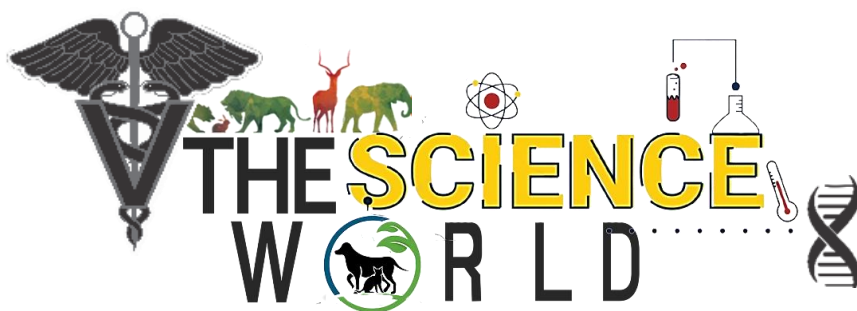




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Popular article

Botiid Loaches of India: Biology, Ecology, Threats, and Sustainable Management towards their Conservation

Paramita Banerjee Sawant^{1*}, Vikas Kumar Ujjania¹, Gouranga Biswas² and Debajit Sarma¹,

¹Division of Aquaculture, ICAR-Central Institute of Fisheries Education, Mumbai, Maharashtra- 400061, India

²ICAR- Central Institute of Fisheries Education, Kolkata Centre, Kolkata, West Bengal- 700091, India

Corresponding author: paramitabanerjee1006@gmail.com
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Abstract

Indian botiid loaches (Family: Botiidae) are ecologically important benthic freshwater fishes that contribute to river ecosystem functioning and support India's ornamental fish trade. Several species, particularly the endemic *Botia striata*, are increasingly threatened by habitat degradation, hydrological alterations, pollution, overexploitation, and climate change. This article reviews the taxonomy, diversity, distribution, habitat ecology, life-history traits, reproductive biology, feeding ecology, socio-economic importance, and conservation of Indian botiid loaches. Their dependence on clean, fast-flowing rivers with rocky substrates and seasonal hydrological cycles makes them highly vulnerable to anthropogenic disturbances. Although the ornamental fish trade provides valuable livelihood opportunities, continued reliance on wild-caught populations raises concerns about long-term sustainability. Conserving these fishes requires an integrated approach involving habitat protection, environmental flow management, captive breeding, sustainable harvest, community participation, and science-based trade regulation. Continued research on population biology, genetics, and captive propagation will strengthen conservation efforts and support the sustainable management of India's unique freshwater loach diversity.

Keywords: Botiidae; Conservation; Freshwater biodiversity; Habitat ecology; Ornamental fish trade; Sustainable management; Western Ghats

Introduction

Freshwater ecosystems occupy less than one percent of the Earth's surface yet harbour nearly half of all known fish species, making them among the most biodiverse aquatic environments on Earth. These ecosystems provide essential ecological services, including nutrient cycling, food-web regulation, and the maintenance of aquatic biodiversity. However, increasing anthropogenic pressures such as dam construction, pollution, habitat degradation,



overexploitation, invasive species, and climate change have accelerated the decline of freshwater habitats and fish populations worldwide.

The family Botiidae (Order: Cypriniformes) comprises a distinctive group of benthic freshwater loaches distributed across South and Southeast Asia. These fishes are characterized by elongated bodies, four pairs of barbels, defensive suborbital spines, and striking colour patterns. Adapted to clear, well-oxygenated, fast-flowing rivers with rocky and gravel substrates, botiid loaches feed primarily on benthic invertebrates, molluscs, worms, and other small aquatic organisms, thereby contributing to the ecological functioning of riverine ecosystems.

India represents an important centre of botiid loach diversity, particularly within the Western Ghats and the Himalayan river systems. Species including *Botia striata*, *B. almorhae*, *B. rostrata*, *B. dario*, and *B. histrionica* contribute significantly to the country's freshwater biodiversity and ornamental fish trade. Among these, the zebra loach (*Botia striata*) is of particular conservation concern because of its restricted distribution in the northern Western Ghats, specialized habitat requirements, and increasing exploitation for the aquarium trade. These factors, together with habitat degradation and hydrological alterations, have heightened the vulnerability of natural populations.

Despite considerable progress in the taxonomy, ecology, reproductive biology, genetics, and conservation of Indian botiid loaches, important knowledge gaps remain regarding population status, captive propagation, and sustainable management. Integrating current knowledge on their diversity, distribution, biology, ecology, socio-economic importance, threats, and conservation is essential for supporting evidence-based management, strengthening conservation initiatives, and promoting the sustainable utilization of India's unique freshwater loach diversity, particularly the endemic and endangered *Botia striata*.

Diversity, Taxonomy, and Systematic Position of Indian Botiid Loaches

Botiid loaches are a distinctive group of benthic freshwater fishes belonging to the family Botiidae under the order Cypriniformes. Distributed primarily across South and Southeast Asia, they were formerly classified within the family Cobitidae but are now recognized as a separate evolutionary lineage based on



morphological and molecular evidence. Advances in systematic studies have improved our understanding of their taxonomy, phylogenetic relationships, and geographical distribution.

The family Botiidae comprises several genera, including *Botia*, *Sinibotia*, *Yasuhikotakia*, *Chromobotia*, *Syncrossus*, *Ambastaia*, and *Leptobotia*. Members of this family are characterized by an elongated body, four pairs of barbels, a ventrally positioned mouth, defensive suborbital spines, and distinctive colour patterns of bands and markings. These morphological adaptations enable them to thrive in rocky, fast-flowing freshwater habitats and efficiently exploit benthic food resources.

India represents an important centre of botiid diversity, particularly within the Western Ghats and Himalayan river systems. Species such as *Botia striata*, *B. histrionica*, *B. rostrata*, *B. almorhae*, *B. dario*, and *B. lohachata* occur in Indian waters. Among these, the zebra loach (*Botia striata*) is of particular conservation concern because of its restricted distribution in the Western Ghats and increasing pressure from habitat degradation and ornamental fish collection. Accurate species identification can be challenging due to similarities in external morphology and colour variation; therefore, integrating conventional taxonomy with DNA barcoding and cytogenetic approaches is important for reliable species identification and biodiversity assessment.

A sound understanding of the taxonomy and systematic relationships of Indian botiid loaches provides the foundation for biodiversity assessment, conservation planning, sustainable ornamental fish trade management, and the protection of endemic species. Continued taxonomic and molecular studies will further improve species identification and support evidence-based conservation and management programmes.

Distribution, Habitat Ecology, and Environmental Requirements of Indian Botiid Loaches

Indian botiid loaches are distributed primarily in the Western Ghats and the Himalayan–Indo-Gangetic river systems, where they inhabit clear, well-oxygenated, fast-flowing streams with rocky and gravel substrates. The endemic zebra loach (*Botia striata*) is largely confined to tributaries of the Krishna River basin in Maharashtra and northern Karnataka, while species such as *Botia almorhae*, *B. rostrata*, and *B. histrionica* occur in the Ganga, Brahmaputra, and Barak river systems. Their distribution reflects the availability of suitable habitat, water quality, and seasonal hydrological conditions.



These benthic fishes depend on structurally complex habitats with abundant benthic fauna that provide food, shelter, and breeding sites. Seasonal fluctuations in river flow influence habitat use, feeding activity, and reproduction, with juveniles generally occupying shallow marginal areas and adults inhabiting deeper riffle–pool habitats. However, habitat fragmentation caused by dam construction, sand mining, pollution, urbanization, and river modification has reduced habitat quality and connectivity, particularly for range-restricted species such as *B. striata*. Maintaining natural river habitats, environmental flows, and riparian vegetation is therefore essential for sustaining wild populations and preserving the ecological integrity of freshwater ecosystems.

Life-History Traits and Population Biology of Indian Botiid Loaches

Life-history traits strongly influence the survival, population dynamics, and conservation of Indian botiid loaches. Species such as the zebra loach (*Botia striata*) exhibit moderate growth, seasonal reproduction, habitat specialization, and limited dispersal ability. Growth is influenced by environmental factors including temperature, food availability, and habitat quality, with rapid growth during early life stages followed by a gradual decline as individuals approach maturity. Reproductive activity is closely synchronized with seasonal hydrological changes, particularly the monsoon, while successful spawning, larval survival, juvenile recruitment, and the availability of suitable habitats collectively determine population stability. Healthy populations typically comprise multiple size classes, indicating continuous recruitment, whereas disturbed habitats often exhibit reduced numbers of larger breeding individuals.

Population persistence depends on habitat quality, food availability, and environmental stability. However, pollution, river modification, dam construction, sand mining, and unsustainable collection for the ornamental fish trade have increasingly affected wild populations, especially habitat-specialized species such as *B. striata*. Protecting breeding and nursery habitats, maintaining environmental flows, monitoring wild populations, and promoting sustainable management practices are therefore essential for conserving Indian botiid loaches and ensuring their long-term survival.

Reproductive Biology and Breeding Ecology of Indian Botiid Loaches

The reproductive biology of Indian botiid loaches is closely linked to seasonal changes in river ecosystems, particularly the monsoon, when increased water flow, favourable temperature, high dissolved oxygen, and abundant food promote spawning and early life-stage development. Species such as the zebra loach (*Botia striata*) are seasonal spawners that produce



numerous small eggs, with successful recruitment depending largely on suitable habitat conditions and environmental stability. Their reproductive cycle comprises gonadal maturation, spawning, and larval development, all of which are strongly influenced by seasonal hydrological patterns. Habitat degradation, pollution, and alteration of natural river flows can adversely affect spawning success, egg survival, and recruitment. Although captive breeding protocols have been developed for several ornamental fishes, a standardized breeding protocol for *B. striata* is still lacking. Further studies on reproductive biology, induced breeding, and environmental spawning cues are needed to support captive propagation and reduce pressure on wild populations.

Feeding Ecology and Trophic Role of Indian Botiid Loaches

Indian botiid loaches, including the zebra loach (*Botia striata*), are primarily benthic carni-omnivorous fishes that feed on insect larvae, small crustaceans, molluscs, worms, and occasionally algae, detritus, and other organic matter. Their diet varies with season, ontogenetic stage, and food availability, reflecting changes in environmental conditions and reproductive requirements. By exploiting diverse benthic food resources, these fishes occupy an important intermediate trophic position in freshwater food webs.

As active benthic foragers, botiid loaches regulate populations of aquatic macroinvertebrates, facilitate nutrient recycling through the breakdown of organic matter, and contribute to energy transfer between lower and higher trophic levels. Their feeding behaviour also influences benthic community structure and ecosystem functioning. Because their diet responds to changes in habitat quality and prey availability, feeding ecology can serve as a useful indicator of river health and ecological integrity. Understanding the trophic ecology of Indian botiid loaches is therefore important for assessing ecosystem condition, predicting the impacts of environmental change, and developing effective conservation and management strategies.

Threats to Indian Botiid Loaches: Anthropogenic Pressures and Environmental Change

Indian botiid loaches, including the endangered zebra loach (*Botia striata*), are increasingly threatened by habitat degradation, overexploitation, and environmental changes. As bottom-dwelling fishes dependent on clean, fast-flowing streams with rocky substrates, they are highly vulnerable to river modification, dam construction, sand mining, and altered flow regimes that reduce shelter, breeding habitats, and food availability. Pollution from agricultural runoff, industrial discharge, and domestic waste further deteriorates water quality and disrupts aquatic biodiversity. Additionally, unregulated collection for the ornamental fish trade,



particularly the harvesting of wild adults, places significant pressure on natural populations. Climate change, through changes in rainfall patterns, rising temperatures, and reduced stream flow, along with invasive species, may further intensify these pressures. The combined effects of these threats accelerate population decline and increase the risk of local extinction. Effective conservation of Indian botiid loaches requires habitat protection and restoration, sustainable river management, pollution control, regulation of ornamental fish exploitation, and development of captive breeding programmes to reduce dependence on wild populations.

Ornamental Fish Trade and Socio-Economic Importance of Indian Botiid Loaches

Indian botiid loaches, including the zebra loach (*Botia striata*), yo-yo loach (*Botia almorhae*), and Burmese border loach (*Botia histrionica*), are highly valued in the ornamental fish industry due to their distinctive colour patterns, active behaviour, and suitability for aquarium keeping. Their commercial demand in domestic and international markets contributes to India's ornamental fisheries sector by generating income opportunities for fish collectors, traders, breeders, and rural communities associated with aquarium fish enterprises. However, the dependence on wild-collected stocks highlights the need for scientific management and sustainable utilization strategies to ensure long-term availability of these valuable species. Captive breeding and seed production technologies provide promising opportunities to develop a sustainable supply chain while reducing pressure on natural populations. The advancement of breeding protocols, larval rearing methods, and culture practices can support commercial production of native botiid loaches and create new livelihood opportunities. Integration of scientific stock assessment, responsible trade practices, farmer participation, and market regulation will be essential to promote sustainable ornamental fisheries. Such approaches can enhance the economic value of Indian botiid loaches while contributing to the conservation and responsible utilization of native freshwater fish resources.

Conservation Strategies for Indian Botiid Loaches

Effective conservation of Indian botiid loaches requires a coordinated framework based on scientific research, policy support, and stakeholder involvement. Priority should be given to developing species-specific conservation plans, including regular population assessments, genetic studies, and long-term monitoring programmes to understand population trends and conservation status. Standardized protocols for captive breeding, broodstock management, and restocking programmes



should be developed to support population enhancement and sustainable ornamental fish production. Strengthening collaboration among research institutions, government agencies, conservation organizations, and local communities will be essential for implementing practical conservation measures. Awareness programmes and capacity-building initiatives should be promoted among fish collectors, traders, and aquarium hobbyists to encourage responsible practices. In addition, improved documentation of wild populations, development of conservation databases, and enforcement of science-based management policies will help ensure the long-term survival of endemic botiid loaches, including *Botia striata*, while supporting their sustainable utilization.

Conclusion

Indian botiid loaches are valuable components of freshwater biodiversity, contributing to ecosystem functioning and the ornamental fish sector. However, their specialized habitat requirements, restricted distribution, and dependence on riverine ecosystems make them vulnerable to environmental changes and human pressures. *Botia striata* represents the conservation concerns faced by endemic freshwater fishes of the Western Ghats. The conservation of Indian botiid loaches requires integrated efforts involving scientific monitoring, habitat management, sustainable ornamental fish practices, and development of captive breeding technologies. Continued research on population biology, genetics, reproduction, and conservation aquaculture will support evidence-based strategies for their long-term protection and sustainable utilization.

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