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**REVIEW ARTICLE**

# Influential Factors on the Fish Species in the Western Ghats: A Comprehensive Review

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**ABSTRACT**

The Western Ghats, a UNESCO World Heritage Site, is a significant area of biological diversity, with 290 freshwater species. The region is also home to the highest number of species at risk of extinction, with the IUCN Red List categorizing them into severely endangered, endangered, and vulnerable. Threats to freshwater fish include aquaculture, biological resource exploitation, human encroachment, invasive species, natural system changes, pollution, and climate change. The construction of dams has significantly impacted native fish species. Human activity and global climate change have led to population depletion and species extinction. Overfishing and harmful fishing methods have led to a decline in catch per hour for most fish species. Future threats include decreased precipitation, which could harm perennial streams. The ichthyofauna in the river basins of the west and east-flowing rivers is also declining due to human activities. Understanding fish species and their geographical distribution is crucial for developing conservation plans. The Fisheries Department and the Department of Environment must implement legislation and measures to minimize anthropogenic activities and promote conservation.

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## Introduction

Fish are aquatic vertebrate creatures that possess gills and lack limbs with digits. Fishes undergo ongoing evolution during the Paleozoic period, resulting in their extensive diversification. There are more than 33,100 documented species of fish, making them the most diverse group of vertebrates (Gillis & Tidswell, 2017). The species are further categorized into freshwater and marine environments. Freshwater fishes are defined as those that inhabit freshwater environments, such as lakes, rivers, and ponds, with a salinity level below 0.05%. These fishes make up 41.24% of the total fish population in this category (Nelson et al., 2016). India possesses abundant biodiversity, encompassing many geographical features such as the snow-clad Himalayas, the Indo-Gangetic plains, the Deccan Plateau, the Western Ghats, coastal areas, and marine ecosystems. This expansive region sustains a wide range of water resources, providing a habitat for a plentiful supply of fish genetic resources (Kah Choon, 2021). India is home to over 17,000 kinds of flowering plants,

with around 4,500 species located specifically in the Western Ghats region. Elsewhere of these, 1,720 species, which is more than one third, are unique to this region and cannot be found anywhere else (Khoshoo, 1995). Out of the total 24,618 fish species found worldwide, around 8.60% or 2,118 species are found in India (Ministry of Environment and Forests, 2014). The National Bureau of Fish Genetic Resources has created a database specifically for these fish species. 8% of the fish species found in India possess significant commercial and scientific importance (Lakra et al., 2010). This includes 500 species of freshwater fish, of which 65% are endemic and restricted to the Western Ghats and the North East regions, which are considered as two prominent biodiversity hotspots in India (Pathak et al., 2021). The anticipated consequences of global warming are projected to result in elevated average global and oceanic temperatures, impacting all kinds of life on Earth. This review focuses on the consequences of significant climate change factors on freshwater fish species in the Western Ghats region of India.

### *The Western Ghats - Geological Characteristics and Topographical Features*

The Western Ghats mountain chain, which predates the Himalayas, has significant geomorphic characteristics and hosts distinctive biophysical and biological processes (Chandran, 1997). The mountain range is situated in parallel to the western coast of the Indian peninsula and is recognized as one of the eight most significant areas of exceptional biological variety in the world (Pankajakshan & Scaria, 2023). The Western Ghats, sometimes referred to as Sahyadri, were created approximately 150 million years ago as a result of the faulting and erosion of the Deccan plateau. This plateau was formed during the fragmentation of the supercontinent Gondwana, leading to the emergence of the western coast of India as a steep cliff with an elevation of 3,300 feet (Padma Rao & Ravi Kumar, 2022). The rock types in the area include predominantly basalt, along with charnockites, granite gneiss, khondalites, leptynites, metamorphic gneisses including isolated deposits of crystalline limestone, iron ore, dolerites, and anorthosites, as well as residual laterite and bauxite ores (Subrahmanya, 1987).

The Western Ghats' topography spans from Gujarat to Tamil Nadu, stretching from the Satpura range in the north and extending southwards through the states of Maharashtra, Goa, Karnataka, and Kerala (Kamra & Nair, 2015). There are three gaps: the Thal Ghat (also known as the Goa gap), the Bhor Ghat (located between the Maharashtra and Karnataka parts), and the Pal Ghat (situated between the Nilgiri Hills and the Anaimalai Hills) (Pankajakshan & Scaria, 2023). The region is partitioned into three distinct sections - the Konkan, which is a thin coastal plain located between the Western Ghats and the Arabian Sea, the Kanara, which is the central area, and the Malabar, which is the southern component (Padma Rao & Ravi Kumar, 2022). The Western Ghats and the Eastern Ghats converge in Nilgiris in the northwestern region of Tamil Nadu. The Anamala Hills are situated to the south of the Palghat Gap, in the western regions of Tamil Nadu and Kerala (WGEEP, 2011). Further south, there are lesser mountain ranges, including the Cardamom Hills, followed by the Aryankavu pass and the Aralvaimozhi pass near Kanyakumari. Anamudi, located in the southern region of the range, stands as the tallest mountain in the Western Ghats, reaching an elevation of 2,695 meters (8,842 feet) (Fig 1) (Kamra & Nair, 2015).

### *Diversity of fish species in the Western Ghats*

The Western Ghats was classified as a hotspot mostly due to its abundant plant diversity. Subsequently, upon uncovering the abundance of different species in freshwater habitats, it was verified that this location is a highly important hub for the diversity and uniqueness of freshwater species on a global scale (Ramachandra et al., 2018). The Southern part of the Western Ghats, which includes South Karnataka, Kerala, and Tamil Nadu, holds the record for the highest number of threatened species (Molur et al., 2011). In contrast, the northern region of the Western Ghats, comprising Maharashtra and North Karnataka, has

a smaller number of reported freshwater species. The perennial streams of the Western Ghats offer a distinctive habitat for the fish species (Radhakrishnan & Rajmohana, 2012). The proliferation of aquatic organisms can be ascribed to the presence of rivers that run in both the western and eastern directions, as well as the accompanying wetland habitats. This, along with elevated precipitation levels, a temperate climate, and a diverse array of forests, contributes to the profusion of aquatic life (Daniels, 2000). A total of 290 species of freshwater fishes, belonging to 11 orders, 33 families, and 106 genera, have been found in this region (Fig 2). Over 50% of fish species are caught for the purpose of being consumed by humans, whereas more than 37% of fish are captured for the aquarium trade.

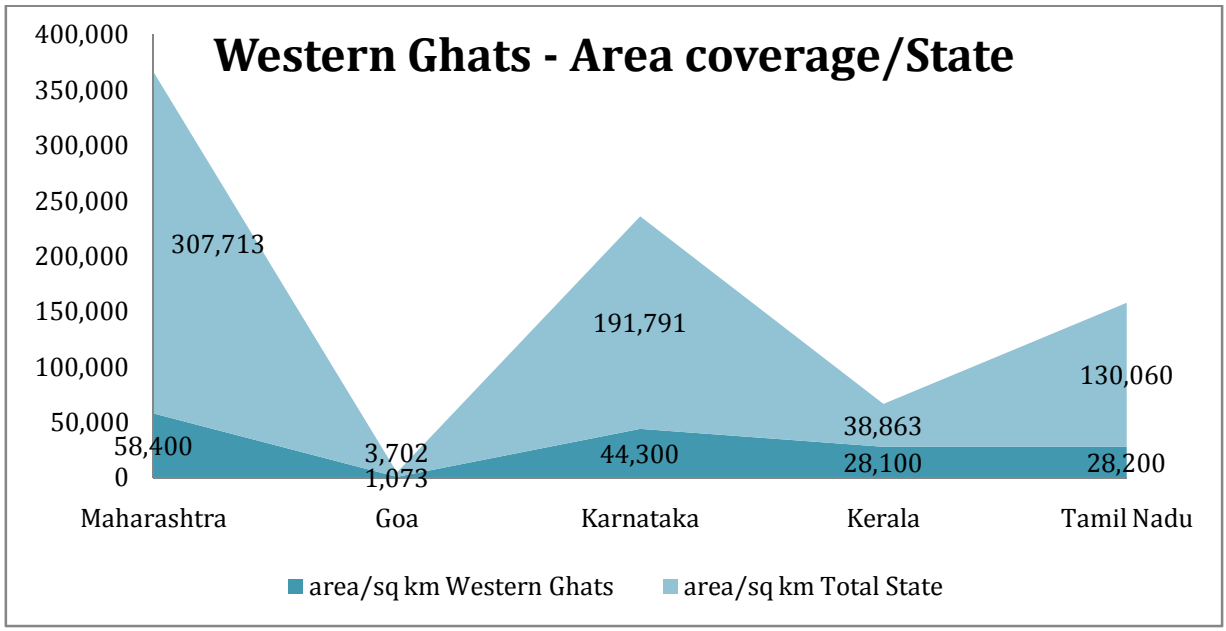


**Fig 1.** Area of Western Ghats covered in each state (area/sq km)

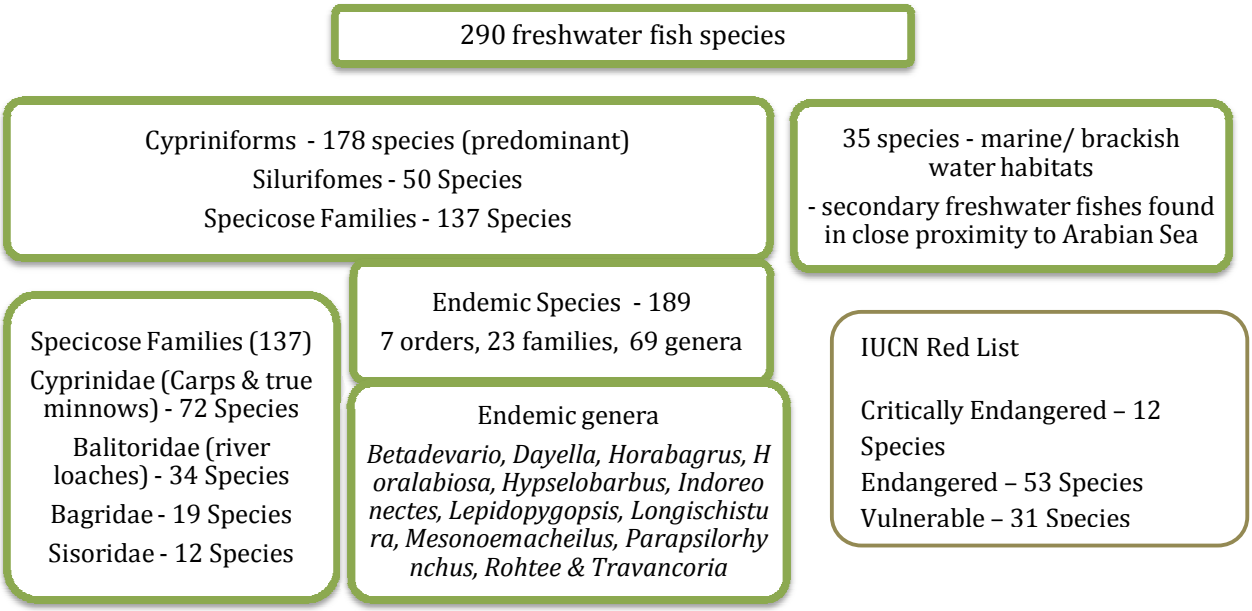


**Fig 2.** Ichthyofaunal Diversity – The Western Ghats

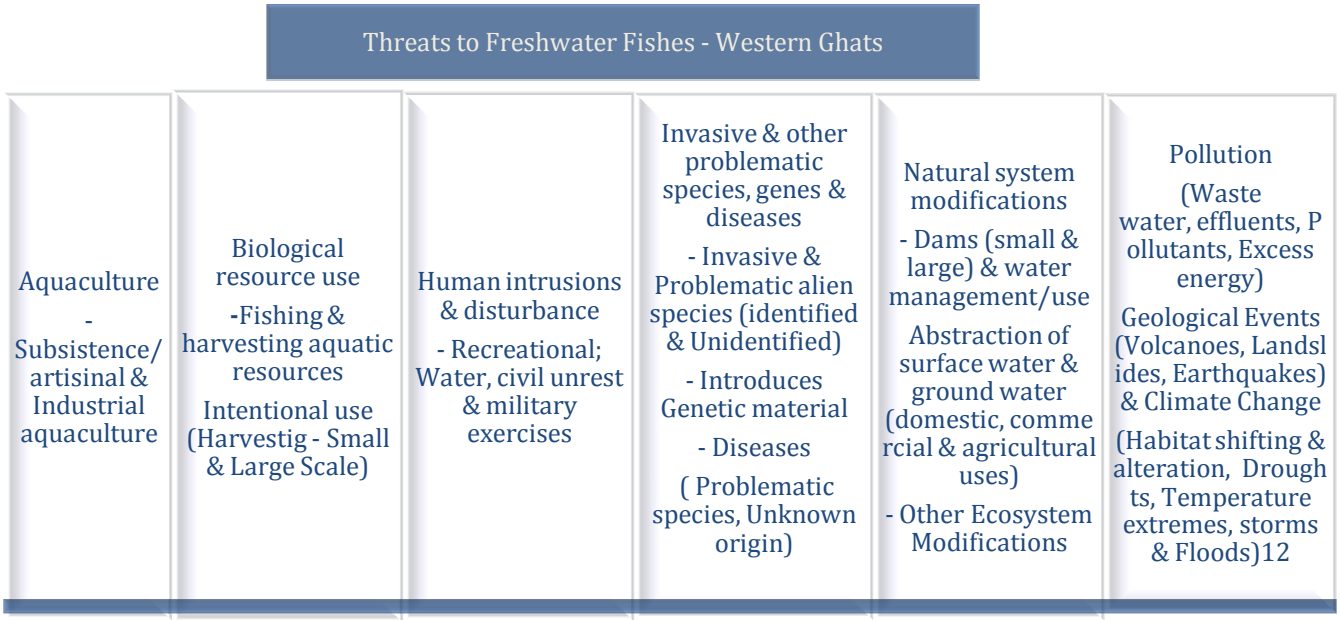


**Fig 3.** Threats Freshwater fishes – Western Ghats (IUCN)


**Fig 4.** Threats due to Pollution – Freshwater Fishes

***Effects of threats on the biodiversity of the Western Ghats***

Urbanization has led to intentional habitat alterations in the Western Ghats, resulting in significant impacts on its biodiversity (Byatt et al., 2018). Multiple studies suggest that downstream water systems are impacted, resulting in reduced surface flow due to water extraction for agricultural or drinking purposes, as well as pollution (Mohite & Samant, 2012; Paudel & States, 2023). This poses a significant threat to various localized species (Fig 3 & 4). The elimination of riparian vegetation and runoffs have severely impacted the spawning environment for fish species, leading to the formation of uniform sandy substrates due to the deposition of silt along stream beds (Alikhani et al., 2021). The modification of river flow due to sand mining and the disappearance of riffle habitats, as well as harmful fishing methods, have significant impacts on the microbial and invertebrate populations in freshwater ecosystems (Pankajakshan & Scaria, 2023).

Human actions, in conjunction with global climate change, have not only led to the depletion of fish populations, but have also resulted in the extinction of numerous fish species. The fish species *Hypselobarbus lithopidos*, which is native to the Western Ghats, was not observed in Kerala, Karnataka, and Tamil Nadu between 1950 and 2010 (Ponniah et al., 2000). The last known distribution of this species was documented between 1929 and 1941. It was found in the drainages of Trivandrum District, Periyar National Park and Tiger Reserve, and the Chaliyar River at Nilambur. The potential cause for the extinction of

this species is habitat alteration, while the specific factors remain unidentified (Arun et al., 2001).

The population of *Hypselobarbus mussullah*, a sought-after species for both recreational fishing and high-end culinary purposes, has been significantly fragmented as a result of intensive hunting. The fragmentation of this species in the Western Ghats, spanning from Maharashtra to Tamil Nadu, is primarily attributed to overfishing and dynamite fishing, which are prevalent due to the diverse range of habitats in the region. The *Hypselobarbus* genus has the greatest number of endangered fish species that are native to the Western Ghats (Pinder, 2020). Due to the greater prevalence of species in the southern sections of the Western Ghats, they are more susceptible to a diverse array of human and climate change impacts (Chitale et al., 2014; Pramanik et al., 2018; Shivanna, 2022). They are highly appreciated for their economic worth, both for consumption and the aquarium trade. There are only three species that may be found in the rivers of Maharashtra: *H. mussullah*, which is already extensively fragmented, as well as *H. jerdoni* and *H. kolus*. All three of these species are classified as endangered according to the IUCN Red list (Fig 5, 6 & 7) (Molur et al., 2011).

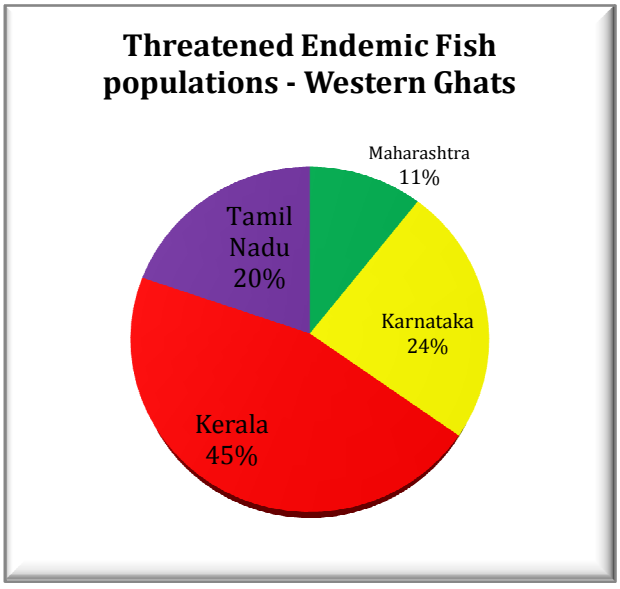


**Fig 5.** Endemic Freshwater Fishes of Western Ghats – Threatened fish population per state

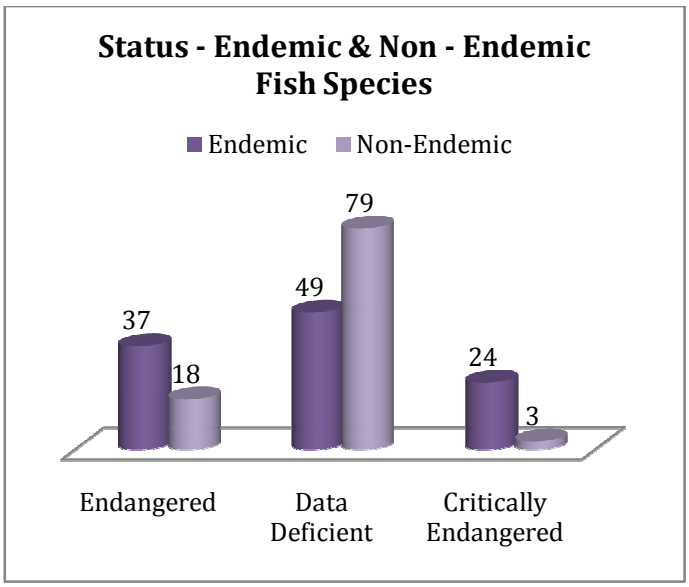


**Fig 6.** Non-Endemic Fish species status (IUCN)


**Fig 7.** Major Threats to Endemic Fishes – Western Ghats (a – aquaculture, b – Biological resource use, c- Human Intrusion, d – invasive species, e – Natural system modifications, f – pollution, g – Climate change)

### *Aquaculture and Fisheries*

The fish species *Hypselobarbus curmuca*, much sought after for the aquarium trade, were found in large numbers in the reservoirs of Manampuzha. However, its population is experiencing a decline of over 50% as a result of detrimental practices such as dynamite fishing and poisoning, as well as habitat degradation and fragmentation caused by sand-mining and dams (Raghavan et al., 2013). *Rohtee ogilbii*, often known as *Osteobrama neilli*, is an aquarium fish that is being exported, leading to a decline in the population of this species in the

Krishna and Godavari rivers (Ponniah et al., 2000). *Batasio travancoria*, which resides in the rivers of Coorg district, Pamba, Achenkoil, Periyar, Chalakudy, Manimala, and Neyyar rivers, is heavily exploited for the purpose of the aquarium trade. Fingerlings of the *Horabagrus brachysoma* and *H. nigricollaris* species are captured and sent overseas for the international aquarium trade (Ajithkumar et al., 1999). These fish are highly valued for their delicious taste and are in great demand in Central Kerala. They are extensively harvested and typically sold alive.

The populations of *Hypselobarbus curmuca, Hypselobarbus dobsoni,* and *Hypselobarbus jerdoni* have decreased by more than 50% due to overfishing (Raghavan, 2019). According to sources, the population of *H. dubius*, which accounted for 55% of the landings from Amaravathy reservoir in Tamil Nadu during 1965-1966, decreased significantly to less than 2% after a decade and eventually vanished from the captures (Joseph Antony Reneese et al., 2018). The hourly catch *of H. dubius* in the Kabini river system is reported to be rather low at Baveli, Noolpuzha, and Vythiri. The population of *H. micropogon*, a significant game fish, is rapidly decreasing in the Kabini river and adjacent river system habitats due to overexploitation, leading to a significant decline in its availability as a food source and an increase in its market value (Thampy et al., 2021a). *Batasio travancoria* and *Travancoria elongata* are endangered as a result of excessive fishing activities in the Chalakkudy and Periyar rivers, as well as the Anamalai Hills. The populations of *Puntius denisonii* and *P. chalakkudiensis* have decreased by approximately 70% due to excessive exploitation for the aquarium trade (Ali et al., 2103).

### *Utilization of Biological Resources*

The combination of deforestation and recreational activities on the mountain causes siltation and degrades the habitat necessary for the reproduction of *Parapsilorhynchus discophorus*, thereby endangering their survival (Baliarsingh et al., 2017). Deforestation and recreational activities, particularly on the mountain tops, have a detrimental impact on the hill stream habitats of *Parapsilorhynchus tentaculatus* in the northern Western Ghats (Gadgil, 1979). Similarly, deforestation and tourism in the Eastern Ghats also pose a threat to these habitats. *Horalabiosa palaniensis* is a species found in the southern Western Ghats in the state of Tamil Nadu (Arunkumar & Manimekalan, 2018). It is specifically known to inhabit the Palani hills. The species is at risk due to activities and the promotion of tourism in this area.

*Horabagrus nigricollaris*, a highly prized edible fish, is facing the threat of extinction due to destructive fishing techniques such as dynamite poisoning in the Periyar and Chalakudy rivers (Raghavan, 2019). The projected hydroelectric power plant in Periyar lake poses a growing threat. The species *Horalabiosa joshuai* is at risk because to the destruction and deterioration of its habitat caused by tea plantations, tourism, water extraction, plantation runoff, encroachment, and potential impacts of climate change (Baruah & Handique, 2021). Potential future hazards to the species include the consequences of decreased precipitation, which may harm the perennial streams where the species is found.

### *Exotic species invaded*

More than 13 non-native species, including *Cyprinus carpio, Oreochromis mykiss, O. mossambicus,* and *Gambusia affinis*, which are all listed in the global database of the most harmful invasive alien species, have entered the waters of the Western Ghats (Bertaco & Azevedo, 2023; A. K. Singh et al., 2017; Thapa et al., 2014). This invasion poses a significant risk to the diversity of endemic fish species in the region. The species *C. carpio, Labeo mrigala, Catla catla, Clarias gariepinus,* and *O. mossambica* have caused the decline of the *Hypselobarbus curmuca* and *H. periyarensis* populations in Periyar lake (Lakra et al., 2010). The introduction of non-native species by the fisheries department into reservoirs has posed a threat to *Hypselobarbus kurali*, a bottom-dwelling fish species that mostly feeds on algae and

searches for macroinvertebrates (Gadgil, 1979). *C. gariepinus* has also infiltrated the population of *Glyptothorax poonaensis* in the Indrayani River.

The population status of *Lepidopygopsis typus* is being threatened by intense competition from *C. carpio* (Maiztegui et al., 2019). Furthermore, *Poecilia reticulata* and *G. affinis* are engaged in a competition with the indigenous fish species *Aplocheilus lineatus* for limited resources in the Mula – Mutha river (Kharat et al., 2003). *Mesonoemacheilus pambarensis*, a species found in the Pambar river within the Chinnar Wildlife Sanctuary in Kerala (Arunkumar & Manimekalan, 2018), India, is potentially at risk of extinction due to the introduction of Tilapia, an invasive fish species, and *O. Mossambicus* (Raghavan, 2019). The presence of alien invasive species, including *O. mossambicus, C. gariepinus,* and *C. carpio*, poses a potential risk to the endemic fish species *Nemacheilus menoni*, which inhabit the Mullayar and Periyar rivers (Sreekanth et al., 2022). The presence of introduced fishes, specifically *O. mossambicus*, has posed a threat to the population of *Parapsilorhynchus prateri* in the upper Godavari river basin (Ujjania et al., 2020), as their numbers have been steadily increasing. However, the potential consequences of the introduction of alien fish species on the survival of indigenous fish species could be highly detrimental in the future.

***Alterations to the natural system***

The construction of dams, which impede fish movement and modify river flow patterns, has had a negative impact on the populations of *Anguilla bicolor* and *Glyptothorax* species, respectively. The species *Hypselobarbus periyarensis* is under a threat due to the construction of a dam in Periyar lake (S Molur et al., 2011). There are more than 53 dams constructed along the rivers in the southern region of the Western Ghats. These dams pose a threat to the native fish species in the area since they create circumstances similar to a lake. Experts have forecasted that the projected Athirapally dam project will have a devastating effect on the *Horabagrus nigricollaris* and *Travancoria elongate* species (Latha & Vasudeva, 2016). The projected hydroelectric power plant poses a hazard to *H. nigricollaris* in Chalakudy River (Baird & Hogan, 2023).

*Horabagrus brachysoma, Hypselobarbus curmuca, H.dosboni, H.dubius, and H.thomassi; Glyptothorax poonaensis* and *Nemacheilus petrubanarescui* (found in the Nethravathi river) are at risk due to sand mining and land reclamation activities inside their river habitats, which are causing changes to their breeding grounds (Padmakumar et al., 2011). *Horalabiosa joshuai* is at risk because to the destruction and deterioration of its habitat caused by tea plantations, tourism, water extraction, plantation runoff, encroachment, and potential impacts of climate change (Ali et al., 2103). The activities conducted in the Palnai hills and the promotions of tourism have the potential to pose risks to *Horalabiosa palaniensis*. The species of *Hypselobarbus curmuca, H. dubius, H. jerdoni, H. kolus, H. kurali, Lepidopygopsis typus,* and *Mesonoemacheilus herrei* have been negatively impacted by habitat destruction and fragmentation caused by siltation, urbanization, presence of dams, and deforestation (Ponniah et al., 2000).

The species *Longischistura striatus* is impacted by changes in its habitat caused by the elimination of forest canopy, resulting in the loss of river systems due to excessive sedimentation. The rate of deforestation is occurring at a concerning pace, resulting in the rapid depletion of forest covers, particularly at hilltops (Kumari et al., 2019). This has a detrimental impact on the populations of hill stream species, such as *Parapsilorhynchus* and *Nemacheilu*.

***River contamination caused by harmful substances or activities***

The river systems on our continent suffer from severe pollution caused by industrial waste, home sewage, and pesticides, resulting in some of the most damaged water bodies in the world (Uddin & Jeong, 2021). The lack of adequate waste management strategies for industrial waste and its direct release into rivers and streams have devastating consequences on the fish populations

in India (Arumugam et al., 2021; Arumugam & Ramaiah, 2018; Mohan et al., 2018). Industrial contamination has resulted in increased fish mortality. *Schismatorhynchos nukta, Osteobrama bakeri, Rohtee ogilbii,* and *Hypselobarbus dubius* (significant food fish) are affected by multiple stressors, including pollution from domestic, agricultural, and industrial sources in the upper regions of the Krishna and Godavari river systems (Ramakrishna & Alfred, 2007), as well as the Bhima and Tungabhadra river system. The primary hazards to *H. micropogon* in the Kabini river system are overexploitation, detrimental fishing methods using dynamite and poisoning, as well as pollution (Thampy et al., 2021b). It is therefore plausible to assume that this species faces similar dangers in the other river systems where it has been observed. *Indoreonectes evezardi, Labeo boggut,* and *Proeutropiichthys taakree* under a threat from both organic and inorganic pollution in the Mula-Mutha river. The primary factor contributing to the decline of *Longischistura striatus* is pollution resulting from pesticide contamination (Molur et al., 2011). The discharge of pesticides from tea, coffee, and rubber plantations, as well as the dumping of acidic waste from rubber companies, into the water systems of the Western Ghats has resulted in increased fish mortality rates and reduced fish biodiversity (Molur et al., 2011).

### *Climate crisis*

*Horalabosa joshuai* is in risk due to the impacts of climate change. Potential future hazards to the species include the consequences of decreased precipitation, which may harm the perennial streams where the species is found. *Hypselobarbus dobsoni*, a species inhabiting the river basins of Krishna, Kali, Tamiraparani, and Kabini, is facing threats as a result of human activities (Johnson & Arunachalam, 2009). The species richness of 98 in this case surpasses that of several major river systems in Asia, such as the Irrawady (79 species), Narmada (77 species), and the Sepik (55 species) (Taxi, 1975). The Chalakudy river is currently facing significant risks from numerous human activities, and the survival of its diverse species is severely *H. dubious*.

### *Conservation measures*

In addition to the elevated prevalence and risk levels of fish species in the Western Ghats, there are still more unidentified species awaiting discovery (Raja et al., 2014). The lack of data has greatly hindered the ability to develop and execute an effective conservation strategy. The prioritization of ecosystem services such as hydroelectric power, water, and irrigation over the ichthyofauna in this region has resulted in the management and conservation of freshwater fishes being considered of least concern (Prasad et al., 2009; Singh et al., 2010; Strayer & Dudgeon, 2010). Conservation strategies such as riparian reforestation, dam management to facilitate fish passages and reduce disruption to river flows, regulation of sand mining, effective treatment of pollution from human activities through waste treatment plans and legislation on industrial effluents, agricultural and municipal runoffs, captive breeding, control of invasive species, live gene banking, and ranching should be implemented to improve the ecology of the Western Ghats and promote human well-being.

## Conclusion

The Western Ghats' biological niche is currently under threat, highlighting the fact that even little changes to the higher sections of the waterways caused by human activities or erosion in overgrazed areas can significantly impact species and could lead to their extinction. Despite being one of the eight global hotspots, there has been a lack of substantial scientific contribution to the development and execution of legislation and initiatives aimed at conserving the biodiversity of the Western Ghats. Human activities that are not wise have greatly increased the detrimental effects on the variety of plants and animals worldwide. The lack of data regarding numerous uncharted areas of the Western Ghats has highlighted the necessity for thorough research to identify new species and reassess the classification of existing

species. The effectiveness of implementing various programs relies heavily on the shift in individuals' mindset towards self-realization and embracing the concept of "living in harmony with nature".

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**Conflict of interest**

All authors declare that there is no conflict of interest in this work.

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