Environment and Ecology 44 (2) : 274—282, April—June 2026
Article DOI: https://doi.org/10.60151/envec/PADM5483
ISSN: 0970-0420 (Print), ISSN: 3049-3625 (Online)

Role of Bao Rice Agro-Wetlands in Supporting Fish Populations, Breeding and Habitat-Adaptive Fishing Practices in Lakhimpur District, Assam, India

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Received 7 February 2026, Accepted 13 April 2026, Published on 27 April 2026

ABSTRACT

The present study evaluates the ecological characteristics of bao rice (deep-water rice) fields and assesses their role as breeding, feeding and refuge habitats for indigenous fish species. Seasonal fish sampling was conducted during pre-monsoon, monsoon, and extended post-monsoon periods using traditional fishing gears, along with dewatering catch after harvest. A total of 30 indigenous fish species, including several ornamental fishes, representing 16 families and 8 orders were recorded. This study provides the first evidence of seasonal fish abundance patterns in bao-rice fields, where the continuous presence of larvae and juveniles suggests their importance as *in-situ* breeding and nursery habitats. Prolonged inundation enables these agro-wetlands to function as conservation wetlands and human-supported natural fish gene banks. The findings highlight the ecological importance of bao rice fields in sustaining fish diversity and their socio-economic significance for communities dependent on traditional fisheries. The study emphasizes the need for targeted conservation and sustainable management of deep-water rice ecosystems to support biodiversity conservation and rural livelihood security.

Keywords Adaptive fishing, Deep-water rice, Indigenous fish, Nursery habitat, Refuge habitats, Seasonal fish diversity.

INTRODUCTION

Traditional rice-based agro-ecosystems are increasingly recognized as integral components of wetland biodiversity conservation, inland fisheries production and rural livelihood security (Mandal *et al.* 2024, Luo *et al.* 2025). In Assam, bao rice (deep-water rice) is traditionally cultivated in low-lying, flood-prone areas of the Brahmaputra floodplain, where fields remain inundated for about six to nine months each year depending on rainfall and river flooding (Singha and Singh 2022). During peak monsoon, water depth commonly exceeds 50 cm, and in certain pockets may reach even higher levels, thereby transforming agricultural fields into semi-permanent aquatic habitats (Rohilla *et al.* 2019). Bao rice fields have a unique ecological setting characterized by tall, dense rice stems, slow or stagnant water, buildup of organic

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detritus, and generally low use of agro-chemicals, which enhance primary and secondary productivity by encouraging the growth of phytoplankton, periphyton, and benthic macroinvertebrates (Mohanty *et al.* 2010). In addition, the breakdown of rice biomass releases nutrients into the water, helping to maintain complex food webs that can support diverse fish communities throughout the flood period (Freed *et al.* 2020a). Rice fields have long been recognized as alternative habitats for fish feeding, breeding and refuge, particularly in floodplain regions where seasonal hydrological connectivity allows fish migration between rivers, wetlands and agricultural landscapes (Chakraborty 2021, Paulino *et al.* 2025). In bao-rice systems, seed sowing is usually carried out in early April during the mid pre-monsoon period. Germination begins with the onset of the first rains, and the fields gradually become inundated through rainfall accumulation rather than artificial irrigation. This natural inundation establishes aquatic conditions well before peak monsoon flooding. With the progression of the monsoon, floodwaters from adjoining rivers and channels spread into these low-lying fields, allowing fishes to enter and colonize the system (Debnath and Yengkokpam 2024). The prolonged inundation and dense rice vegetation provide abundant food and shelter, enabling fishes to remain in bao-rice fields for extended periods and supporting spawning, larval development, and juvenile growth, thus functioning as *in-situ* breeding and nursery habitats rather than only temporary feeding grounds (Freed *et al.* 2020b). Despite these ecological attributes, systematic seasonal documentation of fish diversity, abundance patterns, habitat utilization and use of adaptive fishing gears in bao-rice ecosystems of Assam remains limited. The present study was therefore undertaken to describe the ecological characteristics of bao-rice fields, document seasonal fish diversity and abundance, evaluate their role as breeding, feeding and refuge habitats, and record indigenous fish species harvested through traditional fishing practices in the bao-rice fields of Lakhimpur district, Assam.

MATERIALS AND METHODS

Study area and sampling design

The study was conducted in selected bao-rice (deep-water rice) fields covering an area of approximately 3.1 hectares (about 23 bighas) located at Mohaijan (27°14′58.5″ N, 94°08′36.8″ E) in Lakhimpur district, Assam. The study area is characterized by low-lying terrain and seasonal hydrological connectivity with the floodplains of the Subansiri River. During the monsoon, floodwaters from the river and associated channels enter the rice fields, while during the post-monsoon and winter periods, water gradually recedes and remains confined to residual pools, trenches and ponds within the fields. Fish sampling was carried out during three distinct seasonal phases: pre-monsoon (March–May), monsoon (June–September) and extended post-monsoon (October–December). These seasons correspond to major hydrological phases of the floodplain system and rice cultivation cycle. Sampling design and seasonal classification followed established protocols used in rice-field and floodplain fisheries studies (Halwart *et al.* 1996, Kaller *et al.* 2013).

Fishing gears and collection procedure

Fish sampling was conducted with the active participation of local fishermen and the owner of the bao-rice fields, ensuring that traditional knowledge and locally prevalent fishing techniques were adequately represented. A variety of fishing gears were employed to capture fishes occupying different microhabitats and exhibiting varied behavioral traits. Gill nets were set in open water pockets and along field margins, while cast nets were operated in limited open patches within the rice fields. Juluki, a hand-operated bamboo scoop device, was used in shallow areas with sparse vegetation. A ball-shaped bait prepared from rice bran and cowdung was placed underwater for about 30 minutes before juluki operation to attract fishes. Dingara, a cylindrical bamboo pipe traps, was deployed overnight between rice clumps and narrow channels, either with or without bait. Hook fishing was practiced in multiple forms. Individual hooks of varying sizes were tied with short nylon ropes (1.5–2 ft) to small floating sticks (locally called Nal borokhi) and baited overnight to target carnivorous fishes (Islam *et al.* 2013, Kihia *et al.* 2018). Actively operated bamboo fishing rods with sinkers and floaters, locally known as chip borokhi, were also used. At selected locations, long bamboo handles fitted with nylon thread, without sinker or float, and baited with live small toads were employed to capture *Channa spp.* (Baruah *et al.* 2018). After rice harvest during November–December, residual water accumulated in low-lying areas and ponds was pumped out to collect the assembled fishes; this locally practiced farmer-based technique, referred to as dewatering catch, and was treated as a separate sampling method in the analysis. Captured fishes were temporarily kept in aerated containers and identified up to species level using standard taxonomic literature (Hora and Mukerji 1934, Talwar and Jhingran 1991, Jayaram 2010). Identified species were enumerated and analysed season-wise.

RESULTS

Species composition

A total of 30 indigenous fish species belonging to 16 families and 8 orders were recorded, representing the first detailed seasonal documentation of fish assemblages from bao rice fields of the study area. Cypriniformes showed the highest species richness, dominated by the family Cyprinidae, including *Puntius sophore*, *P. ticto*, *Amblypharyngodon mola*, *Esomus danricus*, *Brachydanio rerio*, *Chela laubuca*, *Salmostoma bacaila*, and *Labeo calbasu*. *Anabantiformes* was represented by the families Anabantidae, Osphronemidae, Channidae and Nandidae, comprising nutritionally and ornamentally important species such as *Anabas testudineus*, *Trichogaster fasciata*, *Colisa lalia*, *Channa spp*., and *Nandus nandus*. Siluriformes included three families—Clariidae, Heteropneustidae, and Bagridae—represented by protein-rich species such as *Clarias magur*, *Heteropneustes fossilis*, *Mystus vittatus*, and *M. cavasius.* Overall, Cypriniformes and Anabantiformes were dominant across all seasons.

Feeding guild composition

Of the 30 species, 15 species were primarily carnivorous. *Esomus danricus* showed a carnivorous–omnivorous feeding habit, indicating dietary flexibility. Nine species were omnivorous, exploiting a wide range of food resources, while four species were herbivorous, feeding mainly on phytoplankton and periphyton. *Labeo calbasu* was classified as herbivorous–detritivorous (Table 1).

Seasonal variation and gear efficiency

During the premonsoon season, overall fish abundance and species richness with 26 species was comparatively lower. Small indigenous fishes such as *Puntius sophore*, *Amblypharyngodon mola*, *Gudusia chapra, Esomus danricus* and *Brachydanio rerio* dominated the catches (Table 2). In the monsoon season, fish abundance increased substantially. This season represented with 29 species exhibited the highest diversity and abundance of small and medium-sized fishes, particularly cyprinids . Species such as *Puntius sophore, Anabas testudineus, Channa punctata* and *Clarias magur* showed a pronounced increase during this period (Table 3). The extended post-monsoon season, including the dewatering period after rice harvest, recorded the maximum total abundance (Table 4). This season was represented by 30 fish species, with the catch dominated by *Hetero-*

Table 1. Feeding guild classification of fish species recorded from Mohaijan bao rice field.

Feeding guild	Species
Carnivorous (15 spp.)	*Notopterus notopterus, Lepidocephalichthys guntea, Clarias magur, Heteropneustes fossilis, Xenentodon cancila, Channa punctata, C. gachua, C. striata, C. marulius, C. stewartii, Nandus nandus, Macrognathus aral, Amphipnous cuchia, Glossogobius giuris, Chanda nama*
Carnivorous–omnivorous (1 sp.)	*Esomus danricus*
Omnivorous (9 spp.)	*Brachydanio rerio, Chela laubuca, Salmostoma bacaila, Botia dario, Mystus vittatus, Mystus cavasius, Anabas testudineus, Trichogaster fasciata, Colisa lalia*
Herbivorous (4 spp.)	*Gudusia chapra, Puntius sophore, P. ticto, Amblypharyngodon mola*
Herbivorous–detritivorous (1 sp.)	*Labeo calbasu*

Table 2. Fish species recorded from Mohaijan bao rice field during the pre-monsoon season. (March-May) using different fishing gears.

Fish species	Gill net	Cast net	Juluki	Dingara	Hook	Bamboo pipe traps	Dewatering catch	Total
Gudusia chapra	√	√	√	–	–	–	–	95
Notopterus notopterus	√	√	–	–	–	–	–	0
Puntius sophore	√	√	√	–	–	–	–	239
Puntius ticto	–	√	√	–	–	–	–	57
Amblypharyngodon mola	–	√	√	–	–	–	–	201
Esomus danricus	–	√	√√	–	–	–	–	116
Brachydanio rerio	–	√	√√	–	–	–	–	74
Chela laubuca	–	√	√√	–	–	–	–	57
Salmostoma bacaila	–	√	√√	–	–	–	–	64
Labeo calbasu	√	√	–	–	–	–	–	10
Botia dario	√	√	√	–	–	–	–	0
Lepidocephalichthys guntea	–	–	√	–	–	√	–	34
Clarias magur	√	√	–	√	–	√	–	60
Heteropneustes fossilis	–	√	–	√√	–	√	–	61
Mystus vittatus	–	√	–	√	–	–	–	2
Mystus cavasius	–	√	√	–	–	–	–	100
Xenentodon cancila	–	√	–	–	–	–	–	6
Anabas testudineus	√ √	√	–	–	√	–	–	182
Trichogaster fasciata	√√	√	–	–	√	–	–	29
Colisa lalia	√√	√	√	–	–	–	–	24
Channa punctata	√	√	–	√	√	–	–	143
Channa gachua	–	√	–	√	√	–	–	40
Channa stewartii	–	–	–	–	–	–	–	0
Channa striata	–	–	–	√	√	–	–	18
Channa marulius	–	–	–	–	–	–	–	0
Nandus nandus	√	–	√	–	–	–	–	12
Macrognathus aral	–	√	–	√	–	–	–	4
Amphipnous cuchia	–	–	–	√	√	–	–	23
Glossogobius giuris	–	√	√	√	–	–	–	6
Chanda nama	–	√	√	√	–	–	–	99
Total								**1756**

Note: Catch abundance was categorized qualitatively based on relative frequency in gear samples as low (√), high (√√), and absent (–).

Table 3. Fish species recorded from Mohaijan bao rice field during monsoon (June-September) season.

Fish species	Gill net	Cast net	Juluki	Dingara	Hook	Bamboo pipe traps	Dewatering catch	Total
Gudusia chapra	–	√√	√	–	–	–	–	107
Notopterus notopterus	√	√	–	–	–	–	–	37
Puntius sophore	√	√	√	–	–	–	–	431
Puntius ticto	–	√√	√	–	–	–	–	188
Amblypharyngodon mola	–	√	√√	–	–	–	–	286
Esomus danricus	–	√	√√	–	–	–	–	233
Brachydanio rerio	–	√	√√	–	–	–	–	308
Chela laubuca	√	√	√√	–	–	–	–	193
Salmostoma bacaila	–	√	√√	–	–	–	–	195
Labeo calbasu	√	√	–	–	–	–	–	27
Botia dario	–	–	√	√	–	–	–	21
Lepidocephalichthys guntea	–	–	√	√	–	√	–	242
Clarias magur	√	√	–	√√	√	√	–	141
Heteropneustes fossilis	√	√	–	√	√	√	–	99

Table 3. Continued.

Fish species	Gill net	Cast net	Juluki	Dingara	Hook	Bamboo pipe traps	Dewatering catch	Total
Mystus vittatus	–	√√	–	√	√	–	–	220
Mystus cavasius	–	√	–	–	–	–	–	2
Xenentodon cancila	–	–	–	–	–	–	–	0
Anabas testudineus	√√	√	–	√	√	√	–	357
Trichogaster fasciata	√	√	√	–	√	–	–	104
Colisa lalia	√√	√	√	–	-	–	–	66
Channa punctata	√√	√	–	√	√√	√	–	274
Channa gachua	–	√	–	√	√	–	–	118
Channa stewartii	–	–	√	√	√	–	–	2
Channa striata	√	√	–	√	√√	–	–	29
Channa marulius	–	–	–	√	√	–	–	2
Nandus nandus	√	√	–	√	–	–	–	38
Macrognathusaral	√	√	–	–	–	√	–	18
Amphipnous cuchia	–	–	–	√√	√	–	–	47
Glossogobius giuris	–	√	√	√	–	–	–	23
Chanda nama	–	√√	√	√	–	–	–	202
Total								**4010**

Note: Catch abundance was categorized qualitatively based on relative frequency in gear samples as low (√), high (√√), and absent (–).

pneustes fossilis, Clarias magur, *Anabas testudineus* and *Channa* spp.

Fishing gear efficiency varied seasonally in response to changes in water depth, vegetation cover, and fish behavior. During the pre-monsoon, cast nets and juluki were most effective in capturing small schooling and surface-dwelling fishes in shallow, vegetated habitats, while gill nets showed moderate efficiency (Table 2).

In the monsoon season, cast nets and gill nets yielded the highest catches across diverse species and size classes, whereas dingara and hooks became more effective for carnivorous and air-breathing fishes as water levels stabilized and fish movements became

Table 4. Fish species recorded from Mohaijan bao rice fields during extended post-monsoon season (October-December).

Fish species	Gill net	Cast net	Juluki	Dingara	Hook	Bamboo pipe traps	Dewatering catch	Total
Gudusia chapra	√	√	–	–	–	–	√	71
Notopterus notopterus	–	–	–	–	–	–	√√	74
Puntius sophore	–	√	–	–	–	–	√√	280
Puntius ticto	–	√	–	–	–	–	√√	160
Amblypharyngodon mola	–	√	–	–	–	–	√√	
Esomus danricus	–	√	–	–	–	–	√√	187
Brachydanio rerio	–	√	√	–	–	√	–	156
Chela laubuca	–	√	√	–	–	–	–	180
Salmostoma bacaila	–	√	√	–	–	–	–	158
Labeo calbasu	√	√	–	–	–	–	–	50
Botia dario	–	√	–	–	–	√	–	95
Lepidocephalichthys guntea	–	–	–	–	–	√	–	141
Clarias magur	√	√	–	√	√	√√	–	311
Heteropneustes fossilis	√	√	–	√	√	√	–	613
Mystus vittatus	–	–	–	–	–	√	–	196
Mystus cavasius	√	–	–	–	–	√	√√	75

Table 4. Continued.

Fish species	Gill net	Cast net	Juluki	Dingara	Hook	Bamboo pipe traps	Dewatering catch	Total
Xenentodon cancila	–	√	–	–	–	–	√√	54
Anabas testudineus	√	√	–	–	√	–	√√	600
Trichogaster fasciata	√	√	–	–	√	–	√	160
Colisa lalia	√	√	–	–	–	–	√	122
Channa punctata	–	–	–	–	√	–	√ √	280
Channa gachua	–	–	–	–	–	–	√ √	130
Channa stewartii	–	√	–	–	–	–	√	8
Channa striata	–	–	–	–	√	–	√ √	97
Channa marulius	–	√	–	–	√	–	√ √	7
Nandus nandus	–	√	–	–	–	–	√ √	126
Macrognathus aral	–	√	–	–	–	–	√ √	22
Amphipnous cuchia	–	–	–	√√	√	–	√ √	67
Glossogobius giuris	–	–	–	–	–	–	√ √	18
Chanda nama	–	√	–	–	–	–	√ √	175
Total						–		**4770**

Note: Catch abundance was categorized qualitatively based on relative frequency in gear samples as low (√), high (√√), and absent (–).

localized (Table 3).

During the extended post-monsoon period, dewatering resulted in comparatively high fish catches of multiple species, and bamboo pipes, hooks, and dingara showed high efficiency, particularly for burrowing, air-breathing, and bottom-dwelling fishes (Table 4).

DISCUSSION

The present study provides the first detailed seasonal assessment and records the presence of a large number of indigenous fish species in bao rice field arenas of Lakhimpur district. A total of 30 indigenous fish species belonging to 16 families and 8 orders were recorded, highlighting the significant conservation importance and livelihood value of bao rice systems.

Fish diversity and community structure

The dominance of Cypriniformes, particularly the family Cyprinidae, is consistent with earlier studies on floodplain wetlands and rice–fish systems of Assam and other parts of South and Southeast Asia (Boruah *et al.* 2023, Biswas and Singh 2022). Small indigenous fishes (SIFs) such as *Puntius sophore, Amblypharyngodon mola, Esomus danricus* and *Brachydanio rerio* were abundant across seasons, reflecting their strong adaptation to shallow, vegetated and periodically inundated habitats. Similar dominance of SIFs in rice fields has also been reported earlier (Duarah *et al.* 2019). Dominance of Small indigenous fishes indicates active colonization and breeding within flooded rice fields. Larger and air-breathing fishes occurred in low numbers, suggesting early life-history utilization of the habitat. The monsoon season exhibited the highest diversity and abundance of small and medium-sized fishes for Enhanced availability of food and shelter due to standing water and dense rice vegetation supported higher fish recruitment and growth (Lianthuamluaia *et al.* 2024). Air-breathing and predatory fishes were dominant in the extended post-monsoon season, reflecting concentration of fishes in residual pools and trenches during water recession. Dewatering revealed the presence of cryptic and bottom-dwelling species that were under-represented in earlier seasons.The strong representation of Anabantiformes and Siluriformes, including air-breathing fishes such as *Clarias magur*, *Heteropneustes fossilis*, *Anabas testudineus,* and *Channa* spp., indicates that bao rice fields serve as important refuge habitats under fluctuating and sporadically dense vegetation conditions, while adjacent open water patches also support broader fish assemblages. Many of these species possess accessory respiratory organs and behavioral adaptations that enable survival in low-oxygen environments (Zhang *et* *al.* 2025). In the present study, residual ponds within bao rice fields received nutrient-rich sewage from decomposing bao paddy biomass, supporting abundant macroinvertebrates and providing shelter and feeding grounds for fishes during the winter dry period.

Feeding guild structure and ecosystem function

The coexistence of carnivorous, omnivorous, herbivorous and detritivorous feeding guilds reflects high trophic complexity and productivity of bao rice fields. The dominance of carnivorous fishes suggests abundant availability of insect larvae, zooplankton, benthic macroinvertebrates including oligochaetes and small fishes, which are typically enhanced in flooded rice ecosystems (Saowakoon *et al.* 2021, Saikia *et al.* 2024). Omnivorous and herbivorous species further contribute to efficient energy transfer by exploiting diverse food resources such as periphyton, phytoplankton and detritus. This functional diversity underscores the role of bao rice fields as nutrient-rich and self-sustaining ecosystems.

Seasonal dynamics and breeding ecology

The presence of juveniles and larvae during the monsoon season confirms in-situ breeding within bao rice fields, supporting earlier observations that flooded rice fields serve as spawning and nursery grounds for many floodplain fishes (Aqmal and Ahmad 2026). Dense paddy stems and submerged vegetation provided shelter from predators and strong currents, thereby enhancing larval survival. The exceptionally high abundance recorded during extended post-monsoon dewatering reflects the concentration of fishes in residual pools and trenches, a phenomenon widely documented in Bangladesh floodplain fisheries (Kelkar *et al.* 2022).

Fishing gear efficiency and traditional knowledge

Seasonal variation in fishing gear efficiency reflects adaptive fishing practices aligned with changing environmental conditions. Cast nets in open areas and juluki in thinner paddy stands were most effective during the monsoon and early post-monsoon periods, when fishes were widely dispersed. In contrast, dewatering, Bamboo pipe traps, hooks, and dingara proved most efficient during the post-monsoon season. Similar seasonal selectivity of fishing gears has been reported from rice–fish systems of Assam and Bangladesh (Tikadar, Kunda and Mazumder 2021) highlighting the ecological wisdom embedded in traditional fishing techniques.

Implications for conservation and management

The occurrence of fish larvae and juveniles during the monsoon season indicates that bao rice fields function as in-situ breeding and nursery habitats for indigenous fish species. The dense growth of bao paddy stems provides natural cover, reducing exposure to predators and buffering the effects of water movement and disturbance, thereby improving early life-stage survival. After harvest, when water is drained from the fields, many fishes become confined to residual pools and trenches, indicating that these areas serve as temporary refuge habitats during the dry phase. The repeated occurrence of indigenous and small ornamental fish species that are declining in natural habitats underscores the conservation importance of bao agro-wetland systems. Accordingly, maintaining natural flood cycles, preserving small habitat pockets within fields, and limiting agrochemical use are important measures for sustaining fish diversity in bao rice landscapes.

CONCLUSION

The seasonally inundated bao rice fields play an important role in sustaining inland fish populations, including several small indigenous and ornamental species that are now less frequently observed in natural waters. Beyond their biodiversity value, bao rice landscapes provide food security in flood-affected regions through the combined production of rice and edible fish for local communities. Managing these systems as rice–fish environments improves overall biological productivity, while their long-term sustainability depends on regulated human activities and minimal agrochemical use.

ACKNOWLEDGMENT

The author sincerely expresses gratitude to the Honourable Vice-Chancellor and the Registrar of North Lakhimpur University for their necessary support and encouragement. The author also thanks colleagues of the Department of Zoology for their academic cooperation, and the local farmers and fishermen for their valuable assistance during fieldwork and data collection

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