Invasive fish and its consequences in the freshwater ecosystem of undivided Midnapore, West Bengal, India

Original Article

LIMNOLOGY FRESHWATER BIOLOGY

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ABSTRACT. A primary goal of the current study is to conduct a complete survey of the diversity of freshwater exotic fish in Midnapore, West Bengal, India, with special attention paid to their effects on local fish species. Freshwater fish species from all the blocks in the three districts under study have been surveyed. According to observations, there are 14 foreign freshwater fish species in the research region, classified into 12 genera and 7 families. Two species, *Barbonymus gonionotus* and *Piaractus brachypomus*, are recorded for the first time from the study area and are comparatively recent phenomena. Most exotic fish species (12 species) were introduced in India as food fish for aquaculture purposes; two species were introduced for mosquito control for their larvicidal feeding habits. Of the twelve food fishes, three are also used in aquariums as pet fish among the residents of the study area. The ecological consequences of the exotic fish species on local fish diversity is an added criterion of the present investigation. All species in the study area have a complete set of distributional information. Thus, the focus of the current study is on the exotic fish faunal diversity in the study area.

Keywords: exotic, fish, diversity, ecological, consequence

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1. Introduction

Any species that a man has accidentally or intentionally transferred from its native environment and released is considered an exotic species (Kottelat and Whitten, 1996). As per IUCN, an invasive species is an alien species that establishes itself in naturally occurring or partially naturally occurring ecosystems or habitats, leads to a change, and poses a threat to the native biological diversity of the area. All categories of living organisms, including invasive or exotic species, can be found in these widely dispersed habitats around the globe (Raghubanshi et al., 2005). It has been more than a century since exotic fish were first introduced to Indian waters. While the country was under British rule, such fisheries were possibly introduced for recreational fisheries. Francis Day (1863) first tried to introduce the brown trout (Salmo trutta fario) in the Nilgiri region, but he was unsuccessful for the same purpose (Jhingran, 1975). This was followed by the addition of exotic fishes from various countries to more and more water bodies of India for augmenting fish production through aquaculture, for sport fishery, mosquito control, weed control, ornamental purposes, etc., with successes and failures. Larvicidal fishes, including *Poecilia reticulata* and *Gambusia affinis*, were added in 1908 and 1928, respectively, to reduce mosquito larvae in stagnant waters where they were not well established. The ornamental fish species, which are imported to our country, have progressive results in the aquarium trade, but their insecticidal value did not reach a satisfactory level. Because of human activity related to pleasing, ornamental fish kept in aquarium tanks are easily transferred into natural water bodies, but their effects on the ecosystem have not been studied.

Exotic fish species were distributed around the world for a number of reasons, such as (a) promoting species diversity in aquatic systems and boosting local fishery potential, (b) game fishing, (c) aquarium fish keeping, and (d) preventing pests like mosquitoes (Kumar, 2000). Additionally, exotic fishes of one country may spread to nearby countries via floods and other causes. For this reason, the uncontrolled import and introduction of aquatic species, particularly fishes,

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caused alarm all over the world because it led to a broad variety of problems, including the extinction of native species. The invasive fishes seriously compete with the indigenous species in relation to habitat and food supply. They pose a threat to local fish populations, can spread disease-causing pathogens and parasites, can create hybrids, and can degrade aquatic organisms' genetic purity. Therefore, each and every cause mentioned above is responsible for the loss of local fish diversity (Nyman, 1991b). The optimum threat not only affects the quantity of biodiversity but also influences the socio-economy of the people, who depend on the aqua-resources for their daily life maintenance (Philipp et al., 1995). Approximately 20% of the world's recorded freshwater fishes are either extinct or are at the edge of extinction (Moyle and Leidy, 1992). In the long run, the addition of exotic species may cause a highly deleterious problem. According to Nyman (1991a), changes in the aquatic ecosystem caused by the introduction of alien species have the potential to be irreversible and may even result in the extinction of several species. Welcomme (1988b) reported that 168 fish species under 37 families were introduced into its non-native habitats, and as less as 67 species became permanent inhabitants in different water bodies, among which 27 species turned into real pests.

India is one of the countries with the highest biodiversity, having 1027 different species of freshwater fish (Gopi et al., 2017). According to Mogalekar et al. (2017), the West Bengal state is home to 267 different species of freshwater fish, 13 of which are considered invasive species in the freshwater ecology. The previous existing kinds of literature such as Paul and Chanda (2014; 2017), Jana et al. (2015), Pahari et al. (2017), Kisku et al. (2017), Kar et al. (2017), and Chanda (2020) provided information on the diversity of native fish in various rivers and water bodies in the study area except Jana et al. (2021), who only separately enlisted four exotic species during the diversity study of fish in the Kapaleswari River, but none has emphasized the diversity of exotic fish and their ecological consequences in the area under investigation.

As an outcome, the current study will undoubtedly bring attention to the exotic fish faunal diversity at the regional level, particularly in the districts of Purba Medinipur, Paschim Medinipur, and Jhargram located in the West Bengal state. Moreover, such a study will alert the fisherman community and policymakers to take suitable steps to protect indigenous aquatic biodiversity in the study area.

2. Materials and methods

2.1. Geography of the study area

The present study area is located in the southwestern part of the West Bengal state. It has mostly lateritic soil content, and some areas of this state contain loamy soil. Study site (Fig. 1) includes three districts namely Purba Medinipur (21°38′–22°31′N; 87°17′–88°12' E), Paschim Medinipur (21°45′–22°57′N; 87°03′–87°53′E), and Jhargram (21°52′–22°48′N; 86°34′–87°20′E). The climate in the study area is a result of the interaction between the northeasterly and southwesterly monsoons.

2.2. Collection of fish samples

Between July 2019 and January 2021, the specimens were collected from a variety of locations, including beels, ponds, rivers, as well as from market survey of the area. Samples were collected by gill nets, drag nets, and scoop nets with the active help of local fishermen. Morning (7 am to 9 am) was the most common time of sampling. After being collected, the specimens were immediately put into formaldehyde solution at a concentration of 4% and transported to the author's lab, R.N.L.K Women's College.

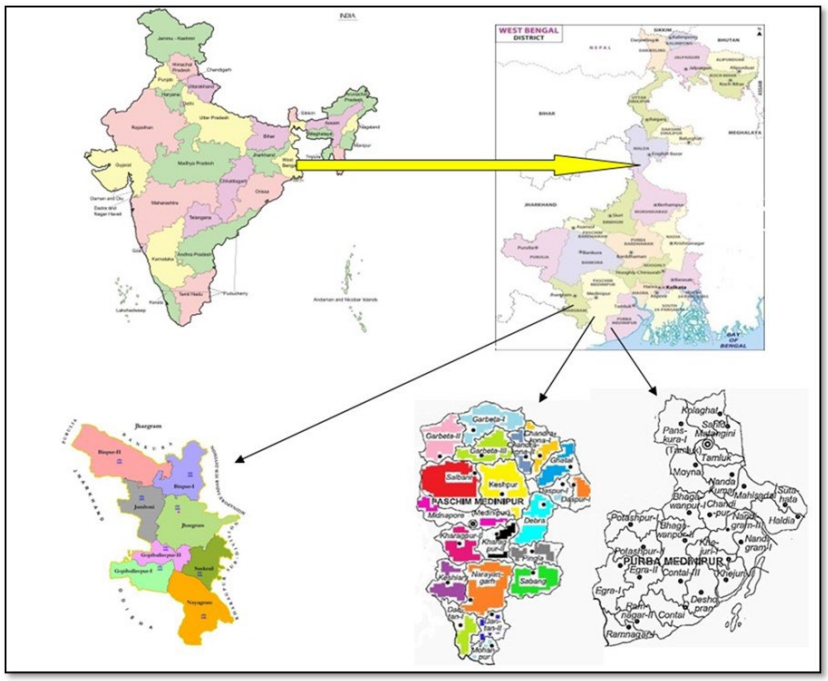

Fig.1. Study Site.

2.3. Laboratory procedure and identification

Finally, the specimens were washed and kept in a labelled container with 6% formaldehyde. Size, colour, pattern, number of fins, fin form, fin rays, number of scales, etc. were some of the morphological characteristics of the specimens, which were examined. Jhingran (1991), Jayaram (2002; 2010), Day (1889), and FishBase were used to properly identify the fish specimens (2021). The meristematic system of Tawar and Jhingran (1991) and Jayaram (2002; 2010) was used for all fish measurements. The range of the species was documented (Table 1). The present status of exotic fish conservation was determined as per the IUCN Red List (2021). Invasiveness for each species under research was estimated by determining the relative abundance of the species.

3. Results and discussion

The current survey has revealed 14 exotic freshwater fish from 12 genera and 7 families (Table 1). Out of the fourteen recorded species, two—*Barbonymus gonionotus* (Bleeker, 1850) and *Piaractus brachypomus* (G. Kuvier, 1818)—are reported here for the first time from the area under investigation, which is a relatively new event. Cyprinidae species were common and dominant at all study sites (42.86%), followed by Poeciliidae (14.29%) and Chichlidae (both 14.29%) (Fig. 2). The relative abundance value calculated for exotic fish species from the study area shows that *Hypophthalmichthys*

Table 1. Distribution and conservation status of different exotic fish in the study area.

Family	Species Name	Local Name	Habitat	Maximum size (TL)	Use	Blocks	IUCN
Cyprinidae	*Carassius auratus* (Linnaeus,1758)	Gold carp	Fr	40 cm	Or, Fo	**Jhargram:** Jhargram **Paschim Medinipur:** Ghatal, Debra, Sabang, Pingla, Keshpur, Daspur-I & II Khargpur- I & II, Keshiary, Narayangarh **Purba Medinipur:** Egra-I & II, Contai-I & III, Mahisadal, Moyna, Panskura, Pataspur-I & II, Bhagwanpur-I & II, Tamluk, Nandigram-I	LC
	Barbonymus gonionotus (Bleeker,1850)	Java punti	Fr	20 cm	Fo	**Jhargram:** Gopiballavpur-I , Binpur I, Sankrail, Jhargram **Paschim Medinipur:** Midnapore, Daspur-I & II, Garhbeta-II &III, Debra, Garhbeta –I, Keshiary, Sabang, Narayangarh **Purba Medinipur:** Mahisadal, Moyna, Pataspur-I, Pataspur-II, Bhagwanpur-I, Nandigram-I	LC
	Ctenopharyngodon idella (Valenciennes, 1844)	Grass carp	Fr	150 cm	Fo	**Jhargram:** Jamboni, Binpur-II, Gopiballavpur-I & II, Sankrail **Paschim Medinipur:** Ghatal, Debra, Sabang, Pingla, Midnapore, Garhbeta I, Salboni, Keshpur, Daspur-I & II, Khargpur- I & II, Keshiary, Narayangarh **Purba Medinipur:** Egra- I & II, Contai- I & III, Mahisadal, Moyna, Panskura, Pataspur-I & II, Bhagwanpur-I & II, Tamluk, Nandigram-I	NE
	Cyprinus carpio (Linnaeus, 1758)	Common carp	Fr	120 cm	Fo	**Jhargram:** Binpur- I & II, Gopiballavpur- I & II, Nayagram, Sankrail, Jamboni, Jhargram **Paschim Medinipur:** Garhbeta- I & II & III, Chandrakona-I&II, Salboni, Keshpur, Ghatal, Daspur- I & II, Midnapore, Khargpur- I & II, Pingla, Debra, Keshiary, Narayangarh, Sabang, Mohanpur, Datan-I&II **Purba Medinipur:** Egra- I & II, Contai- I & II, Mahisadal, Moyna, Nandigram- I, Panskura, Patashpur- I & II, Tamluk, Sahid Matangini, Nandigram-II, Bhagwanpur- I & II, Kolaghat, Chandipur, Deshpran, Nandakumar	VU
	Hypophthalmichthys molitrix (Valenciennes, 1844)	Silver carp	Fr	150 cm	Fo	**Jhargram:** Binpur- I & II, Gopiballavpur- I & II, Nayagram, Sankrail, Jamboni, Jhargram **Paschim Medinipur:** Garhbeta- I & II &III, Chandrakona I&II, Salboni, Keshpur, Ghatal, Daspur –I &II, Midnapore, Khargpur-I&II, Pingla, Debra, Keshiary, Narayangarh, Sabang, Mohanpur **Purba Medinipur:** Egra- I & II, Contai- I & II, Mahisadal, Moyna, Nandigram- I, Panskura, Patashpur- I & II, Bhagwanpur-I&II, Tamluk	NT
	Hypophthalmichthys nobilis (Richardson, 1845)	Bighead	Fr	146 cm	Fo	**Jhargram:** Gopiballavpur-I&II, Sankrail, Jhargram **Paschim Medinipur:** Debra, Garhbeta- II & III, Sabang, Salboni, Keshpur, Datan- I & II **Purba Medinipur:** Egra- I &II, Bhagwanpur-I& II, Contai-I&III, Nandigram- I & II, Panskura, Pataspur-II, Tamluk, Sahid Matangini, Chandipur, Deshpran, Nandakumar	DD

Family	Species Name	Local Name	Habitat	Maximum size (TL)	Use	Blocks	IUCN
Poeciliidae	*Gambusia affinis* (Baird and Girard, 1853)	Gambusa	Fr, Br	04 cm	Or	**Paschim Medinipur:** Daspur-I&II, Chandrakona-I, Sabang **Purba Medinipur:** Bhagwanpur I, Mahisadal, Tamluk, Nandigram-I&II	LC
	Poecilia reticulata (Peters, 1859)	Guppy	Fr, Br	05 cm	Or	**Paschim Medinipur:** Ghatal, Debra, Sabang **Purba Medinipur:** Mahisadal, Haldia, Tamluk	NE
Chichlidae	*Oreochromis mossambicus* (Peters, 1852)	Tilapia	Fr, Br	39 cm	Fo	**Jhargram:** Gopiballavpur-I, Sankrail **Paschim Medinipur:** Midnapore, Garhbeta I&III, Salboni, Keshpur, Daspur-I&II, Khargpur-I&II, Keshiary, Narayangarh, Mohanpur **Purba Medinipur:** Egra-I&II, Contai-I&III, Mahisadal, Moyna, Nandigram-I &II, Panskura, Pataspur-I, Pataspur-II, Bhagwanpur-I &II, Tamluk, Sahid Matangini, Kolaghat, Chandipur, Deshpran, Nandakumar	NT
	Oreochromis niloticus (Linnaeus, 1758)	Nilotica	Fr, Br	60 cm	Fo	**Jhargram:** Binpur-II, Gopiballavpur-I **Paschim Medinipur:** Midnapore, Debra, Garhbeta-I, Khargpur-I&II **Purba Medinipur:** Mahisadal, Moyna, Bhagwanpur-I &II, Pataspur I, Nandigram-I, Pataspur-II	NE
Osphronemidae	*Osphronemusgoramy* Lacepède, 1801	Goramy	Fr, Br	70 cm	Or, Fo	**Purba Medinipur:** Egra-I & II, Haldia, Kolaghat, Tamluk, Chandipur	LC
Clariidae	*Clariasgariepinus* (Burchell, 1822)	Thai magur	Fr	170 cm	Fo	**Jhargram:** Binpur- I & II, Gopiballavpur- I **Paschim Medinipur:** Midnapore, Garhbeta- I & II, Keshpur, Daspur II, Khargpur I&II, Keshiary, Narayangarh, Mohanpur **Purba Medinipur:** Egra- I & II, Mahisadal, Nandigram, Panskura, Pataspur- I &II, Bhagwanpur- I & II, Haldia, Sahid Matangini, Kolaghat, Chandipur, Deshpran, Nandakumar	LC
Pangasidae	*Pangasianodonhypophthalmus* (Sauvage, 1878)	Panngus	Fr	130 cm	Fo	Jhargram: Binpur- I & II, Gopiballavpur- I & II, Nayagram, Jhargram **Paschim Medinipur:** Chandrakona I&II, Salboni, Keshpur, Ghatal, Daspur –I &II, Midnapore, Khargpur-I&II, Pingla, Debra, Keshiary, Narayangarh, Sabang, Mohanpur **Purba Medinipur:** Egra- I & II, Contai- I &II, Nandigram- I, Panskura, Patashpur- I & II, Bhagwanpur- I	EN
Serrasalmidae	*Piaractusbrachypomus* (G. Kuvier,1818)	Rupchand	Fr	45 cm	Or, Fo	**Paschim Medinipur:** Ghatal, Daspur –I **Purba Medinipur:** Moyna, Nandigram I, Panskura, Potaspur-I,Tamluk	NE

Note: IUCN = International Union for Conservation of Nature; TL = Total Length; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated; Fo = Food; Or = Ornamental; Fr = Fresh water; Br = Brackish water

molitrix (Valenciennes, 1844) has the maximum invasiveness (11.5%), followed by *Cyprinus carpio* Linnaeus, 1758 and *Pangasianodon hypophthalmus* (Sauvage, 1878) (both 10.3%). (Fig. 3, Table 1.). Here, the invasiveness of the exotic fish species is expressed in terms of their relative abundance because maximum invasiveness is due to the availability of the species in maximum habitat and in maximum number. The invasiveness of the species is also relative to its length of exposure to the natural habitat. The chronological gradient of invasiveness of the fish species is listed in Table 2. *Hypophthalmichthys molitrix* (Valenciennes, 1844) is the maximum abundant species and available in the maximum habitat of the study area, and *Piaractus brachypomus* (Kuvier, 1818) is the least abundant species and available in the restricted habitat of the study area. As per the IUCN Red List, 35.7% of exotic fish in the study area are in the least concern category, while

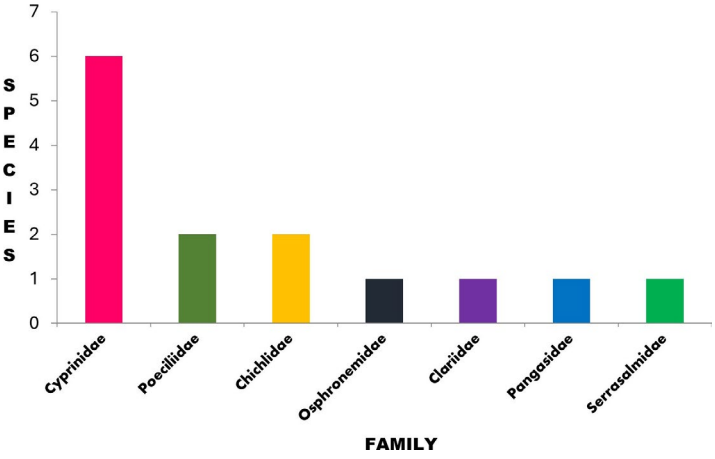

Fig.2. Family level species diversity.

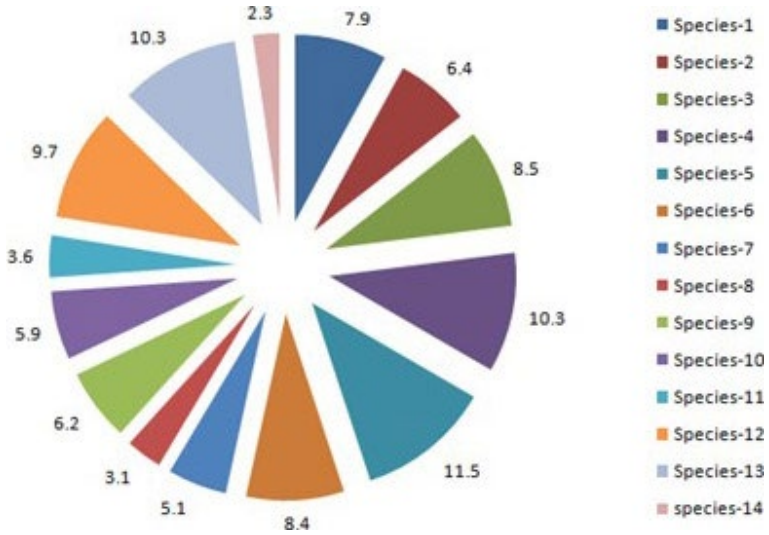

Fig.3. Relative abundance (merit of invasiveness).

28.5% of exotic fishes are in the not evaluated category and 14.2% are in the near threatened category. The endangered, vulnerable, and data deficient categories are of 7.1% each in the study area (Fig. 4).

There are sufficient numbers of fish species that can be cultivated in our country. Any further introduction of exotic fish species into any aquatic bodies would pose a threat to the existing species diversity. The addition of major exotic species such as tilapia, pangasius, etc. has a higher adverse impact on the aquatic ecology, as well as on farming techniques, because farmers alter farm construction and input materials for exotic fish farming in the study area. The significant entry of enzootics and foreign pathogens is always a great threat resulting from the introduction of exotic species. Alien species introductions lead to increased competition for resources and may also cause gene loss, predation, and pathogen inoculation within native species. Instead of indiscriminately introducing exotic species into our native aquatic habitat, we need to focus on protecting our present indigenous fish population and taking measures to enhance the quality of the cultivable fish population. To protect the native fish species that are already present in the study area, appropriate and effective measures should be implemented. The import and trading of aqua-organisms should be restricted through monitoring. In this regard, local, national, and international governing bodies have to play a vital role to regulate the illegal entry of exotic fish.

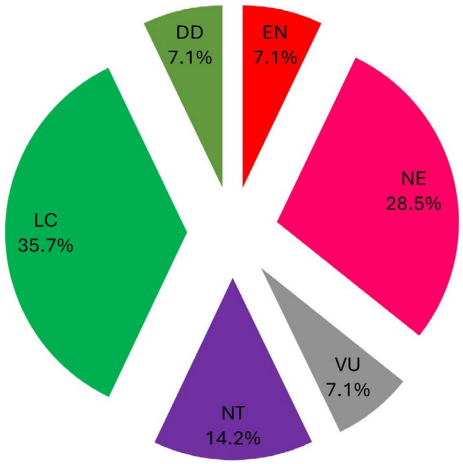

Fig.4. IUCN category (%) of exotic fishes in the study area.

Table 2. Invasiveness of different exotic fish found in the study area

Sl. No. In Table 1	Species Name	Invasiveness in percentage
5.	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	11.5
4.	*Cyprinus carpio* Linnaeus, 1758	10.3
13.	*Pangasianodon hypophthalmus* (Sauvage, 1878)	10.3
12.	*Clarias gariepinus* (Burchell, 1822)	9.7
3.	*Ctenopharyngodon idella* (Valenciennes, 1844)	8.5
6.	*Hypophthalmichthys nobilis* (Richardson, 1845)	8.4
1.	*Carassius auratus* (Linnaeus,1758)	7.9
2.	*Barbonymus gonionotus* (Bleeker,1850)	6.4
9.	*Oreochromis mossambicus* (Peters, 1852)	6.2
10.	*Oreochromis niloticus* (Linnaeus, 1758)	5.9
7.	*Gambusia affinis* (Bird and Girard, 1853)	5.1
11.	*Osphronemu sgoramy* Lacepéde 1801	3.6
8.	*Poecilia reticulata* Peters, 1859	3.1
14.	*Piaractus brachypomus* (G. Kuvier,1818)	2.3

Furthermore, educational campaigning should be initiated to explain the hazards of releasing exotic species into the native environment and encourage the proper disposition of unwanted fish. We have to educate fishers, fish farmers, fish entrepreneurs, hobbyists, and fish keepers, as well as the averge person, that releasing exotic species into the environment is dangerous to the environment.

3.1. Adverse effects on local species

The addition of non-native fish into aquatic ecosystems is controversial, despite significant contributions to aquaculture. Any new species introduced to an ecosystem will have an effect because it will share resources with the native species, but most of the time, the effects may not be noticeable. Exotic fishes are frequently recognized as a threat to native populations, with respect to aquatic diversity resulting from competition for foraging, habitat alteration, ecosystem degradation, and genetic interaction through cross fertilization with native species. It is believed that small native species in the study area suffer from the addition of farmed alien species like the Thai magur, *Clarias gariepinus* (Burchell, 1822).

Although non-indigenous species were only introduced for aquaculture in India, they are commonly found in the inland rivers, reservoirs, floodplains, canals, and wetlands of several states. During the monsoon season, it is easy for non-native species to spread from closed culture systems to open water resources in flood-prone areas. The spread of fast-growing, non-native fish impacts native ecosystems and threatens native, comparatively smaller species. Populations of these introduced fish have grown exponentially, and their range is expanding fast beyond the sites of introduction. Recently, it has been observed that a large number of non-native fishes are found in the local aquatic habitat of the study area. The aquaculturists and inexperienced farmers accidentally introduced non-native fishes into open waters due to their lack of knowledge or awareness. The effects of these escaped fishes were studied, and it was found that they cause ecological problems in several natural aquatic systems (Singh, 2021). Non-native species that were fully established in the local habitat, acclimatised in natural ecosystems, and can reproduce naturally mostly pose ecological risks. These species tend to have very large populations in natural environments when conditions are ideal.

The availability of basic knowledge and cultural techniques for non-native fish species makes them attractive to aquaculturists, as they can easily and quickly adapt to new environments and compete in new markets. Aquaculture entrepreneurs and farmers have been trying for years to bring in new fish strains and varieties like the Viet-Koi to boost production and compete on the global market. Despite productivity concerns, the government authorities took into account environmental and biodiversity factors to protect the local aquatic ecosystem. The government of India authorised National Committee to monitor the import of non-native species into Indian water bodies.

3.2. Novel contribution of the study

This research provides the first documented record of two exotic fish species, *Barbonymus gonionotus* and *Piaractus brachypomus* in the study area of Purba Medinipur, Paschim Medinipur, and Jhargram, West Bengal (Fig. 2). These species have not been previously reported in this region, marking a new addition to the exotic fish fauna. This study also offers a detailed examination of the ecological consequences of exotic fish invasions, particularly their relative abundance and invasiveness in the region (Table 2).

3.3. Comparison with other regions of India

The results on invasive fish species in West Bengal align with patterns observed in other parts of India, where exotic species such as *Cyprinus carpio* and *Oreochromis mossambicus* have also become widespread (Kumar, 2000). However, this study emphasizes that in West Bengal, species like *Hypophthalmichthys molitrix* and *Pangasianodon hypophthalmus* have shown exceptional invasiveness, likely due to their adaptability to the region's monsoonal climate and abundant water bodies. Similar invasions were observed in such states as Andhra Pradesh and Tamil Nadu (Jana et al., 2015), where non-native species outcompeted native fish populations in certain water bodies.

3.4. Assumptions regarding the successful spread of some species

Species such as *Hypophthalmichthys molitrix* and *Cyprinus carpio* have a high tolerance for diverse aquatic environments and can reproduce rapidly in local habitats (Moyle and Leidy, 1992). Intentional introductions for aquaculture and ornamental purposes, coupled with accidental releases, facilitated their spread. The monsoon season further aids their distribution into new habitats (Philipp et al., 1995). Some species are more competitive in terms of food resources and habitat occupation. For instance, *Clarias gariepinus* outcompeted smaller native species due to its predatory nature and large size (Nyman, 1991a).

3.5. Future trends in invasive species spread

Species *Hypophthalmichthys molitrix* and *Cyprinus carpio* will continue to dominate freshwater ecosystems, particularly in regions with abundant aquaculture activities and seasonal flooding (Welcomme, 1988a). With the continued spread of invasive species, hybridization with native fish species may become more prevalent, leading to genetic erosion (Raghubanshi et al., 2005). As global trade and aquaculture expand, the introduction of new invasive species is expected. Surveillance and regulatory measures will need to evolve to address these threats effectively (Moyle and Leidy, 1992).

These insights underline the urgency of regulating the introduction of exotic species and monitoring their impact on local biodiversity to mitigate long-term ecological risks.

4. Conclusion

This study highlights the significant impact of exotic fish species on the freshwater ecosystems of Purba Medinipur, Paschim Medinipur, and Jhargram in West Bengal, revealing 14 exotic species from 7 families and 12 genera. Notably, *Barbonymus gonionotus* and *Piaractus brachypomus* were recorded for the first time in the region. The study further identifie *Hypophthalmichthys molitrix*, *Cyprinus carpio*, and *Pangasianodon hypophthalmus* as the most invasive species, with *Hypophthalmichthys molitrix* showing the highest relative abundance and invasiveness. These findings underscore the ecological risks posed by the introduction of non-native species, including competition with native species, habitat alteration, and genetic risks.

The spread of these species mirrors patterns observed across other parts of India, where non-native fish have become dominant in aquatic ecosystems, often outcompeting indigenous species. The spread of successful invaders can be attributed to their adaptability, rapid reproduction, and human-mediated introductions for aquaculture, ornamental purposes, and pest control. However, some species fail to establish populations due to environmental incompatibilities or competition from established native species.

To safeguard native aquatic species, it is imperative to implement stringent policies, improve regulatory oversight, and raise awareness among local communities and stakeholders about the risks posed by non-native species. Immediate action is required to prevent irreversible ecological damage and ensure the long-term sustainability of local fisheries and ecosystems.

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Conflict of interest

There is no conflict of interest for the present manuscript.

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