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STUDIES ON THE IMPACT OF EXOTIC FISH SPECIES ON THE INDIGENOUS FISH FAUNA OF HIMACHAL PRADESH, INDIA

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Abstract

The introduction of exotic fish species has significantly influenced aquaculture practices and aquatic ecosystems in Himachal Pradesh and across India. This review explores the ecological, economic, and management implications of introducing non-native fish species, focusing on their effects on native fish fauna and aquatic ecosystems. While exotic species have contributed to the growth of aquaculture and recreational fisheries, their ecological impacts, including habitat alteration, competition, and hybridization with native species, pose significant challenges to biodiversity conservation. Effective management strategies, including rigorous quarantine measures, stakeholder collaboration, and a focus on culturing native species, are imperative to mitigate these adverse effects. The review underscores the necessity of balancing aquaculture development with the preservation of local ecosystems and biodiversity.

Keywords: Exotic, Fish, Himachal Pradesh, Aquaculture, Sustainable.

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Introduction

The introduction of foreign species into an environment unit may pose a serious threat to the local fauna (Chattopadhyay et al., 2011), and it becomes a significant ecological concern worldwide, as these species often disrupt native ecosystems and alter the dynamics of local biodiversity. The introduction of exotic fish species, often for aquaculture, recreational fishing, or biological control, has posed serious threats to the indigenous ichthyofauna, leading to habitat alteration, competition for resources, and, in some cases, extinction of native species (Singh &Lakra, 2006; Gozlan, 2008). Additionally, predation by certain exotic species can cause significant declines in local fish populations, undermining the ecological balance of freshwater ecosystems (Moyle & Light, 1996). During the past few decades, exotic fish species have been introduced to India for variety of reasons, adding roughly 13.6% to the country's diversity (Joshi et al., 2021). 31 aquaculture fish species, 600 ornamental fishes and 2 larvicidal fishes are exotic to Indian water bodies (Singh and Lakra, 2011; Singh, 2014). Increasing anthropogenic activities, coupled with the introduction of

non-native species, have exacerbated the pressures on these fragile ecosystems (Kumar et al., 2021).

Himachal Pradesh, nestled in the Northwestern Himalayas, is endowed with a rich diversity of freshwater fish species, many of which are endemic to the region and contribute significantly to the stability of aquatic ecosystems. Exotic fish species such as *Cyprinus carpio* (common carp), *Salmo truttafario* (Brown trout),*Oncorhynchus mykiss* (rainbow trout) etc. have been extensively introduced into the cold-water streams and reservoirs of Himachal Pradesh. While these species provide economic benefits through fisheries, they are known to compete aggressively with native species, often outcompeting them for food and breeding grounds (Pawelec-Olesińska,2020).

The current article aims to assess the ecological impacts of exotic fish species on the native fish fauna of Himachal Pradesh analyzing key ecological parameters, including competition, predation, and habitat disruption. Furthermore, the research seeks to provide a comprehensive understanding of the challenges posed by exotic fish species and propose sustainable management strategies for conserving the region's aquatic biodiversity.

Area of Study

Himachal Pradesh is a state in Northwestern Himalayas, characterized by mountainous terrain, having an elevation of 350 meters to 6,975 meters. It lies in 30°22'40"N to 33°12'40"N latitude and 75°45'55"E to 79°04'20"E longitude, occupying an area of 55,673 sqkm and is bordered by Jammu and Kashmir to the north, Ladakh to the northeast, Tibet to the east, Uttarakhand to the southeast, Haryana to the south and Punjab to the west (Anonymous, 2024).The state encompasses four Himalayan ranges i.e., the Shivalik or the Outer Himalayas, the Lower and the Lesser Himalayas, the Higher or the Greater Himalayas, and the Trans-Himalayas, having abundant water resources in the form of rivers, streams, lakes, pond and reservoirs. These varied water resources serve as critical habitat to the native fish fauna of the state.

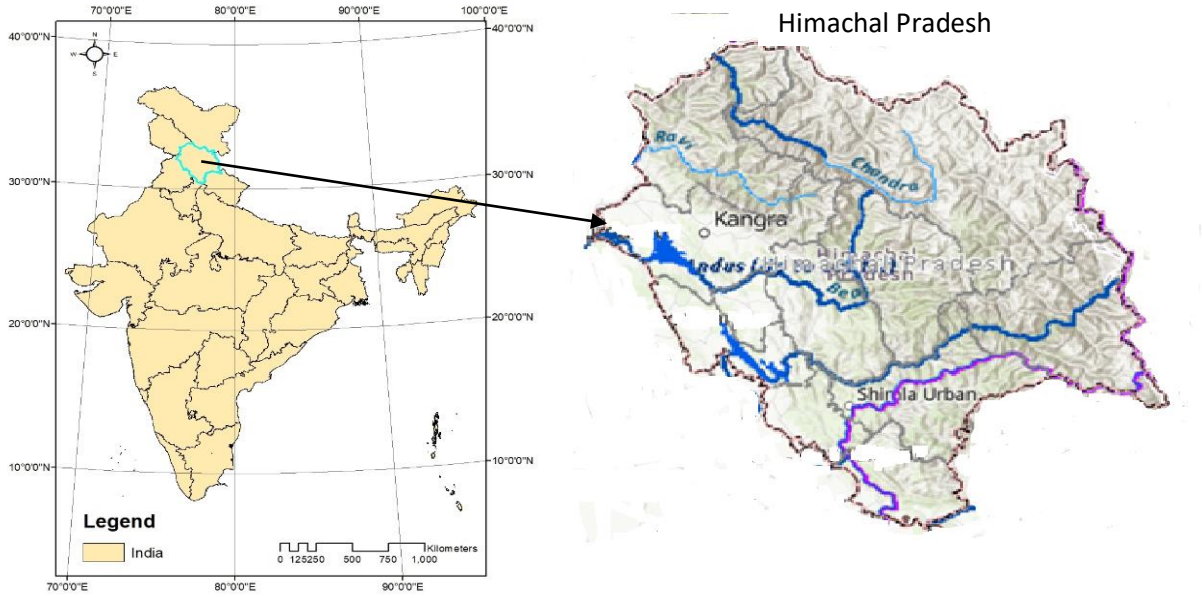


Fig 1: Map showing different water bodies of Himachal Pradesh (*Source: indiawris.gov.in*)

Material and Methods

The methodology for secondary data collection focuses on systematically gathering and analyzing information from various credible sources including PubMed, Scopus, Web of Science, ResearchGate, and Google Scholar. Varied keywords such as exotic fish species, native fish fauna, aquatic ecosystems, Himachal Pradesh, fisheries and ecological impacts were used in search engines and databases. A comprehensive review of journals, books, technical reports and government publications was conducted.

Results and Discussion

A number of exotic fishes which are introduced in India for aquaculture and ornamental purposes (Table.1) have escaped from the aquaculture farms and formed a natural population in open waters of rivers and streams (Singh and Lakra, 2011). Due to their hardy, robust, omnivorous nature, strong adaptability and tolerance to wide range of temperature, these invasive species get established and alters the ecological condition of the natural water bodies (Joshi et al., 2021).

During the pre-independence (1870–1947), nine fish species were brought to India, *viz.*, temperate food fishes such *Tincatinca*, *Carassiuscarassius*, and *Cyprinus carpio*, salmonid game fishes like *Salmo truttafario* and *Salmo gairdnerii* (now *Onchorhynchus mykiss*), larvicidal *Gambusia affinis*, *Lebistesreticulatus*, and tropical osphronemids i.e., *Osphronemusgoramy* (Natarajan and Ramachandra, 1988). Furthermore, many ornamental and food fishes were introduced in India after independence, such as carps (Chinese strain of *C. carpio*, *Ctenopharyngodonidella*, *Hypophthalmichthys molitrix*, *Puntius javanicus*), cichlids (*Oreochromis mossambicus*, *O. niloticus*), and salmonids (*Salvelinus fontinalis*, *Salmo salar*, *Oncorhynchus mykiss*, *O. nerka*) etc. (Joshi et al., 2021).

Table 1: Major fish species introduced in Indian water bodies also invade into water bodies of Himachal Pradesh *(Joshi et al., 2021)*

Fish species	Common name	Year of Introduction in India	Source
Salmo truttafario	Brown trout	1863 - 1908	England, Japan
Onchorhynchus mykiss	Rainbow trout	1909	Sri Lanka, Germany, New Zealand
Ctenopharyngodonidella	Grass carp	1959	Japan, Hong Kong
Hypophthalmicthys molitrix	Silver carp	1959	Japan, Hong Kong
Cyprinus carpiocommunis	Scale carp	1939, 1957	Sri Lanka, Bangkok
Cyprinus carpiospecularis	Mirror carp	1939, 1957	Sri Lanka, Bangkok
Cyprinus carpionudus	Leather carp	1939, 1957	Sri Lanka, Bangkok
Carrasiuscarassius	Crucian carp	1974	England
Oreochromis niloticus	Nile tilapia	-	Thailand, Israel

A large number of exotic fish species also invade the local water bodies of Himachal Pradesh. Some of these are commercially important fish species and serves as a boon to the state pisciculture and economic growth. In-spite of this, they also outcompete local fauna of the state for food and shelter and also acts as carrier of large number of exotic pathogens. A

total of 16 exotic ornamental fish species were recorded in Himachal Pradesh, out of which 6 species (*Carassiuscarrasius, C. auratus, Cyprinus carpiocommunis, C. carpiospecularis, C. carpionudus* and *Trichogasterfasciata*) invade into natural water bodies (Sharma and Dhanze, 2018).

Some of the Exotic Fish Species Found in Himachal Pradesh are (Fig. 2):

- *Cyprinus carpio* (European Carp or Common Carp)
- *Hypophthalmicthys molitrix* (Silver Carp)
- *Ctenopharyngodonidella* (Grass Carp)
- *Salmo truttafario* (Brown Trout)
- *Oncorhynchus mykiss* (Rainbow Trout)
- *Oreochromis niloticus* (Nile Tilapia)
- *Carassiuscarassius* (Crucian Carp)
- *Carrasius auratus* (Goldfish)
- *Trichogasterfasciata* (Banded gourami/ Striped Gourami/ Giant Gourami)

Cyprinus carpio (European Carp or Common Carp): Common carp was introduced in India in 1959 (Singh and Lakra, 2006), three varieties of common carp viz., *C. carpio var. communis* (Scale carp), *C. carpio var.specularis* (Mirror carp) and *C. carpio var. nudus* (Leather carp) were found in water bodies of Himachal Pradesh.*C. carpio var. communis*is widely used in plains for aquaculture, whereas, *C. carpio var. specularis* aqua cultured in hill state water bodies (Singh et al., 2010). In India, initially, German strain of Mirror carp was introduced from Ceylon in 1939, but the strain can't be able to breed freely in tropical water bodies so to overcome the problem Chinese stock of common carp i.e., scale carp was introduced in Uttarakhand (Kumaon lake). Later the species was also recorded in Dal lake (Kashmir), where it outcompetes local fish species, especially *Schizothorax* spp. It was also stocked in Govindsagar reservoir (H.P.), consequently, in-spite of dominant silver carp, it constitutes a profitable fishery. Due to bottom feeding habit, it competes with *Cirrhinusmrigala* and *Clariasmagur* for space and food (Swain et al., 2017). The species was also recorded in numerous natural water bodies of Himachal Pradesh (Sharma and Dhanze, 2018; Sharma and Chandra, 2021, Sharma and Banyal, 2023, 2024; Modeel et al., 2024).

Hypophthalmicthys molitrix (Silver Carp): The silver carp was first introduced in India, in Kulgarhi reservoir, Madhya Pradesh during 1959 (Swain et al., 2017). Later, in Himachal Pradesh silver carp was introduced in Govind Sagar reservoir, which have several negative consequences on native Indian major carps of the reservoir. Currently, the majority of the catch in the reservoir is made up of exotic silver carp (approximately 60–65%), followed by Indian major carps (20–25%), mahseer species (8–10%), and minor carps (8–10%) (Raman et al., 2013). The species also invade in various natural lentic and lotic water bodies of Himachal Pradesh.

Ctenopharyngodonidella (Grass Carp): This species was first introduced in India for controlling overgrowth of submerged vegetations. But later, due to its rapid growth rate it became an integral part of composite fish culture. It brings nutrients locked in weeds in circulation and produces valuable fish proteins. But, it adversely impacts the survival of

fishes and other aquatic organisms which hide beneath these vegetations. Furthermore, the species only feed on selected macrophytes including *Hydrilla verticillata*, but others such as *Eichhorniacrassipes*, *Salvinia molesta*and *Pistia stratiotes* most threatening weeds in water are not fed by the fish (Swain et al., 2017). The species was widely distributed in Bilaspur, Kangra, Mandi, Kullu, Shimla, Solan, Sirmour, Chamba, Una and Hamirpurdistricts of Himachal Pradesh (Sharma and Chandra, 2021).

Salmo truttafario (Brown Trout) and ***Onchorhynchus mykiss*** (Rainbow trout): These two trout species have been introduced all over the world intentionally for commercial uses and recreational purposes (May, 2007). But, there is no systematic study has been conducted till now to evaluate the effects of trout introduction in open water. The mass mortality of rainbow trout in H.P. in 2002 has highlighted the necessity for quarantining and ecological concern among experts. It has been found that local cold-water species have reportedly been exterminated with the introduction of *Salmo truttafario* (Swain et al., 2017). *Onchorhynchus mykiss* was widely introduced in glacier fed water bodies of Kangra, Mandi, Kullu, Shimla and Sirmour, whereas *Salmo truttafario* was introduced in water bodies of Chamba, Kangra, Mandi, Kullu, Shimla and Kinnaur districts of Himachal Pradesh (Sharma and Chandra, 2021).

Oreochromis niloticus (Nile Tilapia): The species have been imported into more than 90 countries all over the world, with a global distribution second to common carp. Over the past few years, tilapias have contributed more to the world's aquaculture output. Because of their prolific breeding tendencies, tilapias have devastated local fish populations both in India and beyond. Recently, Nile Tilapia (*O. niloticus*) have been reported in Beas River basin in Himachal Pradesh (Sharma and Banyal, 2024; Modeel et al., 2024). The Nile tilapia affects the water body by changing native community composition, reduces water transparency, lowers planktonic microcrustaceans abundance, increases the concentration of microalgae (Okun et al., 2008; Simões Vituleet al., 2009).

Carrasius auratus (Goldfish): It is widely distributed ornamental fish found in India, but is also regarded as potential pest in natural water bodies. It causes mass mortality of fishes by resuspending of nutrients present at the bottom, which accelerates blue-green algal growth and causes large-scale aquatic destruction (Morgan, 2004; Sandilyan, 2016). Its bottom feeding behavior increases the turbidity of water, furthermore, the species also feed on eggs, larvae and adults of some native fish species (Richardson et al., 1995; Rowe and Smith, 2001). This fish species is widely distributed in Beas (Kangra, Mandi, Kullu), Sutlej (Bilaspur, Shimla), Ravi (Chamba) and Yamuna (Solan, Sirmour) River basins of Himachal Pradesh (Sharma and Dhanze, 2018).

Advantages of Introducing Exotic Fish Species

More than 300 species of exotic fishes have been brought to India along with Himachal Pradesh, during the past few decades for aquaculture, pleasure fishing, ornamental fish keeping, mosquito control and other purposes (Singh and Lakra, 2010), which offers various advantages to aquaculture.

- "Composite fish culture" of Indian Major Carps (IMCs) viz., *Labeorohita*(rohu), *Cirrhinusmrigala*(mrigal) and *Catlacatla* (catla) along with three exotic carps (*Hypophthalmichthys molitrix*, *Ctenopharyngodonidella* and *Cyprinus carpio*) have gained a popularity in pisciculture.

- Several fish species such as *Carrasiuscarrasius, Carrasius auratus, Trichogasterfasciata* have been introduced to meet the increasing demand of aquarium fishes (Singh and Welfare, 2017).
- Some exotic species can help control aquatic vegetation and maintain ecological balance, such as *Ctenopharyngodonidella* (grass carp), which is used for biological weed control in reservoirs.
- Furthermore, exotic fish species often serve as affordable protein sources for growing population, thus addressing food security issues in rural and urban areas (FAO, 2021).

Disadvantages of Introducing Exotic Fish Species

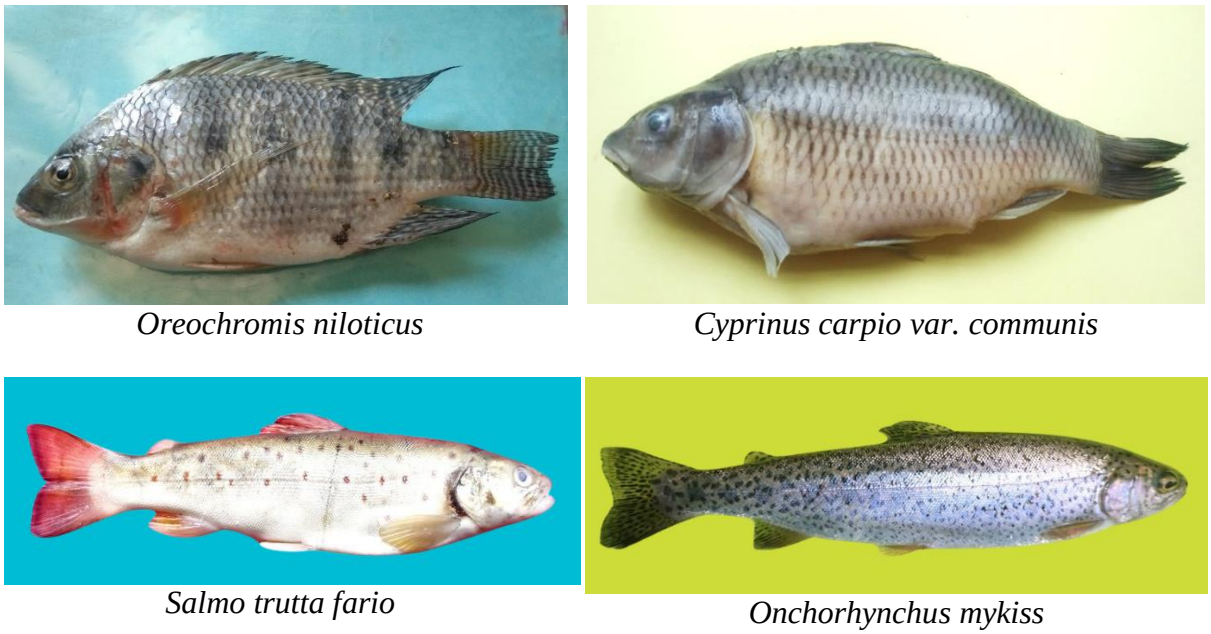
- Non-native/alien fish species, that are intentionally or non-intentionally transferred into natural water bodies can negatively impact local fauna by introduction of pathogens or parasites (Table.2) and spreading of diseases, genetic alterations, environmental modification and also acts as competitors or predators to native fauna (Lakra et al., 2008).
- Fish species such as *Ctenopharyngodonidella* introduced for biological control also have negative consequences on native fish fauna. As the fish feeds non-selectively on aquatic vegetation, changes the habitat quality and availability required by different aquatic organisms (Silva et al., 2014; Zonneveld and Van Zon, 2019).
- One example of a nuisance fish that has seriously harmed a number of aquatic habitats is the common carp. By grazing on submerged vegetation, it uproots plants that other aquatic species use for food and cover and depriving other fish of important resources required for survival (Lakra et al., 2008).
- A large number of ornamental fish species such as *Carassius auratus* (Goldfish) has frequently escaped into the wild and causes menace to local fish species (Erarto and Getahun, 2020).
- One of the most important ecological concern about the introduction of non-native fish species is hybridization between native and introduced species. One such example is hybridization between crucian carp (*Carassiuscarassius*) and Eastern native goldfish (*Carassius auratus*) or *Cyprinuscarpio* (Hanfling et al., 2005; Smartt, 2007).

Table 2: Common pathogenic parasites found in exotic fish species in Indian waters *(Abidi et al., 2011; Raman et al., 2013; Trujillo-González, 2018)*

Host fish species	**Pathogen or Parasite**
Cyprinus carpio	*Tripartiellacopiosa, Gyrodactylusmedius, Diplozoonnipponicum, Dactylogyrousachmerowi, D. anchoratus, D. crassus, D. extensus, D. minutus, D. mrazaki, D. vastator, D. yinwenyingae*
Hypophthalmichthys molitrix	*Tripartiella reticulata*
Ctenopharyngodonidella	*Tripartiellaobtusa, Neoergasilus japonicus*
*Carassius*sp.	*Pellucidhaptorkritskyia*
Carassius auratus	*Dactylogyrous*sp., *Gyrodactylusmedius, Schyzocotyleacheilognathi, Ichthyophthiriusmultifiliis, Argulus japonicus, Lernaeacyprinacea*

Management of Introduced Species:

Even though the introduction of exotic fish species can be seen as beneficial to aquaculture because of its maximum development potential, but we must have to carefully manage our own native ecology and biodiversity to prevent the negative effects of introducing exotic fishes.In order to avoid negative effects and entrance of exotic parasites and pathogens along with introduced species, rigorous quarantine measures are necessary (Lakra et al., 2006). It is the need of the today that the researchers should have to focus on culturing native species, rather than introducing new species, which will fulfill the increasing human demand for fish as food while still conserving local biodiversity. All stakeholders must be involved in the multifaceted management of introduction, in order to coordinate, monitor, and manage the transfer and introduction of species on an international level, it must be implemented at a number of scales, ranging from a homeowner working in their backyard to large government agencies including the Directorate of Fisheries of State Governments and central organizations like NBFGR (National Bureau of Fish Genetic Resources), ICAR (Indian Council of Agricultural research), NFDB (National Fisheries Development Board) etc., taking a state-wise and nationwide approach, respectively. Lastly, it must involve major intergovernmental agencies like FAO (Food and Agriculture Organization), NACA (Network of Aquaculture Centres), World Fish Center, ICES (International Council for Exploration of the Sea), EIFAC (European Inland Fisheries Advisory Commission) and others (Raman et al., 2013).



Oreochromis niloticus | *Cyprinus carpio var. communis*

Salmo trutta fario | *Onchorhynchus mykiss*

Fig 2: Depiction of some of the exotic fish species of Himachal Pradesh.

Conclusion

The introduction of exotic fish species has been a double-edged sword, benefiting aquaculture and fisheries while posing significant risks to native biodiversity and ecosystem stability. The findings of this review highlight the critical need for a systematic approach to manage exotic species. The ecological consequences, such as habitat degradation, competition, predation, and hybridization, threaten native fish populations and aquatic ecosystems. At the same time, the economic benefits from aquaculture and recreational

fisheries cannot be overlooked. Moving forward, it is essential to prioritize native species in aquaculture practices, implement rigorous quarantine measures to prevent pathogen transmission, and foster coordinated management strategies involving local, national, and international stakeholders. By adopting sustainable practices and focusing on biodiversity conservation, we can ensure that the benefits of aquaculture development are achieved without compromising the health and stability of aquatic ecosystems.

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