | ++ | Medium | NE |
| 4. | <i>Apteronotus albifrons</i> | Black feather | South America fish | + | Low | NE |
| 5. | <i>Astronotus ocellatus</i> | Variant Oscar Cichlid | South America | +++ | Low | NE |

| Sl. No. | Scientific Name | Common Name | Native range | Availability | Invasion risk | IUCN Red List Status |
|---------|-------------------------------------|---------------------------------------------|------------------------------------|--------------|---------------|----------------------|
| 5. | <i>Astronotus ocellatus</i> | Variant Oscar Cichlid | South America | +++ | Low | NE |
| 6. | <i>Aulonocara hansbaenschi</i> | African Peacock | Africa | + | Low | VU |
| 7. | <i>Balantiocheilus melanopterus</i> | Bala Shark | South East Asia | ++ | Medium | EN |
| 8. | <i>Barbus schwanefeldi</i> | Tinfoil Red Tail Barb | Thailand | ++ | Medium | LC |
| 9. | <i>Barbus tetrazona</i> | 2 Varieties of Tiger Barb | Sumatra and Borneo | ++ | High | NE |
| 10. | <i>Betta splendens</i> | Siamase Fighting Fish | Thailand and Indonesia | ++ | High | VU |
| 11. | <i>Botia macracantha</i> | Clown Loach | Sumatra and Borneo | + | Medium | NE |
| 12. | <i>Botia striata</i> | Striped Loach | South East Asia | ++ | Medium | EN |
| 13. | <i>Carassius auratus auratus</i> | 10 Varieties of gold fish | China and Japan | +++ | Medium | NE |
| 14. | <i>Cichlasoma meeki</i> | 2 Varieties of Fire mouth Cichlid | Central America | ++ | Low | NE |
| 15. | <i>Cyprinus carpio</i> | Koi carp | Black, Caspian and Aral Sea basins | +++ | Medium | VU |
| 16. | <i>Epalzeorhynchos bicolor</i> | 2 varieties of Rainbow Minnow Shark (Black) | Thailand | ++ | Medium | CR |
| 17. | <i>Epalzeorhynchos frenatus</i> | Albino Rainbow Shark | Mekong River Basin | ++ | High | LC |
| 18. | <i>Gymnocorymbus ternetzi</i> | Blackskirt Hifin Tetra | South America | ++ | Medium | NE |
| 19. | <i>Helostoma temmincki</i> | Kissing Gourami | Thailand to Indonesia | ++ | Medium | LC |
| 20. | <i>Heros severus</i> | Gold Severum | South America | ++ | Medium | NE |
| 21. | <i>Hyphessobrycon eques</i> | Serpae tetra | South America | ++ | High | NE |
| 22. | <i>Labeotropheus fuelleborni</i> | Yellow Cichlid | Africa | +++ | High | NE |
| 23. | <i>Labidochromis caeruleus</i> | Electric Yellow Cichlid | Lake Malawi, Africa | + | Low | LC |
| 24. | <i>Lepisosteus oculatus</i> | Spotted gar | North America | + | Low | NE |
| 25. | <i>Macrogathus siamensis</i> | Peacock eel | Thailand | + | Medium | LC |



| Sl. No. | Scientific Name | Common Name | Native range | Availability | Invasion risk | IUCN Red List Status |
|---------|--------------------------------------|-----------------------------------|--------------------------------|--------------|---------------|----------------------|
| 26. | <i>Parrot fish</i> | 2 Varieties of Red Parrot | Not known | ++ | Low | - |
| 27. | <i>Maylandia estherae</i> | Esther Grant's Zebra | Africa | ++ | Low | VU |
| 28. | <i>Melanochromis cyaneorhabdos</i> | Blue Johanni Cichlid | Africa, lake Malawi | + | Low | VU |
| 29. | <i>Metynnis argenteus</i> | Silver Dollar Fish | South America | ++ | Low | NE |
| 30. | <i>Monodactylus argenteus</i> | Mono-Moonfish | Indo-West Pacific to Australia | + | Low | NE |
| 31. | <i>Myxocyprinus asiaticus</i> | Asiatic Barb asiaticus | China | + | Medium | NE |
| 32. | <i>Nimbochromis venustus</i> | Vanustus or Giraffe | Hap | Africa | + | Low LC |
| 33. | <i>Oreochromis niloticus</i> | Tilapia | Africa | ++ | Very high | NE |
| 34. | <i>Osphronemus goramy</i> | Giant Gourami | Thailand and Indochina | + | Medium | LC |
| 35. | <i>Osteoglossum bicirrhosum</i> | Arowana | South America | + | Low | NE |
| 36. | <i>Pangasianodon hypophthalmus</i> | Iridescent | South East Asia Shark Catfish | +++ | High | EN |
| 37. | <i>Phractocephalus hemiliopterus</i> | Redtail catfish | South America | + | High | NE |
| 38. | <i>Piaractus brachypomus</i> | Red belly Pacu | South America | + | High | NE |
| 39. | <i>Poecilia latipinna</i> | 4 Varieties of Molly | Central America | +++ | High | NE |
| 40. | <i>Poecilia reticulata</i> | Green Cobra Guppy | Central America | +++ | High | NE |
| 41. | <i>Poecilia sphenops</i> | 2 Varieties of Molly | Central and South America | +++ | High | NE |
| 42. | <i>Poecilia velifera</i> | Giant sailfin Molly | Central America | + | High | NE |
| 43. | <i>Poecilia wingei</i> | Endler's livebearer | South America | ++ | High | NE |
| 44. | <i>Pseudotropheus demasoni</i> | Demasoni Cichlid | Africa, lake Malawi | ++ | Low | VU |
| 45. | <i>Pteroplichthys perdis</i> | Crocodile Fish (Black and albino) | South America | +++ | High | NE |
| 46. | <i>Pterophyllum scalare</i> | 2 Varieties of angle fish | Amazon River (America) | +++ | Medium | NE |

| Sl. No. | Scientific Name | Common Name | Native range | Availability | Invasion risk | IUCN Red List Status |
|---------|----------------------------------|------------------------|---------------------------|--------------|---------------|----------------------|
| 47. | <i>Puntius conchonus</i> | Rosy Barb | South East Asia | ++ | High | LC |
| 48. | <i>Puntius titteya</i> | Cherry Barb | Sri Lanka | ++ | High | LR/cd |
| 49. | <i>Pygocentrus nattereri</i> | Red belly Piranha | South America | + | High | NE |
| 50. | <i>Scatophagus argus</i> | Spotted scat | Indo-Pacific area | ++ | Low | LC |
| 51. | <i>Sciaenochromis fryeri</i> | Electric Blue | Africa, Lake Malawi | + | Low | LC |
| 52. | <i>Symphysodon aequifasciata</i> | 2 Varieties of Discus | South America | ++ | Low | NE |
| 53. | <i>Symphysodon discus</i> | Discus Fish | South America | ++ | Low | NE |
| 54. | <i>Synodontis euptera</i> | Featherfin squeaker | Africa | + | | |
| 55. | <i>Trichogaster leeri</i> | Pearl Gourami | Thailand and Indonesia | + | Medium | NT |
| 56. | <i>Trichogaster trichopterus</i> | 2 Varieties of Gourami | Southeast Asia | ++ | Medium | LC |
| 57. | <i>Xiphophorus helleri</i> | Swordtail Platy | North and Central America | +++ | High | NE |
| 58. | <i>Xiphophorus maculatus</i> | 2 varieties of platy | North and Central America | +++ | High | NE |

+ Less abundant, ++ abundant, +++ most abundant; EN: Endangered, LC: Least concern, NT: Near Threatened, (LR/cd): Lower Risk: conservation dependent, VU: Vulnerable, CR: Critically, NE: Not Evaluated

Discussion

Although major introductions of exotic fishes into the state of Uttar Pradesh outside their natural range are a relatively a recent phenomenon (Singh and Lakra, 2011). Alien species particularly Chinese carp excluding bighead and common carp have played an important part in the development of aquaculture. However, these species from aquaculture facilities have escaped and colonized in natural waters. In addition, inadvertent releases of African catfish (*C. gariepinus*) which is relatively large, voracious and highly carnivorous is capable of exerting direct adverse impacts on a wide range of native fish population. In this study, we found increased incidence and occurrences of exotic species in several river stretches, reservoirs, lakes and wetlands which have been considered serious in view of sustainability of local fish diversity (Singh *et al.* 2010;

Singh and Lakra, 2011). **The riverine resources of Uttar Pradesh are currently experiencing an alarming decline in fish biodiversity due to several environmental factors in general and invasion of many exotic species** (Singh and Lakra, 2011) in particular. Uttar Pradesh is a huge delta formed by one main river systems- the Ganges, and its tributaries. More than one-third of the lands in the state remain under water every year during monsoon and to some extent used as habitat for different local and exotic fish species (Sarkar *et al.* 2012). Inundated floodplains are rich in nutrients and natural fish food, and thus are excellent feeding, breeding and nursery grounds for local and exotic fishes. Since exotic fishes are dominant and aggressive in behaviour, they have potential to extirpate the local fish species. Recent invasion of tilapia and common carp has increasingly taken-over at many locations contributing substantially to the fishery of

these river stretches and streams eliminating the catch of locally commercial important species particularly Indian major carps (Singh *et al.* 2010). Similar scenario is also emerging in some lakes, wetland even reservoirs which are also getting adversely affected.

Further, we have also recorded the occurrences of some aquarium fish species such as *Pterigoplichthys perdalis*, *P. disjunctivus*, *Gambusia affinis*, *Poecilia reticula*, *Xiphophorus maculatus*. Such unintentional releases are unsafe for fish biodiversity. Unless stringent measures are taken to monitor the aquarium fish trade and the accidental release of exotic species into our waters; streams and lakes will soon emerge as breeding grounds for several invasive fish that will eventually wipe out our native freshwater fishes.

The Convention on International Trade in Endangered Species (CITES) falls short of protecting aquatic habitats from invasions because it deals only with the trade in listed endangered and threatened species. However, under Convention on Biological Diversity (CBD), it is the responsibility of each nation and the state to prevent spread of any invasive alien species which is harmful to the fish biodiversity and aquatic ecosystem. The aquarium trade industry is spreading fast, therefore, it is essential for educating buyers, sellers, and the public, certifying stock, and preventing species from being released. In addition, certification that aquatic ornamental cultivators and large-scale aquariums sterilize their outflows and take

active steps to prevent the accidental release of species is essential. Educating both retailers and hobbyists about invasive species and the steps that they can take to reduce the risk will have an immediate impact.

Potential risks related to intentional introductions of exotic species can be reduced by careful consideration of an introduction before it occurs. A detailed protocols for this purpose has already been developed by the NBFGR which can serve as guidelines for satisfactorily addressing environmental and biodiversity concerns. Possible measures for reducing the impact of inadvertent releases of exotic fish may be through early detection of escapes and prevention from spread. Any attempts to control or eliminate a problematic exotic species will require tremendous expense if actions are delayed until the exotic species firmly establishes. Prevention and public awareness should be the first approach and are understood to be a better option than measures of control or eradication. The education is not solely the responsibility of public administrations, either financially or otherwise rather aquaculturists should also behave responsibly and refrain from the illicit use of exotics. People in all walks of life must be made aware of the need for study and careful documentation of any unauthorized fish introduction and the potential for irreversible environmental impact of the illegally introduced fish even as single unwise action. To mitigate the negative impacts of introduced fish species will require continued co-operation within governments, academia, and the private sector.

References

- Sarkar, U.K., A.K. Pathak, R.K. Sinha, K. Sivakumar, A.K. Pandian, A. Pandey, V.K. Dubey and W.S. Lakra (2012). Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats and conservation perspectives. *Reviews in Fish Biology & Fisheries*. 22:251–272.
- Sarkar, U.K., A.K. Singh and J.K. Jena (2011). Biodiversity of the freshwater fishes in the protected forest areas of Uttar Pradesh and its significance in management of riverine fish diversity. In: *Souvenir. National conference on forest biodiversity: earth's living treasure*, 22 May, 2011, pp 36–42.
- Singh A.K. and Lakra W.S. (2012). Culture of *Pangasianodon hypophthalmus* into India: Impacts and present Scenario. *Pakistan Journal of Biological Sciences* 15(1):19–26.
- Singh A.K. and Lakra, W. S. (2011). Risk and benefit assessment of alien fish species of the aquaculture and aquarium trade into India *Reviews in Aquaculture* 3, 3–18.
- Singh AK, Pathak AK, Lakra WS (2010) Invasion of an exotic fish- common carp, *Cyprinus carpio* L. (Actinopterygii: Cypriniformes: Cyprinidae) in the Ganga River, India and its impacts. *Acta Ichthyologica* 40(1):11–19.
- Lakra, W. S. and A.K. Singh (2010). Risk analysis and sustainability of *Pangasius sutchi* culture in India. *Aquaculture Asia*. Jan- June 2010 15(1):34–37.
- Singh, A.K., Dinesh Kumar, Abubakar Ansari and Sharad C. Srivastava (2012) Commercial farming of the Red belly Pacu. *Aquaculture Asia-Pacific* July/August 2012, 8 (4), 48–49.