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THEMATIC ESSAY

Sustainable Management of Exotic Fish Biodiversity in Karnataka: Status, Challenges, and Threats

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Abstract: Fish biodiversity, a significant part of the aquatic ecosystem, has been studied widely in India. However, the distribution and diversity of fish species have not been well-researched at the state and/or regional levels. Karnataka is bestowed with 8% of the country's water resources, which are under extreme pressure because of unregulated population growth, biological invasion, and developmental requirements. Since the middle of the nineteenth century, India has been introducing alien species to its water bodies. Currently, 13.6% of the fish diversity in India is exotic and has been established voluntarily or involuntarily for various purposes. The establishment of invasive alien fishes negatively influences native fish communities around the globe. In general, most publications present the latest status of ichthyofauna in several regions of Karnataka; however, there is no up-to-date documentation on strategic environmental developments and unforeseen challenges, such as invasive alien species (IAS). This study reconstructs existing knowledge while analytically reviewing challenges, potential management techniques, advancements, and the impacts of climate change and disseminates the data necessary for the comprehension of the biological invasion of IAS.

Keywords: Invasive alien species, Biological invasion, Fish biodiversity, Threats, Conservation, Aquatic ecosystem, Karnataka.

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1. INTRODUCTION

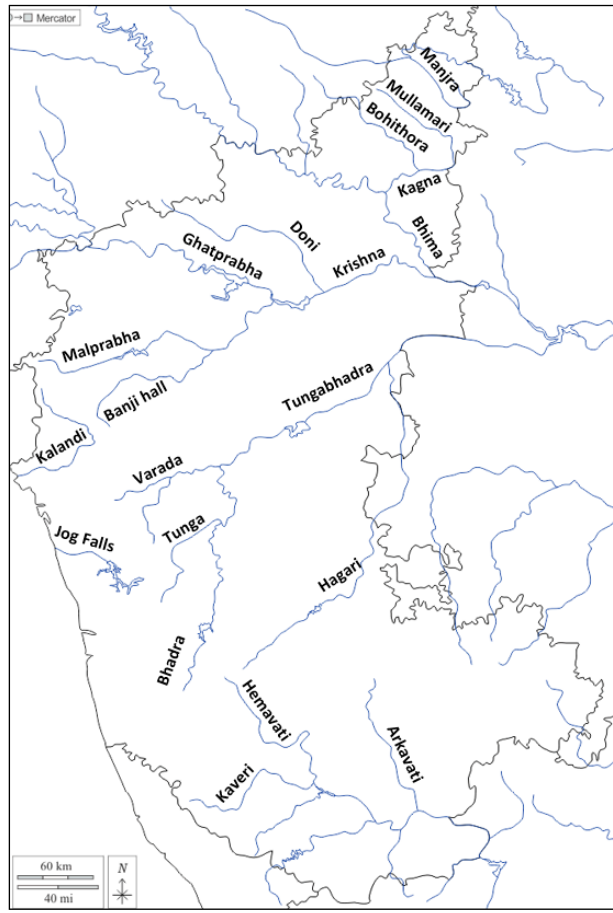
Fishing is a major occupation in most villages in Karnataka (around 30%), second only to farming (Ramchurjee and Suresha 2006). Karnataka has nearly 0.52 million hectares of freshwater resources, with around 0.15 million hectares dedicated to fish farming. Despite the large water-spread area, Karnataka contributes only 8% of the total Indian fish production, indicating that several technical and socio-economic constraints impede fish production (Basavakumar, Devendrappa, and Srenivas 2011). The Karnataka riverine system supplies 75 species for aquarium trade, followed by 48 species for aquaculture, 53 species for capture fishery, and 27 species for game fishing. Among the threatened species category, 5 are critically endangered, 22 are endangered, and 13 are vulnerable. There are 200 non-threatened species, of which 18 are near-threatened, 155 are of least concern, 12 are data-deficient, and 15 have not been evaluated against International Union for Conservation of Nature (IUCN) criteria (NBFGR. 2010). The actual number of invasive species in Karnataka could be higher; however, given the geographically uneven research effort on biological invasions, this figure is yet to be determined.

In recent decades, globalization has facilitated the transportation of goods and people worldwide, resulting in the establishment of exotic species in regions beyond their natural habitats. The cost of controlling these invasive alien species (IAS), and the economic impacts of their persistence, total thousands of dollars annually, according to the IUCN. A 2020 study projects that the number of established IAS will increase by 30% between 2005 and 2050 (IUCN 2021). Thus far, evidence indicates that 13.6% of fish species in India are exotic. They have been established (Joshi *et al.* 2021)—voluntarily or involuntarily—for various purposes, such as aquaculture, therapeutic value, research, capture fishery, game fishing, and aquarium trade (Lakra, Singh, and Ayyappan 2008). This paper summarizes the extensive studies that have been conducted by several researchers on fisheries in Karnataka, i.e., fisheries that have a substantial influence. Currently, there is no comprehensive and dynamic up-to-date documentation on strategic environmental developments to address unforeseen challenges such as the establishing of IAS. This paper reconstructs existing knowledge and analytically reviews the challenges, potential, management techniques, advancements, and the impacts of climate change on fisheries to disseminate the research necessary to understand the nature and impact of the biological invasion of IAS.

2. RIVER DRAINAGE IN KARNATAKA

The Karnataka drainage map features the following salient features (Figure 1). Rapid rivers flow into the Arabian Sea in the west from the Western Ghats (Sahyadri), producing a significant water divide between the eastern and western parts of the state. Some of these rivers are Aganashini, Netravati, Bedti/Gangavalli, Kalinadi, Chakra, and Sharavati. The rivers Krishna,

Figure 1: River Drainage in Karnataka



Source: Maps of India (www.mapsofindia.com)

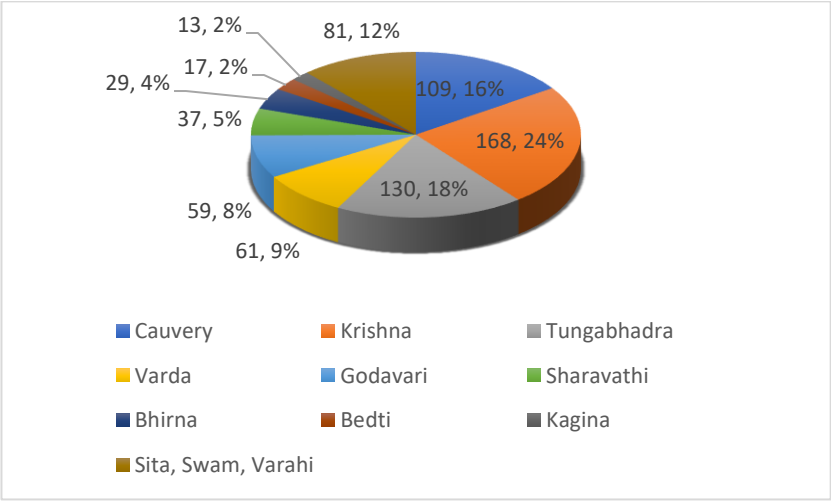
Tungabhadra, and Cauvery are located in the eastern part of the state. The Godavari River has several tributaries, namely, Manjira, Karanja, Painganga, Pranhita, Wainganga, Wardha, Maer, and Sabri. Most of the Krishna River's upstream flow as well as its tributaries pass through northern Karnataka,

some heading straight into Andhra Pradesh. Bhima, Ghataprabha, Malaprabha, and Tungabhadra are its main tributaries. The catchment area and the tributaries of the Krishna, particularly in the northern and central districts, serve more than 60% of the state. The Cauvery River begins its journey in the southern region of Kodagu, travels down the slopes of the Eastern Ghats and flows across the Mysore plateau, eventually passing through upland areas in Tamil Nadu before it enters the Bay of Bengal. A few rivers that flow across the Mysore plateau in southern Karnataka—Uttara Pinakini, Dakshina Pinakini, and Palar—are seasonally active, originating near the Nandi Hills and flowing into the sea after passing through Andhra Pradesh or Tamil Nadu.

3. THE BIODIVERSITY OF THE MAJOR RIVERS OF KARNATAKA

The Cauvery River—the fourth-largest river network draining the southern part of peninsular India—alone accounts for 109 fish species. Around 168 species have been recorded in the Krishna River basin, followed by 130 species in the Tungabhadra, 61 species in the Varda, 59 species in the Godavari, 37 species in the Sharavathi, 29 species in the Bhirna, 17 species in the Bedti, and 13 species in the Kagina. The west-flowing river basins, formed from by the Sita, Swam, and Varahi rivers, recorded 81 species (Mogalekar *et al.* 2016) (Figure 2).

Figure 2. Fish Diversity in the Various Riverine Systems of Karnataka



Source: Mogalekar et al. (2016)

4. INVASION ECOLOGY IN KARNATAKA

This section summarizes the structure of exotic freshwater species in Karnataka.

4.1 Streams and River

The majority of the fish species documented were found to be extensively dispersed in rivers and streams, as demonstrated in a study of the Tunga River. The current analysis suggests that the Cyprinid family is predominant in the region (Naik *et al.* 2013; Bhat 2004). According to local fisherfolk, the river is losing its natural carnivorous fish, including *Wallago attu*, *Channa marulius*, *Heteropneustes fossilis*, and, most notably, *Ompok bimaculatus* (Naik, Kumar, Mahesh, and Benkappa 2013) ; Gowda *et al.* 2015; Zoological Survey of India 2013; Atkore *et al.* 2020; Narasimhaiah *et al.* 2013).

4.2 Wetlands and Lakes

Mydala Lake, Tumakuru, was established for the aquaculture industry and comprises both endemic and exotic species. Current records on exotic species suggest that the presence of *Oreochromis nilotica* and *Oreochromis mossambicus* are a risk to the major endemic carp of India, an issue that ought to be explored (Shivaraju and Ahmad 2017). Although minor carp, such as *Cyprinus carpio* and *Ctenopharyngodon idellus*, are also present in the lake, they are likely to be considered invasive. Kelageri Lake, with a catchment area of 6.36 square miles, has been recorded to have fish belonging to many orders/families, but these species were undetected during the study, perhaps due to the presence of IAS such as catfish, which are abundant in this lake. Eliminating predatory and invasive fishes, reducing anthropogenic threats, and following lake management guidelines might help other sensitive fishes, thereby improving fish faunal diversity in Kelageri Lake (Parimala 2021; Kamble and Ganesh 2016; Thirumala and Kiran 2017a).

4.3 Dams

Conservation efforts are crucial for Savandurga forest—a deciduous forest that serves as a vital resource for the local populace, who rely on it for various purposes. Unfortunately, due to human activities such as burning, a significant portion of the forest has been degraded, leading to the establishment of non-native species and canopy openings. Manchanbele Dam, which is located in the Savandurga forest, serves as a crucial catchment area. Given the rise in tourism activity within this region, it is imperative to implement conservation measures for its preservation (Chetana and Ganesh 2007).

Table 1: Contribution of Exotic Fish Diversity Studies in Karnataka

S. No.	Title	Author	Outcome of the Study
1	Assessment of Fish Diversity of Tunga River, Karnataka, India	Naik *et al.* (2013)	The introduction of *Clarias gariepinus*, also known as the African catfish, has resulted in a decline in indigenous fish stock due to competition for space and food. The Indian government has banned the introduction of this highly carnivorous species, which has caused severe damage to aquatic fauna, and the Union Agriculture Ministry has ordered the mass killing of these fish to prevent further harm.
2	Fish Biodiversity of Tunga, Bhadra and Tungabhadra Rivers of Karnataka, India	Gowda *et al.* (2015)	The paper suggests that the lower and middle stretches of the river support more exotic species. It is possible to ensure species sustainability in the river if fishery regulations are limited to the upper and lower stretches of the river.
3	Ecology and Ichthyofaunal Diversity of Mydala Lake of Tumakuru, Karnataka State, India	Shivaraju and Ahmad (2017)	Findings suggest that there is a need to investigate the potential threat posed by exotic species, such as *Oreochromis*, to the native major carps of India.
4	Ichthyofaunal Diversity Status in Kelageri Lake, Dharwad, Karnataka State	Kamble and Ganesh (2016)	Kelageri Lake is rich in aquatic biodiversity, primarily due to fishing regulations (restrictions on the use of a particular mesh size), which has resulted in lesser fish mortality than in other adjoining lakes.
5	Ichthyofauna of Jannapura Pond, Bhadravathi, Karnataka	Venkateshwarlu and Somashekar (2005)	A study on the ichthyofauna in Jannapura Pond, Bhadravathi, revealed that three species, viz, *Oreochromis mossambicus*, *Ctenopharyngodon idella*, and *Cyprinus Carpio*, were introduced species.

S. No.	Title	Author	Outcome of the Study
6	Survey and Activity Patterns of Nocturnal Mammals in a Fragmented Dry Deciduous Forest of Karnataka	Chetana and Ganesh (2007)	The degradation of the Manchanbele Dam, Savandurga, caused by human activities such as burning has led to the establishment of exotic species and canopy openings.
7	Ichthyofaunal Biodiversity of Tunga Reservoir (Gajanoor Dam), Karnataka (India)	Naik *et al.* (2012)	Exotic fish, including *Oreochromis mossambicus*, *Oreochromis niloticus*, and *Clarias garipinus*, were found in all three landing centres. The rapid breeding of tilapia had a 3significant impact on i4ndigenous fish p5opulations due to co6mpetition for reso7urces.

5. IMPACTS OF INVASIVE ALIEN SPECIES

The introduction of IAS has negatively influenced native fish communities around the globe. Due to a lack of risk assessment studies, indigenous fishes and their habitats are under threat (Cambray 2003). Fishing culture, including the cultivation of ornamental fish, and the rearing of alien fishes in flood-prone zones, are potential risk factors that can result in the depletion of native species (Joshi *et al.* 2021; Knight 2010). IUCN has identified *Gambusia affinis* as one of the worst invasive species. It is recorded as an IAS in the country. Larvivorous fish are widely utilized for mosquito biocontrol and are prevalent among both rural and urban populations. However, in multiple global locations, these fish have been observed to breed prolifically and compete effectively with native fish species, leading to ecological imbalances and compromising environmental integrity (Raja and Ravikanth 2020).

According to reports, the introduction of *Tor khudree* has been linked to the extinction of the indigenous *Tor remadevii* in the Cauvery (Pinder *et al.* 2019). Moreover, since *Tor khudree* has spread outside of its native range to across much of peninsula India, this species has lately been brought down from "endangered" to "least concern" per the IUCN (Pinder *et al.* 2019).

The African catfish (*Clarias gariepinus*) has a significant effect on native species which it competes with for available resources, causing a reduction in the native fish habitat and population (Naik *et al* 2013). It has been observed that the entire native fish flora has been exterminated in some water bodies upon the introduction of this species because it devours aquatic habitat and a range

of aquatic species even though they may exhibit tolerance. The highly predatory African catfish was brought into India's aquatic ecosystem by a different pathway. Over the years, the population of this fish has increased in many aquatic habitats in the country, thereby impacting the local fish population. As a result, the Ministry of Agriculture has mandated the mass extermination of these fish and banned their culture (Naik *et al.* 2013).

In the 1950s, the common carp (*Cyprinus carpio*) was introduced into artificial lakes and has severely impacted the native fish of various river systems. It has been reported that the common carp has replaced and dominates most species in reservoirs; for example, the Krishnarajasagar Reservoir (Yaqoob 2021). Similarly, other reservoirs and perennial tanks have faced the same issue wherein the decision to cultivate common carp has been influenced by tilapia culture. The commercially important major carp of India dominate endemic species like *Puntius pulchellus*, *Puntius jerdoni*, *Puntius carnaticus*, and *Labeo nigrescens* (Singh and Lakra 2011; Silas 1949). Tilapia has substituted most of the indigenous fish species in reservoirs—for instance, in Nelligudda and Manchanabele in Karnataka. This can be attributed to substantial landings of *Oreochromis mossambicus*. Moreover, local fishermen claim that the species is an undesired catch because there is not much of a market locally and the species harvest has been rising over time (Sarkar *et al.* 2018; Naik *et al.* 2013).

Over the past ten years, several new species have emerged in biodiversity hotspot areas such as the Northeast and Western Ghat regions (Sarkar, Mahapatra, and Lakra 2014). A new invasive species, *Pterygoplichthys disjunctivus*, commonly called the loricariid catfish, was first recorded in 2014 in the Cauvery River (Panikkar *et al.* 2015).

Pterygoplichthys disjunctivus has been reported to have significant ecological impacts, including disrupting the food web by extensive grazing on plankton and detritus, out-competing native species for food, causing the death of aquatic birds due to choking on the species' hard spines, disrupting plant communities through tail-lashing, and damaging fishing gear due to their nests and fishing burrows. However, the deleterious effects of these species were not apparent until after their introduction and establishment in the ecosystem (Panikkar *et al.* 2015; Sandilyan *et al.* 2018). According to the literature available on exotic fish in open inland waters, reservoirs located in South Indian states are susceptible to the risks posed by these non-native species.

Climate change and the associated extreme weather events can facilitate the spread of IAS to new regions and reduce the resistance of habitats to invasions. It is necessary to research the impacts of climate change on aquatic

resources, especially IAS, and to integrate measures to prevent and manage their spread through climate change policies (ICAR-CIFRI 2016.)

Table 2: Impacts of Exotic Species in the Aquatic Ecosystems of Karnataka

S. No.	Name of Exotic Species	Recognized and Predicted Impacts of Exotic Species	References
1.	*Gambusia affinis* (Mosquito fish)	Breeds in large numbers and contends with endemic fish, disrupting environmental integrity in several locations around the world.	Raja and Ravikanth (2020)
2.	*Oreochromis mossambicus* (Mozambique tilapia)	High usage as a substitute for most indigenous fish species has led to a decline in the population of indigenous fishes.	Naik *et al.* (2013)
3.	*Oreochromis niloticus* (Nile tilapia)	The high increase in its population has led to competition for resources.	Khan, Preetha, and Sharma (2015)
4.	*Clarias gariepinus* (African catfish)	Its carnivorous nature causes the extinction of native species and, consequently, loss of biodiversity.	Sarkar *et al.* (2018)
5.	*Pterygoplichthys disjunctivus* (Vermiculated sailfin catfish)	Its ability to cause disturbances in the food web and its highly competitive food traits results in the decline of native species, the death of aquatic birds, and disruption in plant communities.	Panikkar *et al.* (2015)
6.	*Cyprinus carpio* (Common carp)	Cirrhinus species (*C. cirrhosus*, *C. reba*, and *C. mrigala*) have declined as a consequence of its presence.	Sarkar *et al.* (2018)
7.	*Ctenopharyngodon Idella* (Grass carp)	Negative effect on large carps, according to the mixed trophic impact routine of ecological modelling research.	Khan *et al.* (2015)
8.	*Hypophthalmichthys molitrix* (Silver carp)	Hinders the growth of catla fish.	Sarkar *et al.* (2018)

6. FISHERIES IN RESERVOIRS OF KARNATAKA

Karnataka has the maximum number of large reservoirs compared to other states (Sarkar *et al.* 2014); around 13.87% of reservoirs in India belong to

Karnataka. Construction of barriers such as reservoirs and dams has increased the share of IAS in the riverine system and decreased the flow of water, creating a potential site for farming and thereby resulting in a controlled ecosystem where selective species—such as tilapia—are preferred due to locals' unawareness of the impact of IAS. Since the middle of the nineteenth century, India has used alien species to diversify its fisheries and aquaculture. However, many of the local indigenous fish species have been adversely affected due to the introduction of these invasive species. In the Girna and Krishnasagar reservoirs, Karnataka, Cirrhinus species *(C. cirrhosus*, *C. reba*, and *C. mrigala*) have declined as a consequence of the existence of common carp (Sarkar *et al.* 2018; Sugunan 2000).

Cyprinus carpio is the prevalent exotic carp in Hemavathy Reservoir, Karnataka, and landings are consistently adequate all through the year. Since they have a faster growth rate and make a substantial contribution to fisheries, common carp are considered ideal for many reservoirs in Karnataka. However, it is not recommended to stock common carp in thermally stratified reservoirs with anoxic hypolimnion due to the unsatisfactory growth and survival reported from the Nelligudda, Manchanabele, and Suvarnavathy reservoirs of Karnataka (Sarkar *et al.* 2018; Thirumala and Kiran 2017b). Reservoirs in Karnataka also contain exotic carp, which satisfies local market demand. In addition, other enormous Indian carp—such as grass carp (*Ctenopharyngodon idella*)—make a significant contribution to fisheries. These exotic carp have a good effect on gobies but a negative effect on large carp, according to the mixed trophic impact routine of ecological modelling research (Khan *et al.* 2015), which was used to study the impact of direct and indirect interactions. Due to poor market demand and consumer preferences, it has been determined that the silver carp (*Hypophthalmichthys molitrix*) and grass carp are not suitable for stocking in South Indian lakes.

In 2009–10, Suvarnavathy Reservoir witnessed an increase of 70% in its fishing yield, of which, large Indian carp made up almost 90% of the catch due to maintained stocking and constrained fishing. Krishnarajasagar Reservoir, Karnataka, was regularly filled with advanced carp fingerlings from 2009 to 2010 under a public–private partnership (PPP), and current research reveals that capturing techniques such as cultured-based fisheries are appropriate for the large reservoirs of Karnataka (Rao *et al.* 2013; Sarkar *et al.* 2014; Hassan *et al.* 2017; Raghavan *et al.* 2008; Khan *et al.* 2015; Thirumala and Kiran 2017a).

7. CONSERVATION MEASURES

Based on the available literature on non-native fish in open inland waters, it has been suggested that reservoirs in the southern states of India are at risk

of being affected by exotic species. Restricting catfish to small reservoirs is necessary because certain catfish species, such as *Heteropneustes fossilis* and *Clarias batrachus*, are highly invasive. However, catfish fisheries remain profitable and in demand in some regions (Sarkar *et al.* 2014). The invasiveness of *Tor khudree* has surpassed its native range, posing a threat to the conservation of the mahseer, *Tor remadevii.* Active removal of *Tor khudree* from the Cauvery is necessary to eradicate the species with the help of anglers and other appropriate approaches (Pinder *et al.* 2019). Bhimasandra Pond currently has a thriving population of the invasive species, *Oreochromis mossambicus*, while native Indian major carp species, including *Labeo* and *Puntius sp.*, face significant threats from rapidly increasing water pollution. To preserve the pond and its ecosystem, multiple conservation measures, such as restoring habitats and promoting education and awareness, must be adopted to enhance fishery yields, optimize economic gains, and maintain species diversity. Culture-based fisheries are an effective management tool for increasing yield from open waters when the selection of desired species is lower than the carrying capacity of the water body. Direct fish stocking for recruitment and recapture from open waters is the foundation of culture-based fisheries. However, most Indian reservoirs and wetlands have insufficient recruitment of desired fish species due to breeding failure caused by habitat degradation and overfishing. To avoid overfishing, a three-month fishing break from July to September is necessary to enable adequate fish growth. Mesh management in fishing is also a vital component that must be properly ensured. Taking appropriate measures to protect these resources through ecologically sustainable aquaculture is crucial (Shivaraju and Ahmad 2017).

8. CONCLUSION

Deteriorating riverine habitats in India are reported to be invaded by alien fishes. If this deterioration continues at the present pace, it will lead to the spread of disease and loss of valuable fish species as well as a decline in the economy (Joshi *et al.* 2021). These factors—along with certain other factors such as anthropological activities in the environment, overexploitation, and habitat loss—are significant threats to aquatic biodiversity, due to which immediate action on conservation strategies in the form of promoting aquatic biodiversity is necessary (Sarkar *et al.* 2014). The conservation policy should promote freshwater ecosystems, encourage the restoration of threatened species, and encourage interactive surveillance, preventative measures, elimination, and awareness to manage the negative impacts of IAS in the ecosystem. Furthermore, introducing divisions such as particular tanks for IAS at institutions has been found to be beneficial (Raj *et al.* 2021). Conservation tools and innovative techniques should be introduced as well,

followed by the cultural recognition that conservation is everyone's responsibility. Lastly, to achieve these goals, extensive research should be conducted on the interactions of native and exotic species, biodiversity alteration, inherited deterioration, and the advent of infectious diseases and parasites.

Ethics Statement: I hereby confirm that this study complies with requirements of ethical approvals from the institutional ethics committee for the conduct of this research.

Data Availability statement: The data used to support this research is not provided in a repository as it has no data set.

Conflict of Interest Statement: No potential conflict of interest was reported by the author.

REFERENCES

Atkore, Vidyadhar, Nachiket Kelkar, Shrinivas Badiger, Kartik Shanker, and Jagdish Krishnaswamy. 2020. "Multiscale Investigation of Water Chemistry Effects on Fish Guild Species Richness in Regulated and Nonregulated Rivers of India's Western Ghats: Implications for Restoration." *Transactions of the American Fisheries Society* 149 (3): 298–319. https://doi.org/10.1002/tafs.10230.

Basavakumar, K V, S Devendrappa, and S T Srenivas. 2011. "A Study on Profile of Fishing Community of a Village in Karnataka." *Karnataka Journal of Agriculture Science* 24 (5): 684–687.

Bhat, Anuradha. 2004. "Patterns in the Distribution of Freshwater Fishes in Rivers of Central Western Ghats, India and Their Associations with Environmental Gradients." *Hydrobiologia* 529 (1–3): 83–97. https://doi.org/10.1007/s10750-004-4949-1

Chandrashekhariah, H N, M F Rahman, and S Lakshmi Raghavan. 2000. "Status of Fish Fauna in Karnataka." In *Endemic Fish Diversity of Western Ghat*, edited by A G Ponniah and A Gopalakrishnan, pp. 98–135. Lucknow: National Bureau of Fish Genetic Resources Publication.

Chetana, H C, and T Ganesh. 2007. "Survey and Activity Patterns of Nocturnal Mammals in a Fragmented Dry Deciduous Forest of Karnataka." *Zoos' Print Journal* 22 (4): 2644–47. https://doi.org/10.11609/JoTT.ZPJ.1576.2644-7

Zoological Survey of India, ed. 2013. *State Fauna Series, 21: Fauna of Karnataka.* Kolkata: Zoological Survey of India.

Gowda, Gangadhara, Ganapathi Naik, Sushanth V Rai, Harsha Nayak, and Sruthisree C. 2015. "Fish Biodiversity of Tunga, Bhadra and Tungabhadra Rivers of Karnataka, India." *Research Journal Animal, Veterinary and Fishery Sciences* 3 (10): 1–16.

Hassan, M A, Mishal Puthiyottil, Gunjan Karnatak, and Anil Prakash Sharma. 2017. "Toward the Blue Revolution in India : Prospects for Inland Open Waters." *World Aquaculture* 48 (1): 25–8.

ICAR-CIFRI. 2016. *Annual Report 2016–17*. Barrackpore: ICAR-Central Inland Fisheries Research Institute.

IUCN. 2021. *Issue Brief February 2021: Invasive Alien Species and Climate Change*. Gland:

International Union for Conservation of Nature.
Joshi, Kripal Datt, V S Basheer, Aditya Kumar, Satyendra Mohan Srivastava, Vikash Sahu, and Kuldeep Lal. 2021. "Alien Fish Species in Open Waters of India: Appearance, Establishment and Impacts." *Indian Journal of Animal Sciences* 91 (3): 167–73. https://doi.org/10.56093/ijans.v91i3.114139
Kamble, Poorvi, and Ganesh C B. 2016. "Ichthyofaunal Diversity Status in Kelageri Lake, Dharwad, Karnataka State." *International Journal of Fisheries and Aquatic Studies* 4 (4): 343–6.
Khan, Feroz, P Preetha, and A P Sharma. 2015. "Modelling the Food Web for Assessment of the Impact of Stock Supplementation in a Reservoir Ecosystem in India." *Fisheries Management and Ecology* 22 (5): 359–70. https://doi.org/10.1111/fme.12134
Knight, J D M. 2010. "Invasive Ornamental Fish: A Potential Threat to Aquatic Biodiversity in Peninsular India." *Journal of Threatened Taxa* 2 (2): 700–4. https://doi.org/10.11609/jott.o2179.700-4.
Lakra, Wazir Singh, A K Singh, and S Ayyappan, eds. 2008. *Fish Introduction in India: Status, Potential and Challenges*. New Delhi: Narendra Publishers.
Mogalekar, H S, Paulraj Jawahar, and Canciyal Johnson. 2016. "Fish Diversity of Rivers of Karnataka." *Journal of the Inland Fisheries Society of India* 48 (1): 56–83.
Naik, A Kumar, Jitendra Kumar, V Mahesh, and S Benakappa. 2013. "Assessment of Fish Diversity of Tunga River, Karnataka, India." *Nature & Science* 11 (2): 82–7.
Naik, A Kumar, S Benakappa, S R Somashekara, H N Anjaneyappa, Jitendra Kumar, V Mahesh, and Shrinivas H Hulkoti. 2013. "Studies on Ichthyofaunal Diversity of Karanja Reservoir, Karnataka, India." *International Research Journal of Environmental Sciences* 2 (2): 1–5.
Naik, A Kumar, Jitendra Kumar, S R Somashekara, S Benakappa, H N Anjaneyappa, V Mahesh, and Shrinivas H Hulkoti. 2012. "Ichthyofaunal Biodiversity of Tunga Reservoir (Gajanoor Dam), Karnataka (India)." *Bulletin of Environment, Pharmacology and Life Sciences* 1 (11): 35–40.
NBFGR. 2010. *Threatened Freshwater Fishes of India*. Lucknow: National Bureau of Fish Genetics Resources Publication.
Panikkar, P, T D Jagadeesh, D S Krishna Rao, Uttam Kumar Sarkar, M Naskar. 2015. "First Record of Non-native Vermiculated Sucker Mouth Catfish, *Pterygoplichthys disjunctivus* (Siluriformes, Loricariidae) in Cauvery River of Peninsular India." *The Bioscan* 10 (4): 1659–63.
Parimala, B. 2021. "Diversity of Fishes in Relation to Habitat of Freshwater Bhimasandra Pond in Tumakuru, Karnataka, India." *Journal of Hunan University (Natural Sciences)* 48 (12). https://doi.org/10.22376/ijpbs.2021.12.4.b21-26
Pinder, Adrian C, J Robert Britton, Andrew J Harrison, Prakash Nautiyal, Shannon D Bower, Steven J Cooke, Steve Lockett, *et al.* 2019. "Mahseer (Tor spp.) Fishes of the World: Status, Challenges and Opportunities for Conservation." *Reviews in Fish Biology and Fisheries* 29: 417–52. https://doi.org/10.1007/s11160-019-09566-y
Narasimhaiah, Narasimhaiah, K Rekha, and Tenjing Singh. 2013. "Ichthyofaunal Diversity of Selected Centres of Nandini River of Western Ghats, Karnataka, India." *Scientific Transactions in Environment and Technovation* 6 (3): 146–50.
Raghavan, Rajeev, Gopalan Prasad, P H Anvar-Ali, and Benno Pereira. 2008. "Exotic

Fish Species in a Global Biodiversity Hotspot: Observations from River Chalakudy, Part of Western Ghats, Kerala, India." *Biological Invasions* 10 (1): 37–40. https://doi.org/10.1007/s10530-007-9104-2.

Raj, Smrithy, Pranav Prakash, Rajesh Reghunath, Josin C Tharian, Rajeev Raghavan, and Appukuttannair Biju Kumar. 2021. "Distribution of Alien Invasive Species in Aquatic Ecosystems of the Southern Western Ghats, India." *Aquatic Ecosystem Health and Management* 24 (2): 64–75. https://doi.org/10.14321/aehm.024.02.10.

Raja, M Nobin, and G Ravikanth. 2020. "The Enemy of My Enemy is Still My Enemy: the Biological Invasion and Management of *Gambusia* in Peninsular India." *Current Science* 119 (11): 1752–9. https://doi.org/10.18520/cs/v119/i11/1752-1759.

Ramchurjee, Nichola, and S Suresha. 2006. "Biodiversity Conservation Problems And Their Consequences On Sustainable Ecotourism: A Case Study Of Bandipur National Park, Karnataka, India." *JSSCWM Quest Journal* 3 (1): 36–41.

Rao, D S K, M Karthikeyan, N R Ramakrishna, B R Jagadish, M E Vijaykumar, P Nagaraju, and A P Sharma. 2013. "Culture-based Fisheries in a Large Indian Reservoir–A Case Study at Krishnarajasagar (Cauvery River Basin, Karnataka)." In *Book of Abstracts, National Seminar on Emerging Trends in Indian Aquaculture*, p. 28. Trivandrum: Department of Aquatic Biology and Fisheries, University of Kerala.

Sandilyan, S, B Meenakumari, A Biju Kumar, and Rupam Mandal. 2018. *A Review on Impacts of Invasive Alien Species on Indian Inland Aquatic Ecosystems*. Chennai: National Biodiversity Authority.

Sarkar, Uttam Kumar, P Mishal, Simanku Borah, Gunjan Karnatak, Ganesh Chandra, Suman Kumari, D K Meena, *et al.* 2018. "Status, Prospects, Threats, and the Way Forward for Sustainable Management and Enhancement of the Tropical Indian Reservoir Fisheries: An Overview." *Reviews in Fisheries Science and Aquaculture* 26 (2): 155–75. https://doi.org/10.1080/23308249.2017.1373744.

Sarkar, Uttam Kumar, Bijay Kali Mahapatra, and Wazir Singh Lakra. 2014. "A Review on Status, Potentials, Threats and Challenges of the Fish Biodiversity of West Bengal." *Journal of Biodiversity, Bioprospecting and Development* 2 (1). https://doi.org/10.4172/2376-0214.1000140

Shivaraju, Venkateshwarlu, and Shahnawaz Ahmad. 2017. "Ecology and Ichthyofaunal Diversity of Mydala Lake of Tumakuru, Karnataka State, India." *International Journal of Zoology Studies* 2 (5): 216–21.

Silas, E G. 1949. "On a Collection of Fish From Travancore." *Journal of Bombay Natural History Society* 48 (4): 792–7.

Singh, Atul K, and Wazir Singh Lakra. 2011. "Risk and Benefit Assessment of Alien Fish Species of the Aquaculture and Aquarium Trade Into India." *Reviews in Aquaculture* 3 (1): 3–18. https://doi.org/10.1111/j.1753-5131.2010.01039.x.

Sugunan, V V. 2000. "Ecology and Fishery Management of Reservoirs in India." *Hydrobiologia* 430 (1–3): 121–47. https://doi.org/10.1023/a:1004081316185.

Thirumala, S, and B R Kiran. 2017a. "Fish Diversity in Jambadahalla Lake of Chikmagalur District, Karnataka." *International Journal for Scientific Research and Development* 5 (5): 1068–71.

Thirumala, S, and B R Kiran. 2017b. "A Review on Fisheries Management and Development in Bhadra Reservoir, Karnataka." *International Journal for Research in Applied Science and Engineering*, 5 (7): 904-908.

Venkateshwarlu, M, and D S Somashekar. 2005. "Ichthyofaunal of Jannapura Pond, Bhadravathi, Karnataka." *Zoos' Print Journal* 20 (9): 1991. https://doi.org/10.11609/JoTT.ZPJ.1294.1991

Yaqoob, Shabeena. 2021. "A Review of Structure, Origin, Purpose & Impact of Common Carp (Cyprinuscarpio) in India." *Annals of the Romanian Society for Cell Biology* 25 (6): 34–47.