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Message from Gauhati University

গুৱাহাটী বিশ্ববিদ্যালয়
GAUHATI UNIVERSITY

Prof. Pratap Jyoti Handique
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MESSAGE

It gives me immense pleasure to know that the GIZ in collaboration with Gauhati University are publishing Research Proceedings with the selected papers presented in the ***International symposium on Aquatic Biodiversity of the North Eastern Region*** held on 26-27 October 2021. The proceedings will be certainly instrumental for stakeholders for protection and sustainable management of Aquatic Resources in NE India because Biodiversity is also essential for stabilization of ecosystems, protection of overall environmental quality for understanding intrinsic worth of all species on the earth as The species diversity of an ecosystem is often related to the amount of living and nonliving organic matter present in it.

Besides Fish, Aquatic insect diversity of NE India has also been taken into consideration in the proceedings. I also emphasize to explore plankton diversity of lotic and lentic water resources of the NE region. Declining situation of amphibian species from NE India is also one of the concerns for delicate balance of the nature.

I must thank to all the members of the organising committee of the symposium both from our University and GIZ as well as all the reviewers of the papers for their untiring efforts to publish the proceedings in the form of a Book. I am sure that the Research proceedings will act as base line information for conservation of precious aquatic biodiversity of NE India.

P.J. Handique

Date: 18.04.2023

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Foreword

Under the aegis of the Indo German Bilateral Cooperation Project "Protection and Sustainable Management of Aquatic Resources in the North Eastern Himalayan Region of India" (NERAQ), the First International Symposium on Aquatic Biodiversity of the North Eastern Region of India was held on 26-27 October, 2021 with the aim to determine status, threats and opportunities to manage aquatic flora and fauna and, in particular, to tackle the threats of climate change. This two-day virtual workshop was organized by GIZ in cooperation with MoEFCC, Gauhati University, and Zoological Survey of India (ZSI).

India is one of the mega biodiversity centres in the world and houses two of the world's thirty-four biodiversity hotspots, located in the North Eastern Region (NER). The region has abundant species of flora and fauna which includes an extraordinary aquatic biodiversity. The NER is also considered as one of the hotspots of freshwater fish biodiversity in the world with nearly 430 species of freshwater fishes (35 endemic), 186 mollusc species and 367 different dragonfly species among others. However, despite ongoing research efforts & surveys, there are still many blind spots on the biodiversity map with a high number of unknown species. The symposium was an endeavour to close some of these knowledge gaps and to get an understanding about the status of research on aquatic biodiversity in NER.. In this symposium, more than 50 national and international experts joined in the dialogue on conserving NER's aquatic biodiversity, sharing knowledge gaps, level of community involvement, and in particular, opportunities for management to tackle threats with a focus on the effects of climate change. The symposium was organized under 4 technical sessions viz. (a) Inventory/knowledge basis of aquatic biodiversity in the North Eastern Himalayan Region with special emphasis on Assam, Meghalaya, Manipur and Nagaland. (b) Threats and opportunities in the aquatic biodiversity sector in the North Eastern Himalayan Region, (c) Innovations, tools and status of protected areas for tackling threats posed by climate change and anthropogenic interferences and (d) Livelihood enhancement and community development in the aquatic sector in Assam, Meghalaya, Manipur and Nagaland, concepts and case studies.

In the event, the authors presented the abstracts and were requested for the full length research papers of those presentations. All of the 27 received research papers were evaluated by a team of experts of the relevant fields. Gauhati University, being NERAQ's research partner, re-examined the papers before finalising these in the present form.

I hope that this compendium will serve as a valuable source of reference to all the researchers of the region and also open doors for future research areas in the aquatic biodiversity sector. Hopefully, this will be an enabler for better protection and sustainable management of the aquatic resources of this region.

Ms Patricia Dorn
Project Manager
Protection and Sustainable Management of Aquatic Resources
in the North Eastern Himalayan Region of India
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Contents

SESSION 1: INVENTORY/KNOWLEDGE BASIS OF AQUATIC BIODIVERSITY IN THE NORTH EASTERN HIMALAYAN REGION

A STUDY ON THE DIVERSITY OF SMALL INDIGENOUS SPECIES OF FISH OF JIA BHARALI RIVER IN SONITPUR DISTRICT, ASSAM, INDIA

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ABSTRACT

An ichthyofaunal exploratory study was conducted between May to September, 2020 at four sampling stations of the Jia Bharali River, Assam, which recorded 27 species of small indigenous species of fish belonging to 23 genera, 13 families and 6 orders. Cypriniformes was the dominant order with 37.03% contribution to the total species followed by Siluriformes (29.63%), Perciformes (18.52%), Synbranchiformes (7.41%), and Clupeiformes and Beloniformes (each 3.70%). The present study also recorded the presence of three Near Threatened species and the remaining twenty-four species are found to be Least Concern (LC).

Keywords: SIS, diversity, Jia Bharali, Assam

INTRODUCTION

Fishes are cold-blooded vertebrates that breathe by means of gills and living water. Half of the total number of vertebrates in the world is constituted by fish species (Nath and Dey, 2000). The 'SIS' or Small Indigenous Species are those fish species that grow to a size of 25 cm or 9 inches in the mature stages of their lifecycle (Felts et al., 1996). The North-eastern region of India is considered to be one of the hotspots of freshwater fish biodiversity in the world (Kottelat and Whitten, 1996; Ramanujam et al., 2010). The Jia Bharali is one of the major tributaries of the river Brahmaputra. It flows down from the lower Himalayas in Arunachal Pradesh in the North-eastern India and runs through the middle of Sonitpur District of Assam for about 66 kms before meeting the Brahmaputra at Tezpur (92°53'53"E; 26°39'15"N). It originates in the Okka hills of Arunachal Pradesh where it flows for about 190 km and is known as Kameng River. It enters the Sonitpur district of Assam at Bhalukpung after which it flows for 56 km in the plains before joining River Brahmaputra near Tezpur. The water of River Jia Bharali is a mixture of warm and cold water which favours the support of a rich Ichthyo-diversity; which is a characteristic mainly marked in the Ecotones. Considering such rich fish fauna, a preliminary survey was carried out to determine the fish diversity of the Jia Bharali River.

MATERIALS AND METHODS

Study area

The present investigation was conducted for five months from May to September, 2021. Four sampling stations (upstream to downstream) were selected during the study as follows: S_1, Nameri (26°59'37.74''N 92°40'40.45''E), S_2, Chariduar (26°52'35.13"N 92°48'13.51"E), S_3, Jamugurihaat (26°43'27.25''N 92°55'28.59''E) and S_4, Panch mile (26°39'54.26"N 92°51'46.15"E).

Data collection

Fishes were collected from the local fisherman at the four sampling sites both in the morning and evening hours. However secondary data were also collected by interaction with local people of embankment areas. The fishes were collected using different fishing gears. The fishing gears employed during the study were mostly gill net, lift net, cast net, fish hooks and lines, and bamboo traps. Some of this information was gathered by interaction with the local fisherman residing there.

Identification of fish

During the study, the fishes were collected in fresh or live condition and photographs were taken with the help of camera by placing them on a white paper with the scale along the length of the specimen. Fishes collected from four sampling stations were identified in the field as per as practicable and unknown fishes were collected in 70% formalin and brought to the lab and identified later on following the literature of Talwar and Jhingran (1991) and Jayaram (1999). Identification of the fishes were also done based on www.fishbase.org (Froese & Pauly, 2021) and the IUCN Conservation Status of the collected species was checked based on www.iucnredlist.org.in (version 2020-1).

RESULTS

Fish species collected from the two sampling stations including their order, family, scientific name, and conservation status (IUCN) are depicted in Table 1. The nomenclature of the collected fish species is based on www.fishbase.org and the conservation status was checked following the IUCN red list (IUCN 2020-1). A total of 27 species belonging to 23 genera, 13 families, and 6 orders have been recorded from the four sampling stations of the Jia Bharali River during the study period (Table 1). The fish fauna from the four sampling stations belong to the orders Cypriniformes, Siluriformes, Perciformes, Clupeiformes, Beloniformes and Synbranchiformes.

The study revealed that Cypriniformes was the most dominant order representing 10 species with 37.03% contribution to the total species followed by Siluriformes with eight species (29.63%), Perciformes with five species (18.52%), Synbranchiformes with two species (7.41%), Clupeiformes, Beloniformes, each with one species contributed 3.70% of the total species identified during the study. Among the families recorded Cyprinidae was the most dominant with nine species followed by Bagridae with three species, Siluridae, Schilbeidae, Ambassidae and Mastacembelidae with two species each and remaining families Botiidae, Sisoridae, Nandidae, Osphronemidae, Gobiidae, Clupeidae, Belonidae, with one species each.

The study recorded the presence of three Near Threatened species viz. *Ailia coila, Ompok pabda, Ompok bimaculatus* and the remaining twenty four species including *Amblypharyngodon mola, Esomus danricus, Puntius sophore, Pethia gelius, Cabdio morar, Barilius bendelensis, Tariqilabeo latius, Pethia guganio, Salmostoma phulo, Botia dario, Mystus cavasius, Mystus tengara, Batasio tengana, Pachypterus atherinoides ,Gagata cenia, Nandus nandus, Chanda nama, Parambassis ranga, Trichogaster fasciata, Glossogobius giuris, Gudusia chapra, Xenentodon cancila, Macrognathus aral, Mastacembelus pancalus* are Least Concern according to IUCN red list assessment (2010).
Similarities in species composition among the study sites were analyzed using the Jaccard index (JI) for calculating the extent of similarity between pairs of data sets (Table 2). The JI value between sites S_3 and S_4 was found to be highest while it was lowest between sites S_2 and S_3. The Shannon-Weiner diversity index (D.I) of the collected SIS fishes (site wise) indicated a diverse distribution with overall index of 1.08(Table III). Chariduar(S_3) was the most diverse and even site carried out during this survey with a maximum diversity index of 0.97 indicated by Simpson's diversity index (D) (Table 3)

DISCUSSION

In India, as documented by ICAR-National Bureau of Fish Genetic Resources, Lucknow, about 450 may be categorized as Small Indigenous Freshwater Fish Species out of 765 native freshwater fish species. Das and Sarmah (2014) studied the ichthyo-diversity of the Jia Bharali River in Assam taking four sampling sites and recorded a total of 56 species belonging to 19 families under 8 orders. The present investigation recorded the presence of 27 small indigenous fish species belonging to 23 genera, 13 families and 6 orders in four sampling stations of Jia Bharali River.

The freshwater aquatic environments are facing serious threats both in terms of biodiversity and ecological stability. In the present investigation, three species were recorded to be Near Threatened namely *Ailia coila, Ompok pabda* and *Ompok bimaculatus.*

CONCLUSION

Jia Bharali River is enriched with a remarkable ichthyo-diversity. A good number of Small Indigenous Species (SIS) of fish are reported in the Jia Bharali River thus alluring attention in terms of food value, market value and research purpose. The present study was an attempt to examine and evaluate the SIS of fish diversity in the Jia Bharali River of Sonitpur district under four sampling stations. The work has been conducted for a period of five months from May to September 2020. Over this small period of time, a total of 27 species of fish have been recorded thus indicating the near-pristine condition of the river body to some extent considering the survey period and stretch of the water body for conducting the current survey. Through the investigation, it can be inferred that a good number of people are dependent on fishing for their livelihood by assessing different traditional gears. However due to lack of proper knowledge, the Small Indigenous Species of fish are deprived of their ornamental value and are prone to some major threats such as loss of natural habitats, use of small mesh-sized gears, use of pesticides, insecticides, industrial as well as domestic pollution etc.

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REFERENCES

Baishya, R.A., Basumatary, S., Kalita, H.K., Talukdar, B., Dutta, A., & Sarma, D. (2016). Present status of small indigenous and diversity of small indigenous fish species (SIS) in the upper reaches of the river Brahmaputra in Assam, north-east India. *Indian Journal of Fisheries, 63(1),* 1-7.

Basumatary, B., Baishya, R.A., Talukdar, B., Kalita, H.K., Dutta, A., Goswami, U.C., Srivastava, S.K., & Sarma, D. (2014). Diversity of Small Indigenous Species (SIS) of Fish in the Lower Reaches of River Brahmaputra, Assam. *Ecology, Environment and Conservation Paper, 20(4)*, 1817-1824.

Biswas, B.C., & Kumar, P.A. (2015). Diversity of Small Indigenous Fishes (SIF) of Nabaganga and Kaliganga rivers of Jhenidah, south western part of Bangladesh. *Research Journal of Recent Sciences, 4(12),* 77-80.

Das, M., & Sarmah, J. (2014). A Study on Icthyo-Diversity of Jia Bharali River, Assam, India. *Reviews of Literature, 2(3).*

Felts, R.A., Fajts, F., & Akteruzzaman, M. (1996). Small Indigenous Fish Species Culture in Bangladesh (Technical brief), IFADEP Sub Pro 2, *Development of Inland Fisheries*, 41pp.

Froese, R., & Pauly, D. (2021). FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2021).

Hanif, M.A., Siddik, M.A.B., Nahar, A., Chaklader, M.R., Rumpa, R.J., Alam, M.J., & Mahmud, S. (2016). The Current Status of Small Indigenous Fish Species (SIS) of River Gorai, a Distributary of the River in Bangladesh. *Journal of Biodiversity and Endangered Species,* 4(2).

IUCN. (2021). The IUCN Red List of Threatened Species. Version 2021-1. https://www.iucnredlist.org

Jana, P., Paul, M., Kumar, P.P., Sahu, S., & Chowdhury, A. (2018). Nutrient Profile Study on Small Indigenous Species (SIS) of Paschim Medinipur District of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences, 7(10),* 634-640.

Jayaram, K.C. (1999). The fresh water fishes of the Indian Region. Narendra Publishing house, New Delhi, 1-322.

Kalita, K.D., Das, K., & Kalita, S. (2019). Fishing Communities and Traditional Fishing Gears in South- West Assam. *ISOR Journal of Agriculture and Veterinary Science (ISOR-JAVS), 12(5)*, 01-07.

Kottelet, M., & Whitten. (1996). Freshwater biodiversity in Asia with Special reference to fishes. The World Bank Technical Report No. 343, Washington DC, 59pp.

Mittermeier, R.A., Robles, P., & Mittermeier, C.G. (1997). Megadiversity, Mexico: CEMEX.

Nath, P., & Dey, S.C. (2000). Fish and fisheries of North Eastern India, Vol. I: Arunachal Pradesh, 217.

Ramanujam, S.N., Manorama, M., & Dey, S. (2010). Icthyodiversity of Meghalaya: India. *Electronic Journal of Ichthyology, 6(2),* 15-26.

Talwar, P.K., & Jhingran, A. (1991). Inland fishes of India and adjacent countries. Oxford and IBH Publishing House, Co. Pvt. Ltd., New Delhi 1 and 2: 115-116.

Thilsted, S.H. (2010). The role of small indigenous freshwater fish species in improving nutrition in rural populations. Abstract. Workshop on "Small indigenous freshwater fish species: Their role in poverty alleviation, food security, and conservation of biodiversity", 23-25 February 2010, CIFRI, Barrackpore.

Table 1 SIS fish species of the Jia Bharali River as reported during the survey between May to September, 2020 in Sonitpur district, Assam

	Nameri S_1	Chariduar S_2	Jamugurihaat S_3	PanchmileS$_4$	IUCN
Order Clupeiformes					
Family Clupeidae					
1. *Gudusia chapra* (Hamilton, 1822)		+			LC
Order Cypriniformes					
Family Cyprinidae					
2. *Amblypharyngodon mola* (Hamilton, 1822)		+	+	+	LC
3. *Barilius bendelisis* (Hamilton, 1807)	+	+		+	LC
4. *Cabdio morar* (Hamilton, 1822)	+	+	+	+	LC
5. *Crossocheilus latius* (Hamilton, 1822)	+		+	+	LC
6. *Esomus danrica* (Hamilton, 1822)		+		+	LC
7. *Pethia gelius*(Hamilton, 1822)				+	
8. *Pethia guganio*(Hamilton, 1822)			+		LC
9. *Puntius sophore* (Hamilton, 1822)	+	+	+	+	LC
10. *Salmostoma phulo* (Hamilton, 1822)			+	+	LC
Family Botiidae					
11. *Botia dario* (Hamilton, 1822)	+	+		+	LC
Order Siluriformes					
Family Siluridae					
12. *Ompok bimaculatus* (Bloch, 1794)	+	+			NT
13. *Ompok pabda* (Hamilton, 1822)	+		+	+	NT
Family Bagridae					
14. *Batasio tengana*(Hamilton, 1822)		+			LC
15. *Mystus cavasius* (Hamilton, 1822)		+		+	LC
16. *Mystus tengara* (Hamilton, 1822)			+	+	LC
Family Sisoridae					
17. *Gagata cenia* (Hamilton, 1822)	+		+	+	LC
Family Schilbeidae					
18. *Ailia coila* (Hamilton, 1822)	+	+			NT
19. *Pachypterus atherinoides* (Bloch, 1794)			+		LC
Order Beloniformes					
Family Belonidae					
20. *Xenentodon cancila* (Hamilton, 1822)				+	LC
Order Perciformes					
Family Ambassidae					
21. *Chanda nama* Hamilton,1822		+	+		LC
22. *Chanda ranga (Parambassis ranga* (Hamilton, 1822))			+	+	LC
Family Nandidae					
23. *Nandus nandus* (Hamilton, 1822)		+			LC
Family Osphronemidae					
24. *Colisa fasciata (Trichogaster fasciata* Bloch & Schneider, 1801)	+	+		+	LC
Family Gobiidae					
25. *Glossogobius giuris* (Hamilton, 1822)				+	LC
Order Symbranchiformes					
Family Mastacembelidae (Spiny eels)					
26. *Macrognathus aral* (Bloch & Schneider, 1801)				+	LC
27. *Mastacembelus pancalus* (Hamilton, 1822)		+		+	LC

Note: +- Species recorded during the current survey; LC- Least Concern; NT- Near Threatened

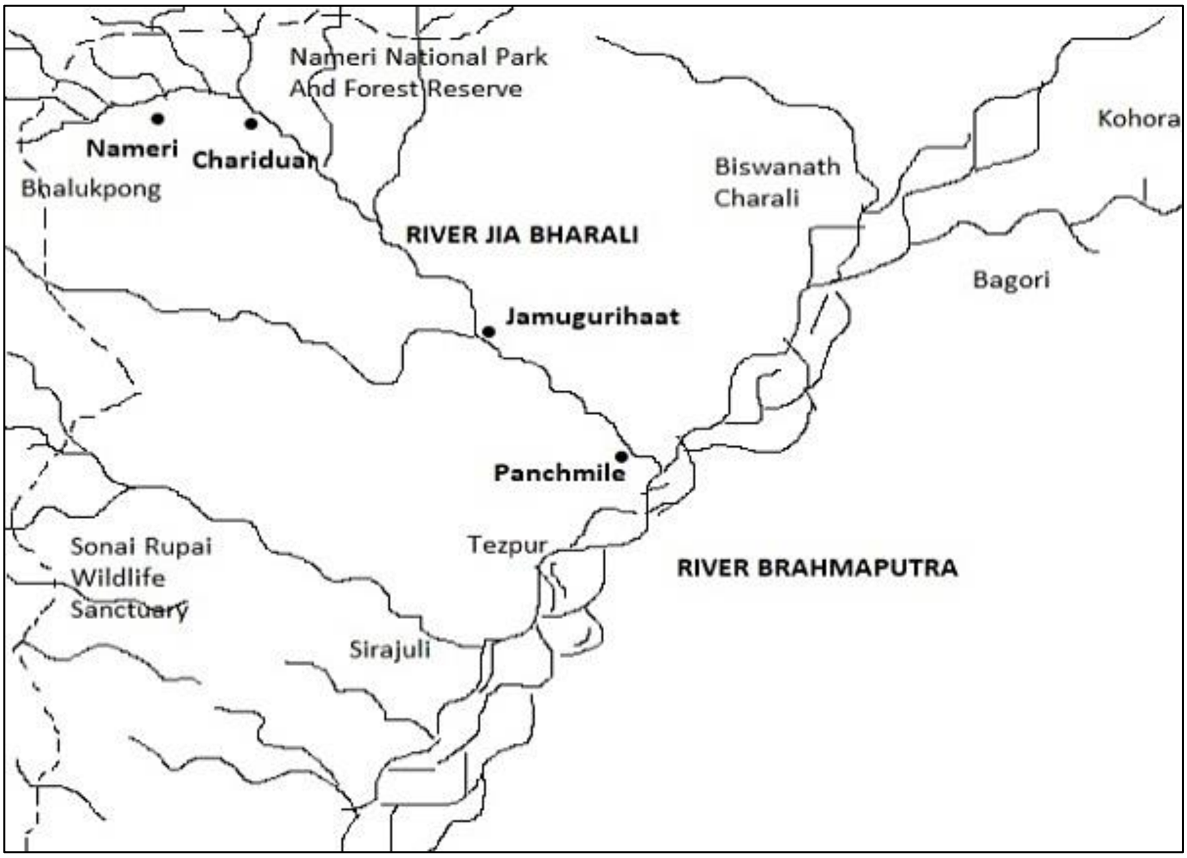
Table 2 Jaccard similarity coefficient of SIS fish among four sampling stations of the Jia Bharali River in Sonitpur district, Assam

Sampling stations	S1	S2	S3	S4
S1	1			
S2	0.389	1		
S3	0.217	0.173	1	
S4	0.380	0.360	0.409	1

Table 3 D.I- Shannon-Weiner diversity index of the collected SIS fishes across four sampling stations of the Jia Bharali River in Sonitpur district, Assam. R/E- Richness and evenness for the four sampling sites. D- Simpson's Diversity Index of the collected SIS fishes.

Site	R/E	D
Nameri	-0.36	0.871795
Chariduar	-0.10	0.97151
Jamugurihaat	-0.36	0.811966
Panchmile	-0.24	0.512821
D.I 1.08		

Figure 1 Survey stretch of Jia Bharali River in Sonitpur district, Assam illustrating the sampling sites (filled circles) of the present study



DIVERSITY AND DISTRIBUTION OF FRESHWATER FISHES IN TWO IMPORTANT RIVERS OF NONGSTOIN, MEGHALAYA, NORTH-EAST INDIA

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ABSTRACT

Among aquatic organisms, fishes are the most well-known species and they also serve as a sign of a healthy aquatic ecosystem. The present study was conducted to investigate the diversity and distribution of freshwater fishes on the two very important rivers i.e., the Nondein and the Nanbah rivers passing through the town of Nongstoin, Meghalaya, North-East India. This study was carried out during the month of February-March and July-August, of the year 2019. A total of five sampling sites were selected along the stretches of these two rivers. The collection and capturing of fishes were done by using various fishing techniques. During the course of study, a total of 12 species of fresh water fishes were collected and identified. Detailed analysis revealed that maximum number and diversity of fishes were observed during the rainy season as compared to the non-rainy season. Simpson diversity index (D) for dominance species was found to be 0.18 during the non-rainy season and 0.13 during the rainy season. Important freshwater fishes such as *Neolissochilus hexagonolepis*, *Garra* sp., *Schistura multifasciata*, and *Pseudecheneis sulcatus* were observed maximum at site-3, possibly due to the clean water running through this area with no human intervention. Thus, this study indicates that rapid urbanization, sewage disposal and other human interventions affects the diversity and distribution of fishes, especially those fishes that reside only in clean environment.

Keywords Diversity, Distribution, Fishes, Nongstoin, Freshwater

INTRODUCTION

Fish are the most well-known species among aquatic organisms. They are also the vertebrate group that has been studied the most. Fish serve as a source of food that can be taken from the natural population. They can serve as a sign of a healthy aquatic ecosystem because they live at or near the top of the food chain (Gorman and Karr, 1978). So far, 2500 species of fish have been identified on the Indian subcontinent, with 930 species found in the freshwater ecosystem. These 930 freshwater species were divided into 20 orders, 100 families, and 300 genera. In North-East India, the diversity within the freshwater ecosystems are also highly diverse and of great economic importance to the inhabitants of this region (Allen et al., 2010). More than hundreds of species of fishes have been described anew from this region since the pioneering work of Hamilton (1822) (Goswami et al., 2012). Just within the last decade, almost 89 new species of freshwater fishes were added to the fish fauna of North-East India (Animal Discoveries, 2009-2017; Eschmeyer, 2012). In spite of this vast discoveries a handful of fish species still remain unexplored in this region. Many studies conducted on freshwater fishes in India has been limited to sporadic investigations of commercial fisheries.

In the current scenario, freshwater fishes are experiencing a significant threat because of various factors such as habitat loss and degradation, untenable fishing practices, illegitimate trade and climate change. However, one of the biggest challenge threatening fish variety is human intervention and other diverse anthropogenic activities (Allen et al., 2005; Carrizo et al., 2017). Even in a country like India, where rivers are often considered sacred and previously teeming with different species of fish. Most if not all of the rivers are now devolved into sewage canals where all kinds of rubbishes are being dumped. Because of these malpractices by human, the population of fish, particularly those that live in clean water bodies, has been rapidly declining. The deteriorating quality of our rivers were also witnessed even in a small state like Meghalaya. Out of the various factors leading to decline in fish fauna of Meghalaya, one of the major factor is the intense human activities that has greatly affect the habitat of fishes. A state which was once filled with varieties and large number of fresh water fishes now has suffer a sharp decline in fish population. Many rivers, especially those running through major towns of the state where human population is high are worst affected in term of biodiversity loss. Taking into consideration all these factors, a rigorous assessment of freshwater fish diversity in each river is urgently required for ichthyology and implication of conservation policies (Molour and Walker, 1998). Studying their diversity and distribution in their natural habitat is the need of the hour to keep track on their statuses before putting any precise management plans or conservative measures. Therefore, the present study was conducted to collect up-to-date information about the diversity and distribution of fishes in relation with the two rivers viz., the Nondein and Nanbah rivers of Nongstoin, West Khasi Hills district, Meghalaya so that suggestions can be made for any conservational strategies.

The rivers Nondein and Nanbah are located in Nongstoin. Nongstoin is the headquarter of West Khasi Hills district, Meghalaya. It is situated at an altitude of 1,409 meter (4623 ft.) above the sea level with a latitude of 25.53° N and longitude of 91.27° E. The climatic conditions in Nongstoin is warm and temperate with good deal of rainfall during summer while the winters have very little rain. The average annual temperature ranges between 17-18 °C reaching to maximum during summer (ranging from about 15 to 30°C) and dipping down to 2°C in winter. The rivers Nondein and Nanbah run through Nongstoin town and they play a significant role for the inhabitants residing nearby these rivers. People uses these rivers for their daily domestic purposes such as washing clothes, utensils, etc. Water from these rivers were also used for irrigation purposes. These rivers also serve as a good place for the fishermen of the entire Nongstoin region for the entire year to spend their time fishing different varieties of fishes. The river Nanbah rises from the uphill region of Mawrusyiar-Porsohsat while the river Nondein rises from the slope of Pyndengrei and Mawthawniaw villages. These rivers meet and join together before passing the ravines and gorges that finally merge with the Kynshi River. These rivers runs at an approximate distance of 5 Kms through the Nongstoin town. In the summer months both these rivers are strong and mighty, while in winter they are lean. As they run in the commercial areas, the waste, garbage etc., generated from the local markets, shops, houses are ultimately discharged into the water body thereby deteriorating the water quality of these rivers. Even though, there are no major industrial estates, however there are isolated small scale industries located in the catchment of these rivers which also contribute in polluting these two importance rivers.

MATERIALS AND METHODS

The present study encompassed the entire stretch of Nondein and Nanbah rivers from upstream to downstream. The study was carried out during the month of February-March and May-August, 2019, these months represent the non-rainy and the rainy seasons at Nongstoin, respectively. Five sampling sites were selected along the entire stretch of these rivers (Fig.1 and Table 1). Sites were chosen and selected on the basis of their location, topography of the rivers and areas of human settlement (Table 1). These sites were marked as site-1, site-2, site-3, site-4 and site-5. Two of these sampling sites viz., site-4 and site-5 were located on the upstream of the rivers with less human settlement, whereas site-1 and site-2 are located on the midstream with maximum human settlement and site-3 which is the confluence of both the rivers is located downstream with no human settlement and running through the forest area Fishes were captured with the help of some local fishermen by using various fishing tools and techniques. Some of these tools and techniques includes cast net, scoop net, basket trap, lift net, etc. Identification of fishes is done by following standard literature (Jayaram, 1999; Vishwanath, 2002) and also with the help of some experts from Zoological Survey of India, Shillong. The identification of the species was done mainly on the basis of the colour pattern, specific spots or marks on the surface of the body, shape of the body, structure of various fins, mouth shapes, etc. After identifying correctly, fishes of different species were then counted manually and separately as per sites and seasons (Table 3). Calculations for fish diversity indices was done as per standard method (Shannon and Weaver, 1963).

RESULTS AND DISCUSSION

The diversity and distribution of fishes in five sampling sites of the rivers in Nongstoin during two different seasons are given in tables 2-4 and figure 2. A total of 12 species of fishes were recorded in this study. These fishes belong to 3 different orders (Cypriniformes, Anabantiformes and Siluriformes) and 6 families (Cyprinidae, Badidae, Channidae, Nemachelidae, Sisoridae and Clariidae) (Table 2). Our result thus revealed quite rich diversity of fish in these two studied rivers. Cypriniformes is the order with highest number of species (8 species), whereas both the orders Anabantiformes and Siluriformes are represented by only two species each. At the family level, family Cyprinidae contain the highest number of fish species (7 species). This may be due to the fact that most fishes which are highly adaptable in the hill streams belong to the family Cyprinidae. Further, the data for different species during the rainy and non-rainy season was calculated for Species Richness, Shannon Diversity Index (H'), Simpson Diversity Index (D) and Evenness (H/S). Highest species richness was recorded during the rainy season for most species, the highest being *Devario aequipinnatus* (474). Similarly, the Shannon diversity index (H') for fish sampled along both the rivers were found to be higher during the rainy season (2.153) than during the non-rainy season (2.04). However, Simpson diversity index (D) for dominance species was found to be more during the non-rainy season (0.18) and less in the rainy season (0.13). The Pielou's evenness index shows to be 0.82 and 0.86 during the non-rainy and rainy seasons, respectively (Table 4).

Among all the study sites, site-3 harbour maximum number of fishes in both the seasons, whereas site-4 bears the least. In the non-rainy season maximum number of species (11 species) was observed at site-3, whereas in the rainy season sites-1, -2 and -3 bears the same number of species (11 species) (Fig. 2 and table 3). Similar results have also been reported in a study conducted by Ramanujam et al., 2010. In their study, they reported the presence of 9 species of fishes belonging to 3 different orders from Kynshi river, West Khasi Hills District (Ramanujam et al., 2010), which is the same district where the present study was conducted. Therefore, maintaining the quality of the rivers is very important for conserving these fish fauna within the district and the entire state of Meghalaya as a whole. Since, freshwater fish are one of the most threatened taxonomic groups (Darwall and Vie, 2005). This is because they are very sensitive to the quantitative and qualitative alteration of aquatic habits (Sarkar et al., 2008; Kang et al., 2009).

Our results also revealed that there are variations in the distribution of fish species in different sites of these rivers at different seasons and even between these rivers (Fig. 2a and b). Important freshwater fishes such as *Neolissochilus hexagonolepis*, *Garra* sp., *Schistura multifasciata* and *Pseudecheneis sulcatus* were found to present abundantly at site 3, possibly due to the clean water running through this area with no human intervention. The *N. hexagonolepis* are found to be totally absent in most of the sites especially during the non-rainy season except at site-2 (in rainy season) and -3 (both seasons). Similarly, some species like *P. sulcatus* and *G. kempi* are also found to be absent in some of the sites during non-rainy season but are present in all of the sites during the rainy season (Table 3). Thus, there seems to be a seasonal variation in the distribution of fishes in these two rivers. The reasons might be because during the rainy season the rivers are torrential, strong and mighty and the water quality tend to remain clean as all sewages will be washed away by the rivers. These allows most of the fishes residing downstream to migrate for food and spawning. While during non-rainy season rivers are lean and tend to remain stagnant, thus, most of the sewages are deposited in the river bed and reducing the hiding places for fishes and at the same time deteriorating the water quality. Information's collected from local inhabitants of Nongstoin revealed that 4-5 decades ago the entire stretches of these two rivers were filled with plenty of fishes. Local fishermen from within and even outside the region used to come and visit these rivers for fishing. However, in the last 1-2 decades they witness a rapid decline in the number of fishes possibly due to habitat destruction (for constructional activities like building of bridges, houses and shops by the river sides) pollution (such as dumping of sewage), use of toxic chemicals to catch fishes, etc. Thus, it seems that various anthropogenic activities are the main caused which effect the diversity and distribution of fishes in these rivers. In near future, the list of declining fish species is expected to lengthen due to indiscriminate disposal of sewages, unplanned developmental activities leading to degradation of rivers and habitat destruction. Considering at the current global scenario, there is continuous rise in the number of fishes that are threatened with extinction. This depressing scenario clearly indicates the global environmental crisis caused by various anthropogenic activities which should be given proper and an urgent attention to deal and resolve the issue. The present study is a significant attempt in this direction. Though this study reveals some significant information on fish fauna, a thorough study is still needed to investigate the ecology and breeding behaviours of these fishes in their natural environment so as to develop their conservation strategy. To conclude, a strong and immediate step towards any conservational measures is needed to be taken seriously by the people, policy makers, village durbars and all the stakeholders to prevent any further damage caused to the fishes and all other aquatic organisms which are still thriving in these rivers.

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REFERENCES

Allen, D.J., Molur, S., Daniel, B.A. (2010). The Status and distribution of freshwater Biodiversity in the Eastern Himalaya. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Allen, J.D., Abell, R., Hogan, Z., Revenga, C., Taylor, B.W., Welcomme, R.L., Winemiller, K. (2005). Overfishin g of inland waters. *Bioscience*, *55*, 1041–1051.

Animal Discoveries, (2009-2017). New Species and New Records. Published by the Director, Zoological Survey of India. Ministry of Environment, Forest and Climate Change. Govt. of India.

Carrizo, S.F., Jähnig, S.C., Bremerich, V., Freyhof, J., Harrison, I. He. F., Langhans, S.D., Tockner, K., Zarfl, C., D arwall, W. (2017). Freshwater megafauna: flagships for freshwater biodiversity under threat. *Bioscience*, *67,*919–927.

Darwall, W.R.T., & Vie, J.C. (2005). Identifying important sites for conservation of freshwater biodiversity: extending the speciesbased approach. *Fisheries Management and Ecology, 12*(2), 287–293.

Eschmeyer, W.N. (2012). Catalog of fishes. San Francisco (CA): California Academy of Sciences.

Gorman, O.T., & Karr, J.R. (1978). Habitat structure and stream fish communities. *Ecology*, *59*, 507-515.

Goswami, U. C., Basistha, S. K., Bora, D., Shyamkumar, K., Saikia, B., & Changsan, K. (2012). Fish diversity of North East India, inclusive of the Himalayan and Indo Burma biodiversity hotspots zones: A checklist on their taxonomic status, economic importance, geographical distribution, present status and prevailing threats. *International Journal of Biodiversity and Conservation*, *4*(15), 592-613.

Hamilton, F.B. (1822). An account of the fishes found in the river Ganges and its branches. Edinburgh & London. Fishes Ganges. pp. 1-39.

Jayaram, K.C. (1999). The Freshwater Fishes of the Indian Region. Narendra Publishing House, Delhi, India. pp. 551.

Kang, B, He. D., Perrett, L., Wang, H., Hu. W., & Deng, W. Wu. Y. (2009). Fish and fisheries in the Upper Mekong: current assessment of the fish community, threats and conservation. *Review in Fish Biology and Fisheries*, *19,* 465–480.

Molur, S., &Walker, S. (1998). Report of the workshop ‘Conservation, assessment and management plan (CAMP) for freshwater fishes of India’. Coimbatore: Zoo Outreach Organization, Conservation Breeding Specialist Group. pp.156.

Ramanujam, S.N., Manorama, M., & Dey, S. (2010). Ichthyodiversity of Meghalaya: India. *Electronic Journal of Ichthyology*, *6*(2), 15 – 26.

Sarkar, U.K., Pathak, A.K., & Lakra, W.S. (2008). Conservation of freshwater fish resources of India: new approaches, assessment and challenges. *Biodiversity Conservation*, *17*, 2495–2511.

Shannon, C.E., & Wiener, W. (1963). The mathematical theory of communication. University Illinois Press, Urbana. pp.36.

Vishwanath, W. (2002). Fishes of North East India: A Field Guide to Species Identification, Department of Life Sciences, Manipur University, Imphal, India. pp 198.

ESTIMATING WATER BEETLE DIVERSITY IN THE NORTH-EAST REGION OF INDIA (INSECTA: COLEOPTERA)

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ABSTRACT

This paper deals with the diversity and distribution of water beetles (Insecta: Coleoptera) in the Northeast region of India, comprising six states: Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura, based on the literature review and data collection data available with the Zoological Survey of India. The Northeast region contains 209 water beetle species belonging to 70 genera and 12 families, which is 27.0% of the overall diversity of Indian water beetles. Dytiscidae is the prominent family (97 species, 21 genera), followed by Hydrophilidae (49, 19), Gyrinidae (22, 6), Scirtidae (12, 5), Psephenidae (9, 5), Noteridae (7, 3), Hydraenidae (5, 5), Hydroscaphidae (3, 1), Dryopidae (2, 2), Haliplidae, Helophoridae (1, 1), and Epimetopidae (1, 1). Manipur represents the maximum number of species (84), followed by Meghalaya (83), Assam (74), Tripura (37), Nagaland (4), and Mizoram (1). The data reveals that Mizoram, Nagaland, and Tripura have a lesser faunal representation of water beetles than Assam, Meghalaya, and Manipur.

Keywords: Diversity, Myxophaga, Adephaga, Polyphaga, Distribution, Taxonomy

INTRODUCTION

Coleoptera, the most species-rich animal order on this planet, includes around 3,89,487 extant species belonging to 29,500 genera and 176 families under four suborders globally (Zhang, 2013). Over 22,303 species in 114 families have been reported from India (Chandra *et al*., 2021). Most beetles are terrestrial, whereas 3.3% of global beetle fauna (~12,600 species) inhabit aquatic ecosystems, like rivers, springs, lakes, ditches, puddles, seepages, and groundwater, in any part of their life cycle. The aquatic beetles are classified into six groups, i.e., True Water Beetles, False Water Beetles, Phytophilous Water Beetles, Parasitic Water Beetles, Facultative Water Beetles, and Shore Beetles, based on their association with aquatic life in adults and immature stages (Jäch, 1998). The suborder Myxophaga is truly aquatic, while suborder Adephaga includes eight aquatic families (Gyrinidae, Haliplidae, Meruidae, Noteridae, Amphizoidae, Aspidytidae, Hygrobiidae, Dytiscidae), out of a total of 11 families. The largest suborder, Polyphaga, consists of only 13 of the 150 families as truly aquatic, i.e., Helophoridae, Epimetopidae, Hydrochidae, Spercheidae, Hydrophilidae, Hydraenidae, Scirtidae, Elmidae, Dryopidae, Lutrochidae, Psephenidae, Cneoglossidae, and Eulichadidae (Jäch & Balke, 2008). Over 776 species of water beetles in 137 genera and 17 families under three suborders are reported from India (Chandra *et al*., 2017). Few taxonomic studies have been carried out on aquatic beetle fauna from Northeast India: Haliplidae and Gyrinidae (Vazirani, 1984), Haliplidae, Gyrinidae and Dytiscidae (Mukhopadhyay and Ghosh, 2004, 2008), Hydrophilidae (Mukhopadhyay and Sengupta, 2004, Mukhopadhyay and Ghosh, 2008). North-East is one of the ten biogeographic zones of India (Rodgers *et al*., 2002). The most recent works on different families of water beetles have been carried out by Devi *et al*. (2014) from Loktak Lake, Gogoi and Gupta (2017) from the river Brahmaputra and Chandra *et al*. (2021) from the northeast biogeographic zone. In this paper, an attempt has been made to estimate the water beetle diversity in the Northeast region of India based on the literature review and data collection data available from the Zoological Survey of India.

MATERIALS AND METHODS

Study Area The study area for the proposed study is the North-East (NE) bio-geographic zone of India, comprising Assam, Meghalaya, Nagaland, Manipur, Mizoram and Tripura states. The total landmass of the region is 1,71,341 sq. km., sharing 5.21% of the total Indian landmass. It is the transition zone between Indo-Malayan and Indo-Chinese geographical realms, and the Himalayan Mountains and Peninsular India receive the highest rainfall globally. North-East receives one of the highest rainfalls globally and is a top humid region of the country, making this biogeographic region rich in flora and fauna with unique features and endemism. Brahmaputra and Barak rivers and their tributaries are the region's freshwater sources. Loktak Lake (Manipur), Deepor Beel (Assam) and Rudrasagar

Lake (Tripura) are the Ramsar Wetland sites in the area.

Compilation of data This paper is documented based on a literature survey of published species records on Indian aquatic beetles and the specimens at the Zoological Survey of India, Kolkata. The map was prepared using the software QGIS 2.8.1.

RESULTS AND DISCUSSION

Altogether, 209 species belonging to 70 genera and 12 families are reported from the Northeast region. At the family level diversity, Dytiscidae is the family with the most species-rich (97 species, 21 genera), followed by Hydrophilidae (49 species, 19 genera), Gyrinidae (22 species, 6 genera), Scirtidae (12 species, 5 genera), Psephenidae (9 species, 5 genera), Noteridae (7 species, 3 genera), Hydraenidae (5 species, 5 genera), Hydroscaphidae (3 species, 1 genus), Dryopidae (2 species, 2 genera), Haliplidae, Helophoridae, and Epimetopidae (1 species, 1 genus each) (Table 1).

Table 1. Number of water beetle species reported in different families from the North-East along with their distribution in two biotic provinces of North-east.

S.N.	Families	Number of Species		
		North-East	**Brahmaputra Valley**	**North-East Hills**
	Order Coleoptera **Suborder Myxophaga**			
	Superfamily Sphaeriusoidea			
1.	Family Hydroscaphidae	3	-	3
	Suborder Adephaga			
2.	Family Dytiscidae	97	50	70
3.	Family Noteridae	7	-	7
4.	Family Gyrinidae	22	10	15
5.	Family Haliplidae	1	-	1
	Suborder Polyphaga **Series Staphyliniformia** **Superfamily Hydrophiloidea**			
6.	Family Hydrophilidae	49	7	43
7.	Family Helophoridae	1	-	1
8.	Family Epimetopidae	1	-	1
	Superfamily Staphylinoidea			
9.	Hydraenidae	5	1	4
	Series Scirtiformia **Superfamily Scirtoidea**			
10.	Family Scirtidae	12	3	10
	Superfamily Byrrhoidea			
11.	Family Dryopidae	2	1	1
12.	Family Psephenidae	9	1	9
	Total	**209**	**73**	**165**

Northeast Hills (9B) represents 203 species, and Brahmaputra Valley (9A) has 70 species. With regards to the distribution of the aquatic beetle from different states, Manipur represents the maximum number of species (84), followed by Meghalaya (83), Assam (74), Tripura (37), Nagaland (4), and Mizoram (1). With the distribution of each family in two biotic provinces, from Brahmaputra Valley, Dytiscidae consists of most number of species (50), followed by Gyrinidae (10), Hydrophilidae (7), Scirtidae (3), Dryopidae, Psephenidae, Hydraenidae (1 each). Families like Hydroscaphidae, Noteridae, Haliplidae, Helophoridae, Epimetopidae have no species reported from Brahmaputra Valley (Table 1). From Northeast Hills (9B), Dytiscidae has the most number of species (70), Hydrophilidae (43), Gyrinidae (15), Scirtidae (10), Psephenidae (9), Noteridae (7), Hydraenidae (4), Hydroscaphidae (3), Haliplidae, Helophoridae, Epimetopidae, and Dryopidae (1 each) (Table 1).

The data thus compiled reveals that the states such as Mizoram, Nagaland, and Tripura have a lesser faunal representation of water beetles than Assam, Meghalaya, and Manipur. Mizoram, Nagaland, and Tripura may be less explored, as evident through consultation of secondary literature compilation. Therefore, there is an urgent need to study by applying standardised data collection techniques and taxa thus collected needs to be identified and reported.

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REFERENCES

Alfred, J.R.B., Das, A.K. and Sanyal, A.K. (2001). *Ecosystems of India*, *ENVIS*, Kolkata: 1-410 (Published by Director, Zoological Survey of India).

Bouchard, P., Bousquet, Y., Davies, A.E., Alonso-Zarazaga, M.A., Lawrence, J.F., Lyal, C.H.C., Newton, A.F., Reid, C.A.M., Schmitt, M., Ślipiński, S.A. and Smith, A.B.T. (2011). Family-group names in Coleoptera (Insecta). *ZooKeys,* 88: 1-972.

Chandra, K, Gupta, D., Ghosh, J., Das, P. and Bhunia, D. (2021). Insecta : Coleoptera. In: *Faunal Diversity of Biogeographic Zones of India* : *North-East* : 377–451 (Published by the Director, Zoological Survey of India).

Chandra, K., Jaiswal, D. and Gupta, D. (2017). Insecta: Coleoptera (Aquatic Beetles). In: Chandra, K., Gopi, K.C., Rao, D.V., Valarmathi, K., Alfred, J.R.B. (Eds.) *Current Status of Freshwater Faunal Diversity in India*: 379–400 pp (Published by the Director, Zoological Survey of India).

Devi, M.B., Devi, O.S., Singh, S.D. and Singh, P.R. (2014). A preliminary survey of aquatic beetles with some new records from the freshwater lake, Loktak of Manipur, North East India. *Indian Journal of Entomol*ogy, *76*(3): 207-214.

Gogoi, A. and Gupta, S. (2017). Aquatic insect community of River Brahmaputra near Dibru Saikhowa National Park, Assam, North East India. *Journal of Entomol*ogy and *Zoology Studies*, *5*(2): 1257–1265.

Jäch, M.A. (1998). Annotated check list of aquatic and riparian/littoral beetle families of the world (Coleoptera). In: Jäch, M.A. and Ji, L. (Eds.) *Water Beetles of China*, *vol. II*. Wien: *Zoologisch-Botanische Gesellschaft in Österreich and Wiener Coleopterologenverein*, 25–42 pp.

Jäch, M.A. and Balke, M. (2008). Global diversity of water beetles (Coleoptera) in freshwater. *Hydrobiologia*, *595*: 419–442.

Mukhopadhyay, P. and Ghosh, S.K. (2004). Insecta : Coleoptera : Adephaga (Fam. Haliplidae, Fam. Gyrinidae and Fam. Dytiscidae). In: *Fauna of Manipur*, *State Fauna Series*, *10*(Part-2): 359-370 (Published by Director, Zoological Survey of India).

Mukhopadhyay, P. and Ghosh, S.K. (2008). Insect: Aquatic Coleoptera (family: Gyrinidae, Dytiscidae and Hydrophilidae). *Fauna of Kopili Hydro Electic Project Site*, *Umrong* - *North Cachar Hills District, Assam and Jaintia Hills District, Meghalaya*. Wetland Ecosystem Series, *8*: 51-57.

Mukhopadhyay, P. and Sengupta, S. (2004). Insecta: Coleoptera: Polyphaga: Hydrophiloidea: Hydrophilidae. In: *Fauna of Manipur, State Fauna Series*, *10*: 449-458. (Published by Director, Zoological Survey of India).

Rodgers, W.A., Panwar, H.S. and Mathur, V.B. (2002). *Wildlife Protected Area Network in India*: *A Review*, *Executive Summary*. *Wildlife Institute of India*, *Dehradun*: 1-51.

Vazirani, T.G. (1984). *The Fauna of India. Coleoptera. Family Gyrinidae and family Haliplidae*. Calcutta: Zoological Survey of India, xvi+140pp.

Zhang, Z.Q. (2013). Phylum Arthropoda. In: *Animal Biodiversity: an outline of higher-level classification and survey of taxonomic richness* (Addenda 2013), (Ed. Zhang Zhi-Qiang). *Zootaxa*, *3703*: 1-82.

A NEW SPECIES OF THE GENUS *GARRA* (TELEOSTEI: CYPRINIDAE) FROM THE BRAHMAPUTRA DRAINAGE, NORTHEAST INDIA

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ABSTRACT

Garra kamengensis, new species, is described from the Kameng River of Brahmaputra drainage in Arunachal Pradesh, India. It has a prominent unilobed, quadrate proboscis, and is distinguished from all its congeners of the Brahmaputra and adjacent river drainages in having 7–8 small to medium-sized unicuspid and 2 large tetracuspid tubercles on the anterior marginal aspect of the proboscis; a prominent transverse lobe with 20–25 small to medium-sized unicuspid tubercles; a deep, concave and creased depressed rostral surface, an anus positioned slightly closer to the anal-fin origin (distance from anus to anal fin 44.2–45.1% of the pelvic-anal distance); 36–37 lateral-line scales; and 12 circumpeduncular scales.

Keywords taxonomy, morphology, new Labeonini, freshwater fish, Arunachal Pradesh

INTRODUCTION

The genus *Garra* Hamilton comprises of small- to medium- sized cyprinid fishes, primarily characterized by the presence of a modified lower lip forming a gular disc (Talwar & Jhingran 1991; Chen *et al*. 2009). These benthic fishes usually inhabit swift-flowing rivers or mountain streams. With some 176 nominal species (references in Fricke *et al*. 2020), the genus has a wide distribution from Sub-Saharan Africa to Borneo, through the Arabian Peninsula, South Asia, and southern China (Zhang & Chen 2002).

The Kameng River, a right bank tributary to the Brahmaputra drainage, is the major river system in East Kameng and West Kameng districts of Arunachal Pradesh, northeast India. It is a complex of several tributaries originating from the Arunachal Himalayas, descending through deep gorges and dense forests in Arunachal Pradesh, and finally draining into the Brahmaputra in Assam (India) as the Jia Bhoroli. Ichthyofaunal surveys of the Kameng River in Arunachal Pradesh revealed an unnamed species of *Garra*, which is described herein as *Garra kamengensis*, new species.

MATERIALS AND METHODS

Measurements were made point-to-point on the left side of the specimens, whenever possible, with a digital slide calliper, and the data recorded to one-tenth of a millimetre. Measurement of body parts and subunits of the head are expressed in proportions of standard length (SL) and head length (HL), respectively. Counts, measurements, and snout terminology follow Nebeshwar & Vishwanath (2013). The gular disc width is measured as the distance between the roots of two maxillary barbels, and its length as the distance from the anterior mid-point of its anterior margin to the posterior mid-point of its posterior margin. Counts were made under a Leica S8APO stereo-zoom microscope. Dorsal and anal-fin ray counts follow Kottelat (2001). Vertebral counts were made from X-radiographs. Abdominal vertebrae include the Weberian complex, assumed as four. Terminology of oromandibular structure follows Kottelat (2020). Numbers in parentheses after a count represent the frequency of that count. Type specimens are deposited at the Gauhati University Museum of Fishes (GUMF), Assam.

Published information used for comparisons: Nebeshwar & Vishwanath (2013) for *G. arunachalensis*; Thoni *et al*. (2016) for *G. bimaculacauda*; Sun *et al*. (2018) for *G. bispinosa*; Deng *et al*. (2018) for *G. dengba*; Gong *et al*. (2018) and Sun *et al*. (2018) for *G. gravelyi*; Nebeshwar *et al*. (2012) for *Garra kalpangii*; Gong *et al*. (2018) and Sun *et al*. (2018) for *G. motuoensis*; Moyon & Arunkumar (2018) for *G. moyonkhulleni*; McClelland (1838) for *G. nasuta*; Thoni *et al*. (2016) for *G. parastenorhynchus*; Gong *et al*. (2018) and Sun *et al*. (2018) for *G. qiaojiensis*, Nebeshwar & Vishwanath (2013) for *G. quadratirostris*; Gong *et al*. (2018) and Sun *et al*. (2018) for *G. rotundinasus* and *G. surgifrons,* Rath *et al*. (2019) for *G. simbalbaraensis*; Gurumayum & Kosygin (2016) for *G. tamangi*; Gong *et al*. (2018) and Sun *et al*. (2018) for *G. yajiangensis*.

RESULTS

***Garra kamengensis*, new species**
(Figure 1, Table 1)

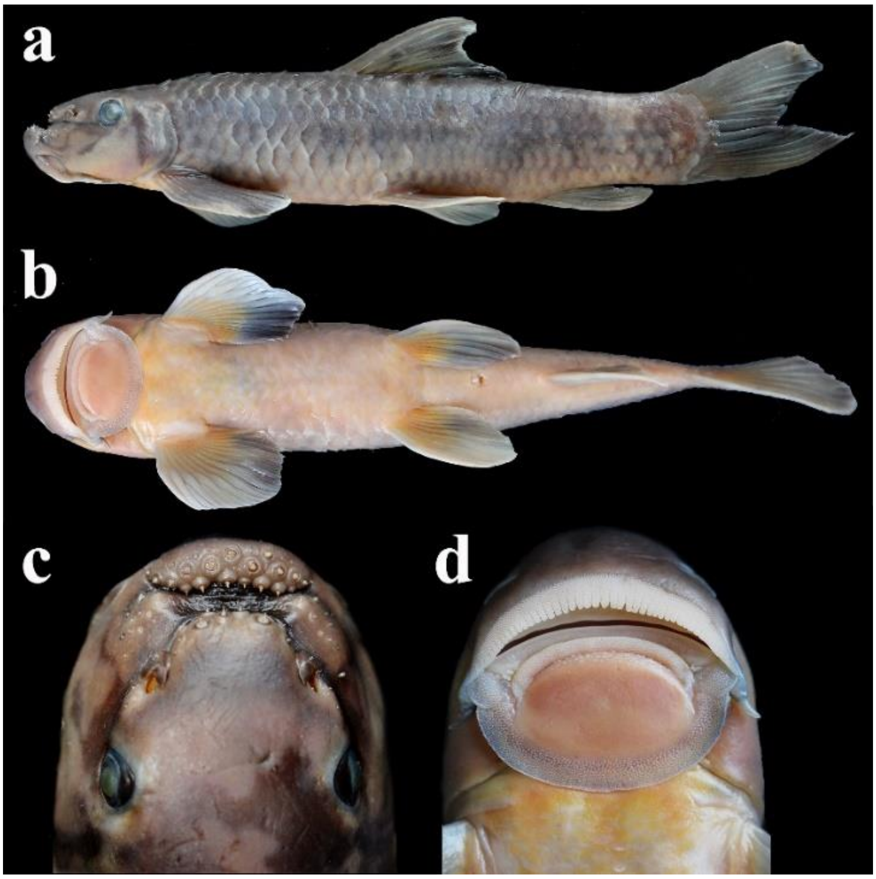

Figure 1 *Garra kamengensis*, GUMF 601, holotype, 144 mm SL; India: Arunachal Pradesh: West Kameng District: Pachai stream of Kameng River (Brahmaputra drainage); **a,** lateral, and **b,** ventral views; **c,** unilobed quadrate proboscis; **d,** gular disc.

Holotype. GUMF 601, 144 mm SL; India: Arunachal Pradesh: East Kameng District: Pachai stream of Kameng River (Brahmaputra drainage), about 2 km upstream of Seppa town; 27°23'20" N, 93°03'20" E, 400 m asl; A. Dey & party, 16 February 2017. ***Paratypes***. GUMF 0602/3, 3 specimens, 105–131 mm SL, data same as holotype.

Diagnosis. *Garra kamengensis* is a member of the proboscis-bearing species group. It is distinguished from other members of this group in the Brahmaputra and neighbouring drainages in having a prominent unilobed, quadrate proboscis. It is distinguished from members having a unilobed, quadrate proboscis, viz., *G. chindwinensis*, *G. motuoensis*, *G. quadratirostris*, *G. qiaojiensis* and *G. yajiangensis*, in having two large tetracuspid (vs. unicuspid) tubercles on the anterior margin of the proboscis. It is further distinguished from other proboscis-bearing congeners in having a combination of the following characters: a deep transverse groove with small- to medium-sized, irregularly-distributed unicuspid tubercles; creased, concave depressed rostral surface; bulging lateral surfaces with 6–14 tubercles on each; an ellipsoid pulvinus (width 43.2–47.5% HL; length 29.7–30.3% HL); the anus slightly closer to anal-fin origin than pelvic-fin origin (distance from anus to anal fin 44.2–45.1% of pelvic-anal distance); and 36–37 lateral line scales.

Description. Body elongate, nearly cylindrical in cross-section, compressed caudad. Dorsal body profile rising gently from occiput to dorsal-fin origin, descending moderately towards caudal-fin base; ventral profile almost straight, flattened to anal-fin origin, then ascending concavely up to caudal-fin base. Body deepest at dorsal-fin origin (body depth: 18.1 –20.1% SL).

Head large, depressed; its length about one-fifth of standard length. Eye positioned dorso-laterally in upper half of head, closer to posterior extremity of operculum than snout tip; orbit nearly one-sixth of head length. Interorbital space slightly concave. Snout moderately rounded; transverse lobe with 20–25 small- to medium-sized unicuspid tubercles, demarcated posteriorly by a deep transverse groove and depressed rostral surface ensuing into a conspicuous, tuberculated, quadrate proboscis before nostrils (Fig. 1c). Proboscis maintaining the same angle as nape and slightly projecting forward, with 2 large tetracuspid acanthoid tubercles on its anterior margin, and 7–8 small- to medium-sized unicuspid tubercles on its antero-ventral aspect (Fig. 2a & 2b). Depressed rostral surface concave, creased, without tubercles. Lateral surfaces of snout elevated, lobular, with 6–14 irregularly-arranged tubercles. Sublachrymal groove long, connected to rostral cap groove.

Mouth with two pairs of barbels: rostral barbel anterolaterally located, shorter than eye diameter; maxillary barbel at corner of mouth, shorter than rostral. Rostral cap well-developed, with crenulated margin and numerous tiny papillae, separated from upper jaw by a deep groove, continuous with lower lip posteriorly. Edges of upper and lower jaws covered with thin horny sheath. Upper lip absent; lower lip modified into an ellipsoid gular disc (Fig. 1d). Disc wider than long, its lateral and posterior margins with profuse papillae; anterior margin modified into a transverse, fleshy, bulging torus, densely-covered with tiny papillae. Labellum fused with labrum. Torus separated from lower jaw by deep groove; posteriorly bordered in notch with pulvinus. Anterior margin of pulvinus with regularly-arranged small papillae; latero-posterior margins free, papillate; posteriormost margin extending beyond the vertical through posterior margin of eye.

Dorsal fin with iv, 8½ (4) rays, first branched ray longest, tip of last branched ray not extending beyond the vertical through anal-fin origin; its distal margin concave, origin closer to snout tip than to caudal-fin base. Pectoral-fin with i, 14 (2) or 15 (2) rays; shorter than head length; distal tip not reaching pelvic-fin origin or vertical through dorsal-fin origins. Pelvic fin with i, 8 (3) or 9 (1); its tip surpassing anus; inserted vertically beneath of third or fourth branched dorsal-fin ray; positioned slightly closer to caudal-fin base than to snout tip; fin length less than head length and subequal to pectoral-fin length. Anal fin with iii, 5½ (4) rays; its origin closer to pelvic-fin origin than to caudal-fin base; distal tip not reaching caudal fin base. Anus slightly closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked with 10+9 principal rays; tip of upper lobe pointed; lower lobe blunt, slightly longer than upper lobe. Lateral line complete, with 36 (2) or 37 (2) pored scales. Transverse scale rows above lateral line 3½ (4); between lateral line and pelvic-fin origin 2½ (4); between lateral line and pelvic-fin origin 3 (4). Circumpeduncular scale rows 12 (4). Predorsal scales 11 (4). Chest and belly scaled; scales on chest small, embedded. One long axillary scale at base of pelvic fin, its tip reaching posterior end of pelvic-fin origin. Anus separated by 5 scales from anal-fin origin. Dorsal-fin base scales 6 (3) or 7 (1); anal-fin base scales 4 (4).

Vertebrae: 35 (1) (holotype ZSI A/F, 144 mm SL) or 36 (1) (paratype GUMF 0601/3, 105.0 mm SL); comprising 23 (1) or 24 (1) abdominal and 12 (2) caudal.

Coloration. In preserved specimens, head and dorsum dark brown to greyish black, fading to a lighter shade on flank; creamy-white ventrally. Dorsal and caudal fins greyish-black with darker interradial membranes. Pectoral and pelvic fins dark grey dorsally; proximal halves pale yellow ventrally, grey distally. Pulvinus pale brown.

Geographical distribution. *Garra kamengensis* is known only from its type locality, the Pachai stream, which empties to the Kameng River (Brahmaputra drainage) at Seppa, East Kameng District, Arunachal Pradesh, India.

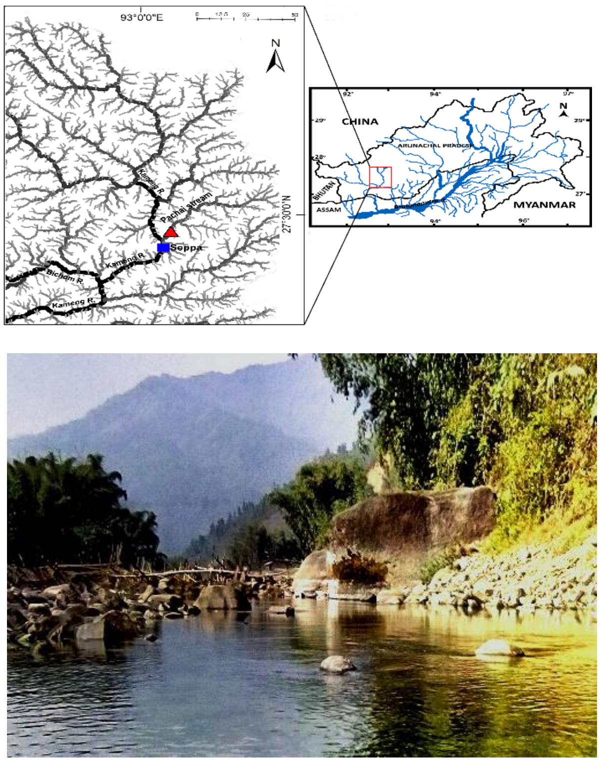

Figure 2 a. Map showing type locality (filled triangle) of *Garra kamengensis*, **b.** Pachai stream of Kameng River, the type locality of *Garra kamengensis*

Etymology. The new species is named after the Kameng River.

DISCUSSION

Members of *Garra* exhibit a conservative body plan with only modest (or, with very few exceptions, the absolute absence of) variations in their basic colour pattern and meristics (Kullander & Fang 2004; Rahman *et al*. 2016). However, the characters of the snout, viz. proboscis shape and size, tubercle number and shape and gular disc position, are of taxonomic significance in delimiting species of *Garra* (Kullander & Fang, 2004; Nebeshwar & Vishwanath ,2013). Based on variations of the snout characters, the Himalayan and Indo-Burman *Garra* are clustered in five species groups (*sensu* Nebeshwar & Vishwanath, 2017)—smooth snout species group, transverse lobe species group, rostral flap species group, rostral lobe species group and proboscis species group. *Garra kamengensis*, by virtue of its prominent unilobed, quadrate proboscis, is a member of the "proboscis-bearing species" group.

Garra kamengensis is most similar to *G. quadratirostris* in having a prominent unilobed, quadrate proboscis. Nebeshwar & Vishwanath (2013) described *G. quadratirostris* from the Teesta, Sikkim, Deopani and Mibung River of the Brahmaputra drainage Arunachal Pradesh (Nebeshwar & Vishwanath 2013). Based on 20 specimens ranging 69.5–132 mm SL, *G. quadratirostris* is characterized by having 3 simple rays of the dorsal fin, a faint blackish spot immediately anterior to the upper angle of gill opening and a bulging depressed rostral surface. The four specimens of *G. kamengensis* fall within the corresponding standard lengths of *G. quadratrirostris*, and have 4 simple dorsal fin rays, lack the blackish spot immediately anterior to the upper angle of gill opening and a concave and creased depressed rostral surface. Moreover, the holotype and additional specimens of *G. quadratirostris* collected from the Kameng River clearly show the presence of two large unicuspid tubercles on the anterior margin of the proboscis. Thus, the former can be easily distinguished from the latter in having (vs. lacking) two large tetracuspid tubercles on the anterior margin of the proboscis. Additionally, *G. kamengensis* differs from *G. quadratirostris* in having a shallower body (body depth at dorsal-fin origin 18.1–20.1% SL vs. 20.3–28.2) and head (head depth at eye 11.3–12.8 % SL vs. 14.0–15.4); a longer snout (59.3–63.4% HL vs. 51–59); a wider gular disc (width 68.1–69.8% HL vs. 57–65); and a shorter dorsal-fin base (15.7–17.3% SL vs. 17.1–18.4) and pelvic-anal distance (17.5–20.4% SL vs. 23.7–26.1).

Four species, viz. *Garra chindwinensis*, *G. motuoensis*, *G. qiaojiensis* and *G. yajiangensis*, also possess a quadrate proboscis. However, *G. kamengensis* is immediately distinguished from them in possessing (vs. lacking) two large tetracuspid tubercles on the anterior margin of the proboscis. Additionally, the new species can be distinguished from them by having a combination of the following characteristics: an unilobed (vs. slightly bilobed in *G. chindwinensis*, *G. motuoensis* and G. *yajiangensis*) proboscis; a more anteriorly-placed anus (distance from the anus to anal-fin origin 44.2–45.1% of the pelvic-anal distance) (vs. 19–24% in *G. yajiangensis*); 36–37 lateral-line pored scales (vs. 34 in *G. chindwinensis*, and 34 in *G. qiaojiensis*); a continuous sublachrymal groove with the lateral groove of rostral cap (vs. discontinuous in *G. chindwinensis*); and a longer snout (59.3–63.4% HL vs. 42–49% in G. *motuoensis*, and 43–49% in *G. yajiangensis*).

The new species is further distinguished from its congeners with a prominent proboscis as follows: a unilobed, quadrate (vs. unilobed, rounded in *G. simbalbaraensis*; bilobed in *G. arunachalensis*, *G. birostris*, *G. bispinosa*, *G. cornigera*, *G. moyonkhulleni* and *G. ranganenesis*; slightly bilobed in *G. biloborostris* and *G. gotyla*; trilobed in *G. koladynensis*, *G. paratrilobata*, *G. tamangi*, *G. trilobata* and *G. surgifrons*; and clubbed in *G. clavirostris*, *G. parastenorhynchus* and *G. substrictorostris*) proboscis; two tetracuspid tubercles on the anterior margin of the proboscis (vs. unicuspid tubercles in *G. arunachalensis*, *G. bispinosa*, *G. cornigera*, *G. gotyla*, *G. parastenorhynchus*, *G. ranganenesis* and *G. surgifrons*); a more anteriorly-placed anus (distance from the anus to anal fin 44.2–45.1 % of the pelvic-anal distance vs. 19–25% in *G. arunachalensis*, 17.8–26.2% in *G. biloborostris*, 21–30% in *G. birostris*, 22–28% in *G. gotyla*, and 15.4–22.7% in *G. paratrilobata*); 12 cicumpeduncular scales (vs. 14 in *G. moyonkhulleni*; and 16 in *G. biloborostris*, *G. birostris*, *G. bispinosa*, *G. gotyla*, *G. koladynensis*, *G. parastenorhynchus*, *G. simbalbaraensis*, *G. substrictorostris* and *G. surgifrons*); the presence of an labellum of the lower lip (vs. absent in *G. arunachalensis*); 36–37 lateral-line pored scales (vs. 32–33 in *G. simbalbaraensis*; 33 in *G. biloborostris* and *G. cornigera*; and 33–34 in *G. clavirostris*, *G. koladynensis*, *G. paratrilobata* and *G. substrictorostris*; and 34 in *G. moyonkhulleni*); a lesser body depth (18.1–20.1% SL vs. 22.4–25.4% in *G. simbalbaraensis*); and a longer adhesive disc (disc length 44.8–48.4% HL vs. 32–42% in *G. cornigera*).

COMPARATIVE MATERIAL EXAMINED

G. arunachalensis: MUMF 4304, holotype, 121.0 mm SL; Deopani River at Roing, Lower Divang Valley district, Arunachal Pradesh, India.
G. biloborostris: MUMF 22017, holotype, 92.4 mm SL; Kanamakra River, Chirang district, Assam, India.
G. birostris: MUMF 4302, holotype, 102.0 mm SL; Dikrong River at Doimukh, Papum Pare district, Arunachal Pradesh, India.
G. chindwinensis: ZSI FF 5906, holotype, 120 mm SL, Laniye River near Laii, Senapati district, Manipur, India.
G. clavirostris: MUMF 22004, holotype, 117.5 mm SL; Dilaima River at Boro Chenam Village below the confluence of Dilaima and Dehangi (misspelled as Dihandi), Assam, India.
G. cornigera: MUMF 12061, holotype, 76.0 mm SL; Sanalok River, Ukhrul district, Manipur, India.
G. gotyla: MUMF 4300, neotype, 104.3 mm SL; Tista River at Rangpo, Sikkim, India.
G. koladynensis: MUMF 4313, holotype, 130.6 mm SL; Koladyne River at Kawlchaw, Lawntlai district, Mizoram, India.
G. paratrilobata: MUMF 22050, holotype, 137 mm SL; Leimatak River at Awangkhul village, Noney district, Manipur, India.
G. quadratirostris: MUMF 4306, holotype, 108.0 mm SL; Tista River at Rangpo, Sikkim, India. GUMF uncatalogued, 112 –121 mm SL; 4 exs., Kameng River at Kafla, Arunachal Pradesh, India.
G. substrictorostris: MUMF 22034, holotype, 173.0 mm SL; Leimatak River, Chura-Chandpur district, Manipur, India.
G. tamangi: ZSI FF 5423, paratypes, 79–100 mm SL; Dikrong River at Hoj, Arunachal Pradesh, India.
G. trilobata: MUMF 12051, holotype, 118.5 mm SL; Sanalok River, Ukhrul district, Manipur, India.

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REFERENCES

Chen, Z.-M. Zhao, S. & Yang, J.-X (2009) A new species of genus *Garra* from Nujiang River basin, Yunnan, China (Teleostei: Cyprinidae). *Zoological Research*, 30, 438–444.

Deng, S.-Q., Cao, L. & Zhang, E. (2018) *Garra dengba*, a new species of cyprinid fish (Pisces: Teleostei) from eastern Tibet, China. *Zootaxa*, 4476 (1), 94–108. https://doi.org/10.11646/zootaxa.4476.1.9

Fricke, R., Eschmeyer, W. N. & van der Laan, R. (Eds) (2020) Eschmeyer's Catalog of fishes: Genera, species, references. (Available from: http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). Electronic Version accessed 04 March 2020.

Gong, Z., Freyhof, J., Wang, J., Liu, F., Lin, P., Jiang, Y. & Liu, H. (2018) Two new species of *Garra* (Cypriniformes: Cyprinidae) from the lower Yarlung Tsangpo River drainage in southern Tibet, China. *Zootaxa*, 4532 (3), 367–384. https://doi.org/10.11646/zootaxa.4532.3.3

Gurumayun, S.D. & Kosygin, L. (2016) *Garra tamangi*, a new species of cyprinid fish (Teleostei: Cypriniformes) from Arunachal Pradesh, northeastern India. *Species*, 17 (55), 84–93.

Kottelat, M. (2001) *Fishes of Laos*. Wildlife Heritage trust Publications, Colombo, 196 pp.

Kullander, S.O. & Fang, F. (2004) Seven new species of Garra (Cyprinidae: Cyprininae) from the Rakhine Yoma, southern Myanmar. *Ichthyological Exploration of Freshwaters*, 15 (3), 257–278.

McClelland, J. (1838) Observations on six new species of cyprinidae with an outline of a new classification of the family. *Journal of Asiatic Society of Bengal*, 7, 941–948.

Menon, A.G.K. (1964) Monograph of the cyprinid fishes of the genus *Garra* Hamilton. *Memoirs of the Indian Museum*, 14, 173–260.

Moyon, W.A. & Arunkumar, L. (2018) *Garra moyonkhulleni*, a new labeonine species (Cyprinidae: Labeoninae) from Manipur, Northeastern India. *International Journal of Fisheries and Aquatic Studies*, 6 (5), 107–115.

Nebeshwar, K. & Vishwanath, W. (2013) Three new species of *Garra* (Pisces: Cyprinidae) from north-eastern India and redescription of *G. gotyla*. *Ichthyological Exploration of Freshwaters*, 24 (2), 97–120.

Nebeshwar, K. & Vishwanath, W. (2017) On the snout and oromandibular morphology of genus *Garra*, description of two new species from the Koladyne River basin in Mizoram, India, and redescription of *G. manipurensis* (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, 28 (1), 17–53.

Nebeshwar, K., Bagra, K. & Das, D.N. (2012) *Garra kalpangi*, a new cyprinid fish species (Pisces: Teleostei) from upper Brahmaputra basin in Arunachal Pradesh, India. *Journal of Threatened Taxa*, 4 (2), 2353–2362. https://doi.org/10.11609/JoTT.o1703.2353-62

Rahman, Md.M., Mollah, A.R., Norén, M. & Kullander, S.O. (2016) *Garra mini*, a new small species of rheophilic cyprinid fish (Teleostei: Cyprinidae) from southeastern hilly areas of Bangladesh. *Ichthyological Exploration of Freshwaters*, 27 (2), 173–181.

Rainboth, W.J. (1991) Cyprinid fishes of Southeast Asia. In: Winfield, I.J., Nelson, J.S. (Eds.) Cyprinid Fishes: Systematics, Biology and Exploitation. Chapman and Hall, London, pp. 156–210.

Rath, S., Shangningam, B. & Kosygin L. (2019) *Garra simbalbaraensis*, a new species of cyprinid fish (Teleostei: Cyprinidae) from Himachal Pradesh, India. *Zootaxa*, 4652 (3), 487–496.

Roberts, T.R. (1989) The freshwater fishes of western Borneo (Kalimantan, Barat, Indonesia). *Memoirs of the California Academy of Sciences*, 14, 1–210.

Sun, C., Li, X., Zhou, W. & Li, Fi. (2018) A review of *Garra* (Teleostei: Cypriniformes) from two rivers in West Yunnan, China with description of a new species. *Zootaxa*, 4378 (1), 49–70. https://doi.org/10.11646/zootaxa.4378.1.3

Talwar, P.K. & Jhingran, A.G. (1991) *Inland fishes of India and adjacent Countries*. Oxford & IHB Publishing Co., New Delhi, 541 pp

Tamang, L., Sinha, B., Abujam, S. & Kumar, R. (2019) *Garra ranganensis*, a new cyprinid fish (Teleostei: Cypriniformes) from Arunachal Pradesh, northeastern India. *Species*, 20, 59–71.

Thoni, R.J., Gurung, D.B. & Mayden, R.L. (2016) A review of the genus *Garra* Hamilton 1822 of Bhutan, including the description of two new species and three additional records (Cypriniformes: Cyprinidae). *Zootaxa*, 4169 (1), 115–132. https://doi.org/10.11646/zootaxa.4169.1.5

Zhang, E. & Chen, Y.Y. (2002) *Garra tengchongensis*, a new cyprinid species from the upper Irrawaddy River basin in Yunnan, China (Pisces: Teleostei*). Raffles Bulletin of Zoology*, 50, 459–464.

Table 1 Morphometric data of the holotype (GUMF 601) and three paratypes (GUMF 0602/3) of *Garra kamengensis*, new species (*: data of holotype included in range; SD: standard deviation)

Measurements	**Holotype**	**Range***	**Mean**	**SD**
Standard length (in mm)	144	105–144	–	–
In % SL				
Body depth	19.7	18.1–20.1	19.3	0.9
Head length	24.2	23.2–24.5	23.7	0.8
Head depth at nape	15.6	14.0–15.6	15.0	0.7
Head depth at eye	12.6	11.3–12.8	12.0	0.8
Head width	20.4	18.0–20.4	19.4	1.1
Body width at anal-fin origin	10.4	10.4–11.2	10.8	0.3
Body width at dorsal-fin origin	18.1	17.0–18.1	17.5	0.5
Caudal peduncle length	15.4	15.5–17.1	16.2	0.7
Caudal peduncle depth	13.4	12.5–14.1	13.3	0.6
Dorsal-fin base length	15.6	15.7–17.3	16.4	0.9
Dorsal-fin length	22.8	22.3–22.8	22.5	0.2
Pectoral-fin length	21.4	19.5–21.4	20.4	0.8
Pelvic-fin length	19.9	19.2–20.8	19.9	0.7
Anal-fin base length	8.3	7.1–9.3	8.3	0.9
Anal-fin length	18.8	17.2–19.7	18.6	1.0
Predorsal length	48.1	45.9–51.9	49.2	2.7
Prepectoral length	20.9	20.3–25.3	22.5	2.3
Prepelvic length	52.6	50.9–59.1	53.5	3.8
Pre anus length	65.1	64.4–74.6	67.3	4.8
Preanal length	76.1	75.6–85.4	78.2	4.8
Pelvic anal distance	18.2	17.5–20.4	19.0	1.4
In % of pelvic anal distance				
Distance from anus to anal fin	45.1	44.2–45.1	44.7	0.4
In % of HL				
Snout length	60.1	59.3–63.4	60.6	1.9
Eye diameter	15.2	15.2–17.3	16.7	1.2
Inter-orbital distance	49.1	46.4–49.1	47.7	1.1
Gular disc width	69.8	68.1–69.8	69.1	0.8
Gular disc length	44.4	44.4–48.4	46.3	1.8
Pulvinus width	47.5	43.2–47.5	45.0	1.9
Pulvinus length	29.7	29.7–30.3	29.9	0.3

MAHSEER FISHES: KING OF RIVERS: DIVERSITY AND CONSERVATION STATUS IN MANIPUR

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ABSTRACT

Mahseer or King of Rivers comprises three genera namely *Neolissochilus, Tor* and *Nazirator* under the family Cyprinidae. Mahseers are very attractive sport-fish with excellent food value fetching high market price and are potential candidate for aquaculture as well. A preliminary study on the Mahseers of Manipur revealed the occurrence of two genera which are *Tor* and *Neolissochilus*. The two genera are represented by eight species viz. *Tor putitora, T. tor, T. mosal*, *T. barakae* and *Neolissochilus stracheyi, N. paucisquamata, N. hexagonolepis*, *N. hexastichus* that are found in the two river basins draining the state, the Barak and the Chindwin. As per recent IUCN report, Mahseer is considered as a threatened species and hence needs special attention in terms of conservation.

Keywords: *Tor*; *Neolissochilus*; Cyprinidae; Conservation

INTRODUCTION

In Hindi, *Maha* means greatness and *Seer* means head; literally, mahseer means having a strong and large head. Mahseers known as the king of rivers, are amongst the largest scaled carp. They are classified into three genera: *Tor, Neolissochilus,* and *Naziritor* under the Cyprinidae family. Mahseers are attractive for sport fishing and commercially valuable as highly esteemed food. Unfortunately, the population of mahseer in waterbodies is decreasing due to habitat destruction caused by overfishing, pollution and increasing unregulated release of artificially bred stock of a very limited number of species has led to the near extinction of these species (Pinder *et al*., 2019 & Sarma *et al*., 2018). The focus of this paper is to study the taxonomic ambiguities within its genus and species and its variation in Manipur.

MATERIALS AND METHODS

Specimens were collected the following traditional methods using nets, traps and electro-fishing equipment and also bought from local fishermen. The specimens were fixed in 10% formalin as voucher specimens and 70% ethanol for longer preservation. Prior to fixation, small muscle and fin tissues were excised whichwere further preserved in 95% absolute ethanol. Measurements were made point to point using digital caliper. Meristic counts and morphometric measurements were done following Hubbs and Lagler (1964) and Kottelat (2001).

RESULTS

Collectively eight species of mahseer viz., *Tor putitora, T. tor*, *T.mosal, T. barakae*, *Neolissochilus stracheyi, N. hexagonolepis, N. paucisquamata* and *N. hexastichus* were found in the river basins of Barak and the Chindwin.

Genus *Tor* (Gray 1834)

Among the three genera of mahseers, the genus *Tor* has been considered as the "true mahseers" based on the presence of morphological structure of the median lobe in comparison to the other two genera (Pinder *et al*., 2019). Generally, *Tor* species are characterized by compressed and elongated body, a strong and large cycloid scale, a large mouth, and a large tail in addition to strong muscles and fins.

Tor putitora (Hamilton, 1822)

This species is characterised by an elongated and nearly straight body, a small mouth with lower jaw slightly shorter than the upper jaw, and a deeply forked caudal fin. The colour of this species appears greenish and silvery on the side of the body, which then turns reddish yellow or golden on the anal and pectoral fin.

Tor tor (Hamilton, 1822)

It is commonly known as "Red fin" or "Deep body" mahseer. The prominent characteristic that differentiate *Tor tor* from other *Tor* species is its big head (23.53-29.41% SL), large scales, sub-terminal mouth with an interrupted fold of the lower lip, two pairs of large barbels, and lateral line scales. The colour of this species is silvery green or greyish green dorsally, with pinkish sides replaced by greenish gold above and light olive green below, lower fin reddish yellow.

***Tor mosal* (Hamilton, 1822)**
Tor mosal is also known as the copper mahseer due to its near reddish coloration on the anal and pectoral fin, which resembles *T. putitora.* However, the head length of this species is distinctively shorter than *T. putitora*. It is diagnosed by having 24-26 lateral line scales; head longer than body depth at dorsal fin origin; terminal mouth position; long lower median lobe; a delicate yellowish shade on the lower body with caudal reddish orange.

***Tor barakae* (Arun Kumar & Basudha, 2003)**
Tor barakae is different from other congeners by having dorsal fin inserted nearer the base of caudal fin, opposite or slightly in advance of ventral fin; dorsal spine length shorter to the body depth, weak and smooth; head length shorter than body depth, pectoral fin not reaching pelvic fin. The back-body colour of this species is dark, greyish brown, belly is white and scales have black margin.

Genus *Neolissochilus* (Rainboth, 1985)
Neolissochilus was described as a new genus by Rainboth (1985). It is characterized by the development of a sharp, keratinous lower jaw, the inter-mandibular space being broader than the mandible, long maxillary and rostral barbels, thick lips, not hypertrophied, and 2-6 long and slender gill rakers on epibranchial segment and 7-12 gill rakers on the ceratobranchial segment of the anterior side of the first arch.

***Neolissochilus stracheyi* (Day, 1871)**
The unique characteristic of this species is the presence of black lateral stripes; smooth and non-osseous last simple dorsal ray, large patch of 8-10 tubercles on side of snout and below eyes. Small eyes located anterior to half of head, not visible from ventral surface. In live, the color of this species is body silvery with golden tinge, dorsal surface dark and ventral surface white.

Neolissochilus hexagonolepis (McClelland, 1839*)*
The body of this species has a sharp truncate lower jaw edge in comparison to the lower jaw blunt in *N. hexasticus* and *N. stracheyi);* mouth subterminal with thick lips in comparison to smooth rounded mouth in *N. paucisquamata* and in *N. stracheyi*; subterminal mouth in *N. hexasticus*; lower labial fold widely interrupted in middle(vs. lower labial fold continuous by a very narrow post labial fold in *N. hexasticus;* lower labial fold interrupted in *N. stracheyi);* lower lobe somewhat more pointed than upper. In live, the scale above lateral line is coppery colored with bronze-green at base and scales below silvery white lateral line. All fins deep slate paling towards margin. Juveniles have darker dorsum and a blackish spot at the base of caudal fin.

Neolissochilus hexastichus (Mc Clelland, 1839*)*
The prominent characteristics that differ from other species is the lower labial fold continuous by a very narrow post labial groove; inter-scale areas from lateral line scale row of 25 (vs. 21-23 in *N. paucisquamata*; 25-26 in *N. stracheyi*; 27-30 in *N. hexagonolepis*) up to mid-dorsum spotted with somewhat rounded, dark brown blotch which are distinct on lateral line scale row. Dorsal parts of head and body is greenish gray in colour with reddish yellow below. Distal margin of all fins is reddish.

Neolissochilus paucisquamata (Smith, 1945)
This species has a strongly compressed body; smoothly rounded mouth; dorsal fin inserted nearer to tip of snout than to caudal-fin base and its last unbranched ray non-osseous and slender. In live, the body are silvery, scales with a dark basal crescent and fins hyaline.

Table 1: List of mahseer, distribution and conservation status as per IUCN Red List of Threatened Species (2022).

Sl. No.	Name of the species	Distribution	IUCN status
1	*Tor putitora*	India: Manipur- Barak River, Nheng Tamenglong	EN
2	*Tor tor*	India: Manipur- Barak River, Nheng, Tamenglong, Tuila River Churachandpur.	DD
3	*Tor mosal*	India: Manipur- Barak River.	DD
4	*Tor barakae*	India: Barak River drainage, Manipur endemic.	NT
5	*Neolissochilus stracheyi*	India: Manipur-Dutah River,Chindwin drainage	LC
6	*Neolissochilus hexagonolepis*	India: Manipur-Tuivai River (Barak basin)	NT
7	*Neolissochilus hexastichus*	India: Manipur-Barak River, Vanchengphai (Brahmaputra basin)	NT
8	*Neolissochilus paucisquamata*	India: Manipur- Khuga River (Chindwin basin)	LC

NE not evaluated; LC least concern; NT near threatened; VU vulnerable; EN endangered; CR critically endangered; DD data deficient.

DISCUSSION

Mahseer- King of rivers are also called "the Tigers of the river" due to their fierce fighting nature at the time of angling which acts as means of recreation. Mahseer is also listed among the 20 "Mega fishes of the world" because of its size which exceeds 50kg. They have various importance which attracts the attention of conservationist however they are in great danger due to the declining trend of their population. There's a huge ecological knowledge gape about the importance of this fish. The IUCN-Red List of threatened species has categorized a majority of Indian mahseers as threatened, and a few as endangered. The conservation status of mahseer found in Manipur as per IUCN Red List of Threatened Species viz. *Tor putitora* (EN); *T. tor* & *T. mosal* (DD); *T. barakae*, *Neolissochilus stracheyi* & *N. paucisquamata*(LC) and *N. hexagonolepis* & *N. hexasticus*(NT). Morphological variations in mahseer are precise as to be difficult to analyze from species to species, which leads to confusion in the identification of species. Measures should be taken to conserve the ecological conditions within the natural range of mahseer. Awareness through programs and seminars for the formulation as well as the implementation of wide holistic conservation measures are essential for the conservation and development of fisheries. In doing that, extensive knowledge of the ecology and biology of the fish should be in hand.

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REFERENCES

Arunkumar, L. & Basudha, C. (2003). *Tor barakae*, a new species of mahseer fish (Cyprinidae: Cyprininae) from Manipur, India. *Aquacult* 4: 271–276

Day, F. (1871). Monograph of Indian Cyprinidae. *Journal of Royal Asiatic Society of Bengal*, 40:277-336.

Hamilton, F. (1822). An account of the fishes found in the River Ganges and its branches. *Edinburgh: A. Constable and Company*, 405p.

Hubbs C.L., & Lagler K.F. (1964). Fishes of the Great Lakes region. *University of Michigan Press, Ann Arbor.* 213 p.

IUCN 2022. The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org.

Kottelat, M. (2001). Fishes of Laos. Colombo 5, Sri Lanka: *WHT Publications Ltd.*, 198p.

McClelland, J. (1839). Indian Cyprinidae. Asiatic Researches, 19: 217-468.Menon A.G.K. 1992. Taxonomy of Mahseer Fishes of the Genus Tor Gray with description of a new species from the Deccan. *J. Bombay Nat. Hist*. Soc. 89, 210-228.

Pinder, A. C., Britton, J. R., Harrison, A. J., Nautiyal, P., Bower, S. D., Cooke, S. J., Lockett, S., Everard, M., Katwate, U., Ranjeet, K.,Walton, S., Danylchuk, A. J., Dahanukar, N., & Raghavan, R. (2019). Mahseer (Tor spp.) fishes of the world: status, challenges and opportunities for conservation. *Rev Fish Biol Fisheries* 29: 417-452.

Rainboth, W. J. (1985). *Neolissochilus*,a new genus of South Asian Cyprinid Fish. *Beaufortia*. 35(3): 25-35.

Sarma, D., Akhtar, M. S., Sharma, P., & Singh, A. K. (2018). Resource, breeding, eco-tourism, conservation, policies and issues of Indian mahseer: A review. *Journal of Coldwater Fisheries* 1(1):4-21.

Smith, H. M. (1945). The freshwater fishes of Siam or Thailand. *Bulletin of the United States Natural Museum*. 188:1-622.

DIVERSITY OF CYPRINIDAE FISHES IN BARAK AND CHINDWIN BASINS OF NORTHEAST INDIA

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ABSTRACT

The North Eastern regions of India with its rich freshwater resources harbour diverse Cyprinidae fishes. The study documented the diversity of the fishes in the Barak and Chindwin basin of this region. It provides the current status and threats of the fishes. The study reveals the occurrence of 85 Cyprinid fishes belonging to 30 genera and 6 subfamilies. Water quality has been degraded by anthropogenic activities. Changes in river courses, soil erosions and floods causes significant changes in the river ecosystem. These factors ultimately lead to declining status of the fish diversity. 29% of the fishes documented were categorized as threatened.

Keywords: Conservation, Cyprinids, Hotspot, Threats

INTRODUCTION

The Eastern Himalayan region is considered as one of the freshwater fish biodiversity hotspots in the world (Kottelat & Whitten, 1996). Out of the 34 biodiversity hotspots listed by International Conservation Union (Roach, 2005), two, viz., the Himalaya and Indo-Burma lie in the Northeast India. The region has rich ichthyofaunal diversity which is endemic to the region. The diversity is attributed to the recent geological history (collision of Indian, Chinese and Burmese plates and the Himalayan orogeny), occurrence of different drainage systems, habitat diversity, etc. These factors altogether led to the speciation and evolution of different groups inhibiting mountain streams (Kottelat, 1989).

Northeast India is drained by four river basins, viz, the Brahmaputra, Barak, Chindwin and the Kaladan. The river Barak, originating in Senapati district of Manipur, after flowing 900 kms through four states in India enters Bangladesh, and flows into the Bay of Bengal. On the other hand, although the Chindwin River flows within Myanmar, a large number of its head waters drain the eastern part of north east India, especially the areas bordering that country. Both the basins are immensely endowed with diverse fish species, with the cyprinids as the most dominant, being able to occupy all possible habitats due to their high adaptive variability. Cyprinidae is also the largest and most diverse sub-family of freshwater fishes.

MATERIAL AND METHODS

Collections of fishes were done from different water bodies of the Barak and Chindwin river basins. The specimens were collected using different nets, traps and local fishing techniques. Collections were also made from the nearby local fish markets. Details of the locality including GPS readings, time and date of collection, local name, color in fresh and habitat were recorded in the field note book. Fishes are tranquilized and then fixed in 10% formalin. Materials from Manipur University Museum of Fishes (MUMF) are also examined. IUCN red list of threatened species (version 2021-3) was considered.

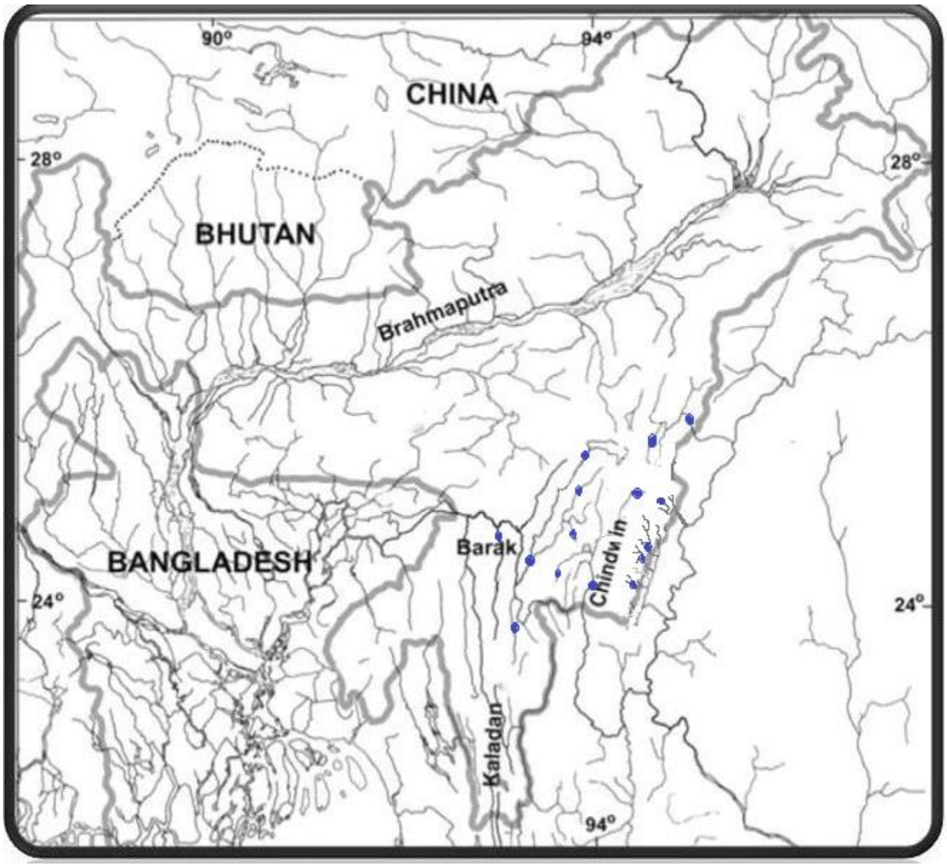

Fig 1. Map of Barak and Chindwin basins depicting collection sites

Laubuca khujairokensis (Arunkumar, 2000)

Opsarius bendelisis (Hamilton 1807)

Garra paratrilobata Roni et.al. 2019

Neolissochilus stracheyi (Day 1871)

Poropuntius burtoni (Mukerji 1933)

Pethia poiensis Shangningam & Vishwanath 2018

Fig 2: Some cyprinids inhabiting the Barak and Chindwin basins
**Blue scale shown in the pictures measures 10 mm. each*

RESULTS

85 Cyprinidae fishes belonging to 30 genera and 6 subfamilies viz., Barbinae, Cyprinidae, Labeoninae, Rasborinae, Squaliobarbinae and Xenocyprinae are recorded. Of these, the Labeoninae shows the highest hill stream adaptation and exhibits the highest diversity, with as many as 28 species. There are 34 species of Cyprinidae fishes in Barak basins where *Labeo* with six species is the most dominant. Chindwin basins harbour 64 species. *Garra* comprises of 13 species and shows the highest diversity. 13 species are common to both the river. Many Cyprinidae fishes are morphologically modified for hill stream mode of life.

Table 1. Cyprinid fishes of Barak and Chindwin basins and their IUCN status

SUB-FAMILY	GENUS	SPECIES NAME	BARAK	CHIDWIN	IUCN STATUS
CYPRININAE	*Cyprinus*	*Cyprinus carpio*	-	+	VU
	Chagunius	*Chagunius nicholsi*	-	+	LC
		C. chagunio	+	-	LC
	Neolissochilus	*Neolissochilus hexagonalepis*	+	+	NT
		N. stracheyi	-	+	LC
	Osteobrama	*Osteobrama belangeri*	-	+	NT
		O. cotio	+	-	LC
		O.cumma	-	+	LC
		O. feae	-	+	LC
	Poropuntius	*Poropuntius burtoni*	-	+	LC
		P. clavatus	+	-	NT
	Semiplotus	*Semiplotus cirrhosus*	-	+	DD
	Tor	*Tor mosal*	+	-	DD
		T. putitora	+	+	EN
		T. tor	+	+	DD
BARBINAE	*Hypsibarbus*	*Hypsibarbus myitkyinae*	-	+	LC
	Pethia	*Pethia ater*	-	+	VU
		P. conchonius	+	-	LC
		P. khugae	-	+	VU
		P. manipurensius	-	+	EN
		P. meinganbii	-	+	LC
		P. stoliczkana	-	+	LC
		P. yuensis	-	+	VU
	Puntius	*Puntius chola*	+	+	LC
		P. sophore	+	+	LC
		P. terio	+	-	LC
	Schizothorax	*Schizothorax chivae*	-	+	LC
		S. richardsonii	-	+	VU
	Systomus	*S. sarana*	-	+	LC
SQUALIOBAR-BINAE	*Ctenophayngodon*	*Ctenopharyngodon idella*	-	+	NE
XENOCYPRIN-IDEA	*Hypothalmichthys*	*Hypathalmichthys molotrix*	-	+	NT
		H. nobilis	-	+	DD
LABEONINAE	*Bangana*	*Bnagana dero*	+	-	LC
		B. devdevi	-	+	LC
	Cirrhinus	*Cirrhinus cirrhosus*	+	+	VU
		C. reba	+	-	LC
	Garra	*Garra abhoyai*	-	+	NE
		G. chakpiensis	-	+	NE
		G. chivaensis	-	+	NE
		G. compressa	-	+	VU
		G. cornigera	-	+	NE
		G. elongata	-	+	NT
		G. lissorhynchus	+	-	LC
		G. litanensis	-	+	VU
		G. manipurensis	-	+	VU
		G. nagaensis	+	-	NE
		G. nambulica	-	+	VU
		G. namyaensis	-	+	NE
		G. paralissorhynchus	-	+	VU
		G. substrictorostris	+	-	NE

SUB-FAMILY	GENUS	SPECIES NAME	BARAK	CHIDWIN	IUCN STATUS
		G. trilobata	-	+	NE
		G. ukhrulensis	-	+	NE
	Labeo	*Labeo bata*	+	+	LC
		L. calbasu	+	+	LC
		L. dyocheilus	+	+	LC
		L. pangusia	+	_	NT
		L. gonius	+	+	LC
		L. rohita	+	+	LC
	Tariqilabeo	*Tariqilabeo burmanicus*	-	+	NE
		T. latius	+	-	LC
RASBORINAE	*Amblypharyngodon*	*Amblypharyngodon mola*	+	+	LC
	Barilius	*Barilius barila*	+	-	LC
		B. vagra	+	-	LC
	Cabdio	*Cabdio ukhrulensis*	-	+	DD
	Danio	*Danio quagga*	-	+	NE
	Devario	*Devario acuticephalua*	-	+	NE
		D. aequipinnatus	+	-	LC
		D. deruptolata	-	+	NE
		D. nagaensis	-	+	VU
		D. yuensis	-	+	VU
		D. manipurensis	-	+	DD
	Esomus	*Esomus dandricus*	+	+	LC
	Laubuka	*Laubuca laubuca*	+	-	LC
		L. khujairokensis	-	+	VU
	Opsarius	*Opsarius barnoides*	-	+	LC
		O. dogarsinghi	-	+	VU
		O. lairokensis	-	+	LC
		O. bendelisis	+	-	LC
		O. telio	+	-	NE
	Raiamas	*Raiamas guttatus*	-	+	LC
	Rasbora	*Rasbora daniconius*	-	+	LC
		R. ornatus	-	+	VU
	Salmostoma	*Salmostoma bacaila*	+	-	LC
		S. phulo	+	-	LC
		S. sladoni	-	+	LC

(+) = Reported, (-) = Not Reported, DD- Data Deficit, EN- Endangered, LC- Least Concern, NE- Not Evaluated, NT- Near Threatened, VU- Vulnerable

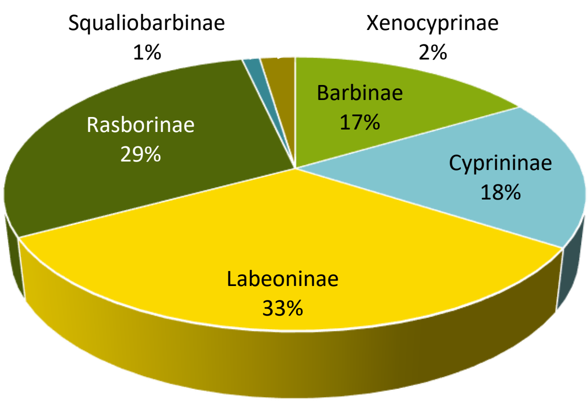

Fig. 3. Pie chart showing percentage composition of different sub-families of Cyprinidae in the study area

DISCUSSION

The Cyprinids are highly valued fishes. Large sized Cyprinids like *Labeo, Osteobrama, Neolissochilus, Tor* etc. are of good food. *Tor* and *Neolissochilus* are also sport fishes. Small sized cyprinids like *Barilius, Chela, Devario, Esomus, Garra, Pethia, Puntius, Rasbora* etc. are ornamental value fishes. Many hilly fishes have aesthetic appearance and serve as good aquarium fishes due to their varying coloration and bizarre shape (Biswas *et al.*, 2015). Breeding and culturing of these fishes promote the socio-economic status of a large number of people living along the river, wherein womenfolk also participated actively.

The study reveals that the understanding of fish diversity in both Barak and Chindwin basins is far from being complete. In the last 30 years, Vishwanath and co-workers discovered 24 Cyprinidae fishes from the Barak and Chindwin basins in Northeast India which are new to science (Vishwanath, 2021). New fishes were also being discovered till date, but with lesser rate. Extensive survey works is lacking in the region. Many areas, particularly the interiors of the hills have never been visited by an ichthyologist because of its difficult topography, inaccessibility and lack of proper language communication. Large number of species probably still awaits discovery. There also exists taxonomic ambiguity among some genera which are needed to be resolved. The study also shows that many species in both the basins are being threatened. Natural hazards such as floods, frequent changes in the river course, natural discharge of both organic and inorganic elements and erosions provide immense threats to the fish population. Large areas of the Barak valley are contaminated with arsenic (Gupta *et al*., 2015). Man-made threats such as deforestation, pollution, river embankments, over exploitation and hydro power dam also causes serious threats to the fishes. Sand mining is largely practised in many areas along the Chindwin basin which results in the formation of deeper pools and losing of run and riffle habitats. All these factors lead to river pollution, which ultimately threatened the fishes therein. According to the IUCN red list 2021-3, 25 cyprinidae fishes in Barak and Chindwin basins are categorised under the threat category. *Pethia manipurensis* and *Tor putitora* are endangered. Another 16 species were vulnerable and seven near threatened.

CONCLUSION

The present study has demonstrated about the biodiversity status, as well as the main threats of the Cyprinidae fishes in the Barak and Chindwin basins of Northeast India. Although the two basins harbour rich ichthyofaunal diversity, many species have been threatened in their natural environment. More discovery and inventory work have to be carried out, involving active participation to the local level. As the threats to the fish biodiversity in the two rivers are slowly becoming serious, urgent and vehement steps should be taken up so as to conserve the fishes. Integrated and sustainable fisheries management plan should be developed so as to ensure a well-balanced aquatic environment.

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REFERENCES

Biswas, S. P., Singh, S. S. A.,& Das, J. N.(2015). Conservation and management of ornamental fish resources of North East India. Journal of Aquaculture and Research Development 6: 310.

Gupta, A., Bhattacharjee, D., Borah, P., Deb kanungo, T., & Paul choudhury, C. (2015). Arsenic Contamination of Groundwater in Barak Valley, Assam, India: Topography-Based Analysis and Risk Assessment, 10.1007/978-3 319-16124-2_6.

IUCN 2022. The IUCN Red List of Threatened Species. Version 2021-3. <https://www.iucnredlist.org>

Kottelat, M.,& Whitten, T. (1996). Freshwater biodiversity in Asia with special reference to fish: World Bank Technical paper No. 343: The world bank, Washington DC, p. 59..

Kottelat, M. (1989). Zoogeography of the fishes from Indochinese inland waters with an annotated check-list. Bull. Zoöl. Mus. Univ. Amsterdam 12(1):1-55.

Roach, J. (2005). Conservationists name nine new biodiversity hotspots. National Geographic News.

Vishwanath, W. (2021). Freshwater Fishes of the Eastern Himalayas. Academic Press.

DIVERSITY OF AQUATIC FROGS OF NORTH-EAST INDIA: SCOPES & OPPORTUNITIES

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ABSTRACT

Amphibia is a taxon in peril due to its dependency on aquatic habitats which are prone to rapid environmental degradations and climate change. Any effort to comprehend their interactions with the environment and to understand their conservation needs, a proper inventory of their diversity is the need of the hour. In the present review paper, effort has been made to compile the diversity of the aquatic frogs of four Northeast Indian states of Assam, Nagaland, Manipur and Meghalaya based on literature and museum vouchers available at Zoological Survey of India, Shillong. Herein, we are reporting 15 species of aquatic frogs from these four states that include two vulnerable species as per IUCN. Besides, a discussion on the scopes and opportunities for future research work and remarks on the imminent threats to this faunal group are also made.

Keywords faunal inventory, NERAQ, threatened species, climate change, IUCN

INTRODUCTION

The life cycle of amphibians, with a few exceptions, are characterised by the use of both land and water as their habitats. As such, they are sensitive to their environment, primarily due to their dependency on aquatic habitats, which are prone to rapid environmental deterioration. With climate change and rapid environmental degradations, these make amphibians a taxon in peril. However, for sustainable conservation, a proper understanding of their natural history is essential, which begins with the compilation of an inventory, and their distribution records.

Among the three living orders of amphibians, the anurans are the most diverse group, both in terms of diversity and their adaptability to varied habitats. Globally, out of 8,380 species of amphibians, 7,401 species belong to the anurans (Frost, 2021). In India, among the 447 species of amphibians recorded so far, 406 species belong to the order anura (Dinesh *et al*., 2020), while in Northeast India, the amphibians are represented by 163 species of which 150 species belong to anurans (*see* Frost, 2021).

The adult anurans are known to occur in ponds, rivers, lakes, streams, trickles, crop fields, marshes, cascades, in burrows, forest leaf litters, bushes, tree canopies, homestead, etc. This has resulted in slight morphological adaptations from a typical anuran body plan, according to the requirement of the habitat or its ecological niche. Among the aquatic frogs this change is characterised by eyes and nostrils projected upwards and toes almost fully webbed that aid in swimming. In the case of certain aquatic frog species like *Euphlyctis cyanophlyctis* and *E. hexadactylus*, the rounded convex webbings also aid in producing more drag which aids in generating more propulsive force to jump out of the water (Nauwelaerts *et al*., 2004).

With the objective to document the aquatic frog diversity of this region, we are inventorying the current aquatic frog diversity of four Northeast Indian states of Assam, Nagaland, Manipur, and Meghalaya (which is also the NERAQ study area) based on literature and museum vouchers. The compiled list will help us to determine the future scopes and opportunities for research in this faunal group. Remarks on the probable distributional errors and threats are also highlighted.

MATERIALS AND METHODS

The documentation of the aquatic frog diversity of the four Northeastern States of India *viz.* Assam, Nagaland, Manipur and Meghalaya were done based on review of published literature (Ahmed et al., 2009; Dinesh *et al.*, 2021; Frost, 2021; Mathew & Sen, 2010; Saikia & Saikia, 2020) and the vouchers deposited in the National Zoological Collections of Zoological Survey of India, Shillong. The state-wise distribution and the IUCN threat status of the species are also included in this study.

RESULTS

Based on our study, we are reporting 15 species of aquatic frogs from the four Northeast India states of Assam, Nagaland, Manipur and Meghalaya (Table 1). The list also includes two vulnerable species. These 15 species are under seven genera and two families. Among the states, Meghalaya with 11 species has the most diverse aquatic frog populations, while Assam and Manipur with 10 species each, and Nagaland with 9 species are also equally diverse.

Table 1 The aquatic species list of four states of NE India; * indicates a special case

S. No.	Species	Distribution (Assam-AS; Nagaland-NL; Manipur-MN; Meghalaya-ML)	IUCN Status (Version 2021-3)
Class: Amphibia **Order: Anura** **Family: Dicroglossidae**			
1	*Euphlyctis ghoshi* (Chanda, 1991)	MN	DD
2	*Euphlyctis kalasgramensis* Howlader, Nair, Gopalan, and Merilä, 2015	AS, NL, MN, ML	NE
3	*Hoplobatrachus crassus* (Jerdon, 1853)	AS, NL, MN	LC
4	*Hoplobatrachus tigerinus* (Daudin, 1802)	AS, NL, MN, ML	LC
5	*Ingerana borealis* (Annandale, 1912)*	NL, MN, ML	VU
6	*Limnonectes khasianus* (Anderson, 1871)	AS, ML	DD
7	*Limnonectes* cf. *kuhlii* (Tschudi, 1838)	AS, ML	LC
8	*Limnonectes mawlyndipi* (Chanda, 1990)	ML	DD
9	*Minervarya asmati* (Howlader, 2011)	AS, MN	NE
10	*Minervarya nepalensis* (Dubois, 1975)	AS, NL, MN, ML	LC
11	*Minervarya pierrei* (Dubois, 1975)	AS, NL, MN, ML	LC
12	*Minervarya sengupti* (Purkayastha & Matsui, 2012)	ML	NE
13	*Minervarya teraiensis* (Dubois, 1975)	AS, NL, MN, ML	LC
14	*Nanorana mokokchungensis* (Das & Chanda, 2000)	NL	DD
Family: Ranidae			
15	*Pterorana khare* Kiyasetuo&Khare, 1986	AS, NL, MN, ML	VU

Of the above list, *Ingerana borealis* (Figure 1) and *Pterorana khare* are vulnerable species as per evaluation done by IUCN in 2004 (Dutta *et al.*, 2004; Lau *et al.,* 2004), while *Euphlyctis ghoshi, Minervarya sengupti* (Figure 2) and *Nanorana mokokchungensis* are known from their respective type locality of Manipur, Meghalaya and Nagaland. Based on the recent phylogenetic study on the *Euphlyctis* group of India (Dinesh *et al.*, 2021), we are removing *Euphlyctic cyanophlyctis* from the fauna of Northeast India and attributing the previous reports of this species to *E. kalasgramensis*. The previous report of *Limnonectes kuhlii* from Northeast India (Mathew & Sen, 2010) may see a revision, as *L. kuhlii* is a species complex, and that the previous reports of this species from India may represent an unnamed species (*see* Frost, 2021).

Ingerana borealis is not a typical aquatic frog; however, the report of a viable population of this species from the Lymput cave of Meghalaya (Saikia and Saikia, 2020) where they were reported to remain in water holes on the cave floor is an interesting find and may remain an interesting scope for further research.

Among the aquatic frogs documented from the study area, only *Hoplobatrachus crassus* and *H. tigerinus* are protected under Schedule IV of the Wildlife (Protection) Act, 1972 of India, while under the Convention on International Trade in Endangered Species (CITES), only *Hoplobatrachus tigerinus* under Appendix II is accorded protection (Saikia and Sinha, 2022).

DISCUSSION

Other than the bush frogs and phytotelma-breeding frogs (Biju *et al.*, 2016; Yang & Chan, 2018), all the anurans spent some of their life cycles in aquatic habitats as tadpoles. So, to conserve the species diversity, conservation of the aquatic habitats is essential. Unsustainable urbanisation is a grave risk to the aquatic faunal diversity where aquatic habitats are destroyed either due to pollution or being filled-up for infrastructure development (Saikia *et al.*, 2021).

One key risk that has direct and immediate threat to these aquatic species is the practice of unsustainable *in-situ* harvest of frogs as a source of food or medicine (Saikia & Sinha, 2022). Species like *H. tigerinus* is a delicacy in the region, while certain vulnerable species like *P. khare* is harvested as food.

A key thrust area *vis-à-vis* the amphibian research should include a thorough exploration of diverse aquatic habitats of the region using integrative taxonomy, particularly molecular phylogeny, for cryptic groups like *Euphlyctis, Limnonectes, Minervarya*, etc., which may result in better documentation of the diversity of aquatic frogs from these states. Very little is known about certain endemic species like *E. ghoshi, L. mawlyndipi* or *N. mokokchungensis*; so, any further studies on these species from their respective type localities or nearby places will throw more light into their natural history and population health.

Status assessment of these frogs is another scope of research, as highlighted in Table 1, where the statuses of many species are either data deficient or not evaluated. Even re-evaluation of the status of those species which were assessed (Dutta *et al.*, 2004; Lau *et al.,* 2004), is also needed to reflect the current state of their population.

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REFERENCES

Ahmed, M. F., Das, A., and Dutta, S. K. (2009). Amphibians and Reptiles of Northeast India. A Photographic Guide. Guwahati, India: *Aaranyak*. Pp 168.

Biju, S. D., Senevirathne, G., Garg, S. Mahony, S., Kamei, R. G., Thomas, A., Shouche, Y. S., Raxworthy, C. J., Meegaskumbura, M., &Van Bocxlaer, I. (2016). *Frankixalus*, a new rhacophorid genus of tree hole breeding frogs with oophagous tadpoles, *PLoS One,* 11, e0145727. https://doi.org/10.1371/journal.pone.0145727.

Dinesh K. P., Radhakrishnan C., Channakeshavamurthy B. H., Deepak, P., & Kulkarni, N.U. (2020). A Checklist of Amphibians of India with IUCN Conservation Status. Version 3.0. updated till April 2020. available at http://zsi.gov.in (online only).

Dinesh, K. P., Channakeshavamurthy, B. H., Deepak, P, Ghosh, A. K., & Deuti, K. (2021). Morphological groupings within *Euphlyctis* (Anura: Dicroglossidae) and description of a new species from the surroundings of Thattekad Bird Sanctuary, Kerala, India. *Zootaxa*, 4990, 329–353 (https://doi.org/10.11646/zootaxa.4990.2.7).

Dutta, S., Sengupta, S., & Bordoloi, S. (2004). *Pterorana khare*. The IUCN Red List of Threatened Species 2004: e.T58488A11776771. https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T58488A11776771.en.

Frost, D. R. (2021). Amphibian Species of the World: an Online Reference. Version 6.1 (*27.09.2021*). Electronic Database accessible at https://amphibiansoftheworld.amnh.org/index.php. American Museum of Natural History, New York, USA. doi.org/10.5531/db.vz.0001

Lau, M. W. N., Dutta, S., Ohler, A., Bordoloi, S., & Asmat, G. S. M. (2004). *Ingerana borealis*. The IUCN Red List of Threatened Species 2004: e.T58407A11774694. https://dx.doi.org/10.2305/IUCN.UK.2004.RLT

Mathew, R., & Sen, N. (2010). Pictorial guide to the amphibians of North East India. (Published by the Director*, Zoological Survey of India,* Kolkata: 1–144.

Nauwelaerts, S., Scholliers, J., &Aerts, P. (2004). A functional analysis of how frogs jump out of water, *Biological Journal of the Linnean Society*, 83, 413–420. DOI: 10.1111/j.1095-8312.2004.00403.x

Saikia, B., & Saikia, U. (2020). A report on *Ingerana borealis* (Annandale, 1912) (Anura: Dicroglossidae) from inside a cave. *Records of the Zoological Survey of India*, 120(3), 247-250. doi: 10.26515/rzsi/v120/i3/2020/143326

Saikia, B., Pdah, D. S. M., & Sengupta, S. (2021). Urban Fauna: Amphibian Checklist of Shillong, Meghalaya, *Journal of Bioresources*, 8(2), 24-34.

Saikia, B., & Sinha, B. (2022). Amphibians need legal protection, *Current Science*, 122 (1), 9-10.

Yang, J., and Chan, B.P.-L. (2018). A new phytotelm-breeding treefrog of the genus *Nasutixalus* (Rhacophoridae) from western Yunnan of China. *Zootaxa,* 4388, 191–206. https://doi.org/10.11646/zootaxa.4742.3.7.

FIGURES

Figure 1 *Ingerana borealis* (Annandale, 1912), a vulnerable species of the region

Figure 2 *Minervarya sengupti* (Purkayastha & Matsui, 2012), an endemic species of Meghalaya

DIVERSITY OF LABEONINE (LABEONINAE: CYPRINIDAE) FISHES OF MANIPUR, INDIA

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ABSTRACT

Manipur comes under the geographical scope of the Eastern Himalaya Freshwater Biodiversity Hotspot. The region being drained by the Barak–Surma–Meghna and Chindwin drainages harbours potentially significant freshwater fish resources. Most of the members belonging to the subfamily Labeoninae are adapted to hill-stream mode of life. In the present preliminary study, the diversity of the Labeonine fishes is studied based on snout morphology, anus position, colouration pattern, and various structural modifications such as oral and gular morphology, tuberculation pattern on the snout, etc. The study found the occurrence of thirty-one (31) Labeonine fishes under five genera in Manipur viz., Bangana, Cirrhinus, Garra, Labeo, and Tariqilabeo, represented by two Bangana, two Cirrhinus, eighteen Garra, seven Labeo, and two Tarqiilabeo, genus Garra exhibits the maximum diversity among the subfamily. As such detailed exploration and proper documentation of the subfamily needs to be undertaken. Possible threats, IUCN status, and conservation measures are broadly discussed. Since the region harbours numerous endemic species and blooming potential threats, immediate conservation measures should be taken up.

Keywords: Labeonine, diversity, freshwater, Manipur, India

INTRODUCTION

The subfamily Labeoninae (Chen et al.,1984) accounts for about 15% of the species diversity of the cyprinid fishes (Nelson, 2006). They are adapted to rapid flowing water habitats and are distributed in Africa, Southwest, South, Southeast and East Asia. Fish diversity comprises of species richness, species abundance and phylogenetic diversity (Gorman and Karr, 1978). The Labeoninaeare distinctive from other cyprinids fishes in having a high degree of modification in its lip and associated structures, and these structures are highly variable within the subfamily such as, terminal or inferior mouth; absence or presence of upper lip, entirely or strongly frindged; mofified lower lips can be tongue like or gular disc; rostral cap entirely or strongly fringed; and absence or presence of barbels. So far, thirty-one (31) species of Labeonine are found under five genera is found in Manipur viz., *Bangana, Cirrhinus, Garra, Labeo* and *Tariqilabeo*.

The headwaters of Barak-Surma-Meghna and Chindwin drainages in Manipur harbours implicitly significant freshwater fish resources. Most of the Labeonine fishes in this region are adapted to hill stream mode of life. The diversity of these fishes is studied based on the snout morphology and its associated structures.

MATERIALS AND METHODS

Specimens of Labeonine fishes are collected from different rivers and streams of Barak and Chindwin drainage of Manipur and preserved in 10% formalin. Specimens deposited in the Manipur University Museum of Fishes (MUMF) is also used for the study. Measurements were taken point to point with adigital calipers to the nearest 0.1mm. Counts, measurements and terminology follow: Hubbs & Lagler (1946), Kottelat (2001); for *Garra*: Nebeshwar& Vishwanath (2013) and Kottelat (2020); *Bangana*: Zhang & Chen(2006); *Cirrhinus:* Roberts (1997); *Labeo:* Jayaram & Das (2000); *Tariqilabeo:* Ciccotto & Page (2016). Lateral line are counted from the anteriormost pored scale to the posterior most pored scale of the caudal fin. Transverse scale rows above the lateral line are counted from the dorsal-fin origin to the lateral line obliquely ventrad and caudad and below lateral line from the anal-fin origin and pelvic-fin origin obliquely dorsad and rostrad to the lateral line.

RESULTS

Out of 31 species of Labeonine fishes found in Manipur (Table 1), highest diversity among the genera is found in *Garra* upto seventeen (17) species, followed by *Labeo* having seven (7) species, and two (2) species each of *Bangana*, *Cirrhinus* and *Tariqilabeo*. Six (6) species are found to VU (Vulnerable), (15) species in LC (Least Concerned), One (1) NT (Near Threatened) and nine (9) NE (Not Evaluated). In the last two decades, Vishwanath and co-workers have discovered 13 new species of Garra from Manipur. So, highest diversity is found in the genus *Garra* in this region.

Table 1 Diversity of Labeoninae in Manipur (Barak and Chindwin drainage)

S. No.	Genus	Species	Barak	Chindwin	IUCN status
1	***Bangana***	*Bangana dero*	+	-	LC
2		*Bangana devdevi*	-	+	LC
3	***Cirrhinus***	*Cirrhinus cirrhosus*	+	+	LC
4		*Cirrhinus reba*	+	-	LC
5	***Garra***	*Garra abhoyai*	-	+	NE
6		*Garra chakpiensis*	-	+	NE
7		*Garra chindwinensis*	-	+	NE
8		*Garra chivaensis*	-	+	NE
9		*Garra compressus*	-	+	VU
10		*Garra cornigera*	-	+	NE
11		*Garra elongata*	-	+	NT
12		*Garra lissorhynchus*	+	-	LC
13		*Garra litanensis*	-	+	VU
14		*Garra manipurensis*	+	-	VU
15		*Garra naganensis*	+	-	LC
16		*Garra nambulica*	-	+	VU
17		*Garra namyaensis*	-	+	VU
18		*Garra paralissorhynchus*	-	+	VU
19		*Garra paratrilobata*	+	-	NE
20		*Garra substrictorostris*	+	-	NE
21		*Garra trilobata*	-	+	NE
22		*Garra ukhrulensis*	-	+	NE
23	***Labeo***	*Labeo bata*	+	-	LC
24		*Labeo boga*	+	-	LC
25		*Labeo calbasu*	+	-	LC
26		*Labeo dyocheilus*	+	-	LC
27		*Labeo gonius*	+	+	LC
28		*Labeo pangusia*	+	-	LC
29		*Labeo rohita*	+	+	LC
30	***Tariqilabeo***	*Tariqilabeo burmanicus*	-	+	LC
31		*Tariqilabeo latius*	+	-	LC

VU- Vulnerable, **NT-** Near Threatened, **LC-** Least Concern, **NE-** Not Evaluated

DISCUSSION

Labeoninae have high diversity in this region therefore there is a need for further exploration and inventory. Also, proper documentation of the species is recommended. Despite being endowed with a wide variety of Labeonine fishes, modification and loss of aquatic habitat is the primary factor threatening the conservation of freshwater fishes and communities (Hewitt et al.,2008, Allen and Flecker, 1993). Riverine biodiversity is greatly affected by habitat degradation, change in climate, global warming, pollution, introduction of exotic species for the commercial gain possess threats to the indigenous ichthyo diversity and over exploitation of fish resources. Fishing by using dynamites, poisons of plant origin by locals and electrofishing are major threats to the fish diversity. Lack of public awareness and political commitment to environmental conservation.

An assessment along with the study of habitat and habit would be necessary for the endemic fish species. In-situ and ex-situ fish conservation may be practiced to conserved endemic fish species. Indigenous methods of rearing along with captive breeding should be taken up. Improving public awareness to the local people such as fishermen about the diversity and in understanding and preserving the diverse Labeonine fish resources.

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REFERENCES

Ciccotto, P. J., & Page, L. M. (2016). Revised diagnosis of the genus Gonorhynchus McClelland (Teleostei: Cyprinidae: Labeonini) with redescription of G. latius (Hamilton) and revalidation of G. wattanah (Sykes). *Zootaxa*, *4127*(3), 471-492.

Dudgeon, D. (Ed.). (2011). *Tropical stream ecology*. Elsevier.

Dudgeon, D. (2000). The ecology of tropical Asian rivers and streams in relation to biodiversity conservation. *Annual review of Ecology and Systematics*, *31*(1), 239-263.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., ... & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological reviews*, *81*(2), 163-182.

Gorman, O. T., & Karr, J. R. (1978). Habitat structure and stream fish communities. *Ecology*, *59*(3), 507-515.

Guo, Q., Liu, X., Ao, X., Qin, J., Wu, X., & Ouyang, S. (2018). Fish diversity in the middle and lower reaches of the Ganjiang River of China: Threats and conservation. *PloS one*, *13*(11), e0205116.

Hewitt, J. E., Thrush, S. F., & Dayton, P. D. (2008). Habitat variation, species diversity and ecological functioning in a marine system. *Journal of Experimental Marine Biology and Ecology*, *366*(1-2), 116-122.

Leidy, R. A., & Moyle, P. B. (1998). Conservation status of the world's fish fauna: an overview. *Conservation biology*, 187-227.

Kar, D., Nagarathna, A. V., Ramachandra, T. V., & Dey, S. C. (2006). Fish diversity and conservation aspects in an aquatic ecosystem in Northeastern India. *Zoos' print journal*, *21*(7), 2308-2315.

Kumar, S. T., Charan, G. B., & Kumar, S. S. (2013). Review of the research on the fish diversity in the river Mahanadi and identifying the probable potential ornamental fishes among them with reference to threats and conservation measures. *Research Journal of Animal, Veterinary and Fishery Sciences*, *1*(3), 16-24.

Kottelat, M. (2020). Ceratogarra, a genus name for Garracambodgiensis and G. fasciacauda and comments on the oral and gular soft anatomy in labeonine fishes (Teleostei: Cyprinidae). *Raffles Bulletin of Zoology*, *35*, 156-178.

Nebeshwar, K., & Vishwanath, W. (2017). On the snout and oromandibular morphology of genus Garra, description of two new species from the Koladyne River basin in Mizoram, India, and redescription of G. manipurensis (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, *28*(1), 17-53.

Yang, L., &Mayden, R. L. (2010). Phylogenetic relationships, subdivision, and biogeography of the cyprinid tribe Labeonini (sensu)(Teleostei: Cypriniformes), with comments on the implications of lips and associated structures in the labeonin classification. *Molecular Phylogenetics and Evolution*, *54*(1), 254-265.

PRESENT KNOWLEDGE OF FRESHWATER CLADOCERA DIVERSITY IN NORTH EAST INDIA: OPPORTUNITIES AND CHALLENGES

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ABSTRACT
Cladocera is one of the most important groups of microscopic organisms in freshwater ecosystems with regard to their interaction along different trophic levels and ensuring smooth energy transfer in the food chain. Out of the more than 700 species of Cladocera known globally, about 131 species are recorded from India. Of the Indian Cladocera, about 75–80 species are known to occur in the North Eastern Region of the country. Out of the four NERAQ project states, virtually nothing is known about the Cladocera diversity of Nagaland. Maximum diversity of 75 species was observed from the state of Assam. The present study highlights the key threats and opportunities and offers some recommendations for Cladocera research in the region.

Keywords Ecosystem, biodiversity hotspot, North East India, Zooplankton, Cladocera

INTRODUCTION

An ecosystem is sustained by the intense interactions between its abiotic and biotic components. However, the interaction among its biotic components is the most important factor as it determines species selection and structure of biological communities (de Berdardi *et al*., 1987). This is more appropriate in aquatic ecosystems where interactions are more intense and severe due to relatively low support offered by the environment such as refuge for protection from predators, options for camouflage etc. It is needless to say that most of the efforts and resources on aquatic biodiversity studies have been directed and focused on select larger groups particularly pisces, amphibians, reptiles, molluscs, crabs and other larger insects like bugs and beetles. But we fail to appreciate the role played by other microscopic organisms like zooplankton in maintaining the good health of an ecosystem and thus avoid our interest and attention.

Cladocera, commonly known as 'water fleas' is the most important group among zooplanktonic organisms in freshwater ecosystems with regard to their interaction along different trophic levels and ensuring smooth energy transfer in the food chain (de Berdardi *et al*., 1987). Though most Cladocera is filter feeders, they also feed on detritus, algae and diatoms, thus keeping a check on eutrophication for which this group is also widely used as good indicators of ecosystem health and sentinels of environmental change (Eggermont & Martens, 2011; Padhye & Dahanukar, 2015). At the same time, Cladocera is the favourite food prey of many invertebrates like midges, aquatic insects, other zooplankton and many vertebrates like larval fishes, small fishes and amphibian tadpoles. Their characteristic jerky movements make them easily visible to the predators and that is why most fish larvae were found to prefer Cladocera over other prey (Mayer& Wahl, 1997). Most importantly, both their preying as well as predation is species specific, thus acts as a determiner for diversity of other organisms. For instance, out of a mixture of green algae, *Daphnia carinata* prefers larger *Scenedesmus obliquus* over other food whereas *D. lumholtzi* and *Ceridaphnia quadriangula* chooses smaller size of *Ankistrodesmus falcatus* (Hanim *et al*., 2019).

Out of nearly 700 species of Cladocera occurring globally, only 131 species are known from India. This appears to be under representation of the Cladocera diversity of the country given the diverseness of habitats and ecosystems prevailing in the country and also home to four of the global biodiversity hotspots. Of the Indian Cladocera, about 75-80 species are known to occur in the North Eastern Region of the country which again appears to be on the lower side as the region is part of the two global biodiversity hotspots, the Indo-Burma and the Eastern Himalaya. The present study appraises the existing knowledge of Cladocera diversity in the NERAQ project states and advocates thorough exploration of the vast and diverse aquatic ecosystems of the region to ascertain the true diversity of one of the critical elements of aquatic ecosystems.

MATERIALS AND METHODS

The present review study covered the four NERAQ project states namely Assam, Manipur, Meghalaya and Nagaland. An extensive survey of the information on the taxa available in the public domain, both electronic as well as the print form was carried out to find out the number of species reported from the concerned states. The authenticity of the species was validated based on the latest taxonomic knowledge of the taxa. Further, the distribution of the taxa in different basins, drainages, wetlands, and protected areas as well as their altitudinal distribution in the project states was also worked out. The study also highlights some of the key threats and opportunities in this sector. Based on the existing state of affairs, a few recommendations are put forth for the betterment of Cladocera studies in the region.

RESULTS AND DISCUSSION

Studies on Indian Cladocera were initiated by Baird (1860) with the description of *Daphnia newporti* from Nagpur and surrounding areas. As of today, about 131 species of Cladocera are recorded from India (Sharma & Sharma, 2017) which accounts for about 19% of the roughly 700 species known globally (Kotov *et al*., 2013). The report of *Simocephalus vetuloides* from Changchang Pani in Nagaland by Brehm (1950) was perhaps the starting point of Cladocera studies in Northeast India, almost a century after it began in India. The next record of Cladocera from the region was the report of *Alona costata* Sars (now *Flavalona cheni*) from the Kameng division in Arunachal Pradesh (formerly NEFA) by Biswas (1964). Though both the species are presently recognised as valid species and are known to be present in India (Michael & Sharma, 1988; Chatterjee *et al*., 2013; Sharma & Sharma, 2017) but the same works does not mention the occurrence of the species in the respective states.

Among the NERAQ states, maximum diversity of 75 species accounting for more than 57% of Indian diversity is known from Assam followed by 58 species (`44%) and 56 species (~43%) from Meghalaya and Manipur respectively (Table 1). Only one species is known from the state of Nagaland which is not even mentioned in subsequent India works. Thus, virtually, no work has been done on the Cladocera diversity of Nagaland.

Table 1 Diversity of Cladocera in NERAQ project states (Figures in parenthesis indicates the percentage of the corresponding Indian figure)

Taxon	Assam	Manipur	Meghalaya	Nagaland	India
No. of Species	75 (57.25)	56 (42.75)	58 (44.27)	01 (0.76)	131
No. of Genera	41(85.42)	30 (62.5)	33 (68.75)	01(2.1)	48
No. of Families	07 (63.64)	07 (63.64)	07 (63.64)	01 (9.1)	11

In terms of ecosystem diversity of Cladocera, not much is known except for some scanty studies. In Assam, 58 species are known from Deepar beel-a Ramsar site which is equal to the diversity known from the Meghalaya state and higher than the 56 species known from Meghalaya. Further, 55 species were reported from the wetlands of the largest river island in the world the Majuli islands in Assam. In Manipur, 51 species are reported to be present in the Loktak lake-another Ramsar site in the region. Thirty-one species from the rice fields and 26 species from Ward's Lake are the only two studies from the ecosystems of Meghalaya. And as evident, no studies from the different ecosystems of Nagaland. Thus, it's apparent that no studies have been carried out on the Cladocera diversity of different unique ecosystems of the region like high altitude wetlands, hot springs, caves and other Ramsar sites which are known to harbour unique faunal elements providing valuable insights into the evolution and climate change.

Further, there is virtually no data is available on the basin-wise or drainage-wise distribution as well as altitudinal distribution of Cladocera in the region. Knowledge of this type of distribution is of critical importance given the rapid developmental activities taking place in the region perhaps owing to the Look East Policy of the nation. This is a pre-requisite for taking informed decisions in implementing developmental infrastructures.

CONCLUSION

To take the studies on Cladocera in the region to the next level, a project for documentation of aquatic invertebrate diversity with special reference to lesser-known groups like Cladocera, of NE India may be launched at the earliest. Emphasis should be given to study the less explored habitats like High altitude wetlands, Caves, Mines etc and less explored states like Nagaland. Also, studies to generate basin-wise diversity like Brahmaputra, Barak, and Chindwin will be much helpful in planning the proper execution of developmental activities as well as conservation of the unique and endemic species.

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REFERENCES

Baird, W. (1860). Description of the two new species of Entomostracous Crustacea from India. *Proc. Zool. Soc. London*, 213 - 234.

Biswas, S. (1964) Five species of Daphniidae (Crustacea: Cladocera) from Simla Hills in India, with a new record of *Alona costata* Sars, from Nefa. *Journal of Zoological Society of India*, 16, 92–98.

Brehm, V. (1950) Contribution to the freshwater fauna of India. Part 2. *Records of the Indian Museum*, 48, 9–28

Chatterjee, T., Kotov, A. A., Van Damme, K., Chandrasekhar, S. V. A. & Padhye, S. (2013). An annotated checklist of the Cladocera (Crustacea: Branchiopoda) from India. *Zootaxa*, 3667(1): 1-89.

de Bernardi, R., Giussani, G., & Manca, M. (1987). Cladocera: Predators and Prey. *Hydrobiologia*, 145, 225-243.

Eggermont, H., & Martens, K. (2011). Preface: Cladocera crustaceans: sentinels of environmental change. *Hydrobiologia*, 676, 1, https://doi.org/10.1007/s10750-011-0908-9.

Hanim, I. A., Scott, M., & Friedrich, R. (2019). Selective feeding of three Cladocera species in mixtures of freshwater algae. *Res. J. Chem. Environ*., 23 (5), 89-97.

Kotov, A., Forró, L., Korovchinsky, N. M., & Petrusek, A. (2013), World checklist of freshwater Cladocera species. World Wide Web electronic publication. Available online at http://fada.biodiversity.be/group/show/17 [Accesses on 10 December 2021]

Mayer, C. M., & Wahl, D. H. (1997). The relationship between prey selectivity and growth and survival in larval fish. *Can. J. Fish. aquat. Sci*., 54, 1504–1512.

Michael, R. G. & Sharma, B. K. (1988). Fauna of India and adjacent countries. Indian Cladocera (Crustacea: Branchiopoda: Cladocera). Zoological Survey of India, Calcutta, 262 pp.

Padhye, S. M. & Dahanukar, N. (2015). Determinants of 'water fleas' (Crustacea: Branchiopoda: Cladocera) diversity across seasonal and environmental gradients of a polluted river. *Current Science*, 109 (10), 1777-1780.

Sharma, B. K. & S. Sharma (2017). Crustacea: Branchiopoda (Cladocera), pp. 199-223. In: Chandra, K., Gopi, K.C., Rao, D.V., Valarmathi, K. & J.R.B. Alfred (eds.). *Current Status on freshwater faunal diversity of India–an overview*. Zoological Survey of India, Kolkata, 624 pp.

CONSERVATION OF ENDEMIC FISH GENETIC RESOURCE OF MANIPUR, NORTHEAST INDIA

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ABSTRACT

Manipur is located in the northeastern part of India. The state lies at a latitude of 23°83'N and 25°68'N and longitudes of 93°03'E and 94°78'E, the total area covered by the state is 22,347 Km^2. Its boundary hills constitute 92% area with altitude ranges from 2000 to 3000 meters above the mean sea level. The capital lies in an oval-shaped valley of approximately 700 square miles (2,000Km^2) surrounded by Blue Mountains and is 786 meters above sea level. Manipur has diversified water bodies with 56,461.05 ha suitable for fish farming. The total fish diversity of Manipur accounts for 218 species. More species are likely to be discovered with the exploration of undisturbed areas. Indigenous/endemic fish such as *Osteobrama belangeri, Bangana devdevi, Ompok sp., Anabas testudineus, Channa sp., Hypsibarbus myitkyinae etc.* are the potential candidate species for aquaculture, which required standardization of culture and breeding protocol. Wild fish genetic resources represent most of the genetic diversity but are under threats with anthropogenic pressure and overexploitation. These wild resources must be protected and conserved to ensure future availability. Declaration of wildlife sanctuaries and protected areas is a scope of In-situ conservative measures. Ex-situ conservation with the development of a live gene bank could be an alternative strategy for conserving high value and endemic fish genetic resources. Additionally, standardization of induced breeding protocol of fish species will help us to sustain the fisheries production and to fulfil the gap of fish production

Keywords: Manipur Genetic Resource, Gene bank, Fish induce breeding, Conservation.

INTRODUCTION

Manipur is situated in the northeastern part of India, located at the latitude of 23°83'N and 25°68'N and longitudes of 93°03'E and 94°78'E, with a total area of 22,347 Km^2. The land is endowed with rich natural resources as it is located under the Indo Burma hotspot, one of the mega biodiversity hotspots of the world. The state fed with two major river systems viz, the Barak-Surma-Meghna system covering the western part and the Chindwin-Irrawadi system in the eastern region of the states. Ichthyofaunal diversity of Manipur accounts for 218 fish species belonging to 92 genera, 32 families and 11 orders (Singh, 2019). Since time immemorial, fish has been an essential component of rituals on special occasions, and it is one of the preferred meats next to pork in Manipur. So, the demand for fish is at an all-time high. But, the current fish production is only 32,150 (,000) tones, which is insufficient to meet the requirement of the population. The present per capita of Manipur is 14.13kg/yr, which is below the average per capita of the world specified by WHO, 20.5 kg in 2018. Hence, the domestic production is deficientto meet the requirement of the state. These could be fulfilled with the intervention of an advanced aquaculture system, diversification of culture system, and species diversification in aquaculture. Many indigenous or endemic species could be a candidate species for aquaculture viz, *Osteobrama belangeri, Bangana devdevi, Ompok sp., Anabas testudineus, Channa sp., Hypsibarbus myitkyinae* etc. These are some of the species that fetch high market price, but their exploitation remains dependent on wild water resources. Furthermore, overexploitation of wild fish genetic resources has reached its optimum level, and there is a need for strategic conservation measures to ensure sustainable utilization of the fisheries resources. These could be achieved by developing an ex situ gene bank and standardization of breeding protocol of the species. The current study aims to develop a gene bank at the central farm, Central Agricultural University, Imphal, and standardization of breeding protocol of *Bangana devdevi* and *Hypsibarbus myitkyinae* for their mass production at commercial scale.

MATERIALS AND METHODS

A. Collection of brooders

Fish were collected from different river systems (Table 1), with the locally available gear like cast net, traps and gill net. The water quality analysis was done for each river with the help of API pond master test kit. Fish were packed in polythene bags filled with 1/3 water, aerated with a battery-operated aerator and brought to the Central farm, Central Agricultural University, Lamphelpat, Imphal, Manipur. Meanwhile, identification of fish was done by following standard key (Vishwanath, 2007). After proper acclimatization, the fishes were given a five ppt saline water bath and released into the pond. The fish were fed formulated diet with 3% of the bodyweight containing 40% crude protein.

Table. 1. Details of sampling sites with geo-coordinates

River mane	Geo-coordinates
Sanalok River, Kamjong District	(24°52'N/94°39'E)
Imphal river, Chanoubung Kangpokpi District	(25°10'N/93°58'E) 1084 msl
Barak river, Karong ,Senapat District	25°18'N/94°02'E, 966 msl
Khuga river, Churachandpur District	24°27' N /93°67'E
Khordak, Bishnupur District	24°46' N /93°85'E
Iril river, Imphal East District	24°46' N /93°85'E 794 msl
Thoubal river, Thoubal District	24°708' N, 93°85'E 790 msl

B. Induced breeding of *Bangana devdevi* and *Hypsibarbus myitkyinae* was carried out using carp pituitary extract (CPE) and synthetic hormone Gonopro-FH for the experiment.

RESULTS AND DISCUSSION

In-situ Physico-chemical parameters were estimated and given in table no. 2.

Table 2. Ranges of Physico-chemical parameters of different river systems of Manipur.

Parameters	Sanalok River, Kamjong District	Imphal river, Chanoubung, T Khullen, Kangpokpi District	Barak river, Karong ,Senapati District	Khuga river, Churachandpur District1	Khordak, Bishnupur District	Iril river, Imphal East District	Thoubal river, Thoubal District
DO (mg/L)	8-15	7-14	6-15	6-12	5-13	6-14	5-13
Alkalinity (mg/L)	50-90	50-80	50-100	50-120	40-120	50-120	50-80
Hardness (mg/L)	50-90	50-100	40-80	50-100	50-110	50-100	50-80
Temperature (°C)	15-26	14-33	12-28	14-34	18-33	17-33	10-33
pH	7.5-8.3	7.2-8.8	7-8.5	7.4-8.2	6.8-8	7.5-8.8	7.5-8.7

Furthermore, the Physico-chemical parameters of the Central farm were also determined to ensure and maintain the favourable ambient condition of the fishes. The observed values were given in Table no. 3.

Table 3. Different Physico-chemical parameters of five farm pond of Central farm, CAU, Imphal.

Parameters	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4**	**Farm 5**
DO **(mg/L)**	5.7-8	6-9	6-8	5.5-9	6-9
Alkalinity **(mg/L)**	40-60	80-100	40-60	60-90	40-70
Hardness **(mg/L)**	95-120	60-100	65-125	60-85	65-75
Temperature **(°C)**	18-33	18-33	18-33	18-33	18-33
pH	7-8.8	6.8-8.5	7-8.5	6.8-8.3	7-8.6

All the physicochemical parameters of the farm pond were maintained within the range observed in different rivers. But, the upper limit of DO and alkalinity is more in the river ecosystem, whereas the lower limit of hardness and temperature is low in rivers and farm ponds, respectively. So, the physicochemical parameters of the farm ponds are found to be favourable for the fish. Fishes were under consistent observations through regular sampling to find the optimum period for breeding purposes. Seed production of *Anabas testudenius, Ompok bimaculatus,* and *Clarias magur* are being done. Additionally, the Optimization of the breeding technique of *Bangana devdevi* and *Hypsibar myitkyinae* had been carried out for the first time. Key observations for the newly developed breeding parameters were summarized in the table no. 4.

Table 4. Key observed parameters of *B. devdevi* and *H. myitkyinae* during the breeding experiment

Parameter	*Bangana devdevi*	*Hypsibarbus myitkyinae*
Peak maturity occurred	Male-August Female-July	Male-June Female -July
Length at first maturity	93mm	78mm
Absolute Fecundity	2,830- 22,024 eggs/female	3,240-28,420 eggs/female
GSI	Male- 1.17 Female -2.24	Male- 1.6 Female-2.69
Hormone used	Gonopro FH	Gonopro FH
Dose	0.4ml/Kg	0.3ml/kg
Hatching rate in %	75-80	80-85
Survival rate in %		
Spawn to fry	45-50	60-70
Fry to fingerling	65-75	80-85

Peak maturity of *B. devdevi* is slightly earlier than the *H. myitkyinae*, between August to July and June to July, respectively. Other carp species breeding was also observed in the same region by Behera *et al.,* 2009, Behera, *et al.,* 2010. Basudha *et al.,* 2017. Female with round belly and free oozes male were chosen in the ratio of 2:1 for hormonal administration. Length at first maturity is slightly higher in *B. devdevi* (93 mm) than *H. myitkyinae* (78 mm). Absolute fecundity is comparatively higher in *B. devdevi.* Synthetic hormone Gonopro-FH were used to carry out the experiment, and male required lower dose of the hormone than female (Routray *et al.,* 2007). The optimum necessary hormonal dosefor breeding is 0.4 ml/kg for *B. devdevi* and 0.3 ml/kg for *H. myitkyinae*. Pandey *et al.,* 2002 also found 0.4 ml/kg as an optimum dose for breeding of Indian Major Carp. Both the male and female were released in the breeding pool after the application of hormone. A higher hatching rate was observed in *H. myitkyinae* 80-85% compared to *B. devdevi* (75-85%). Survival rate of both the fry and fingerling is also higher in *H. myitkyinae*.

CONCLUSION

Maintenance of Gene bank allows us to protect the species from various anthropogenic threats and their overexploitation. Captive seed production of *B. devdevi* and *H. myitkyinae* would substantiate to scale up the necessary conservation strategies and thereby reducing their exploitation in the wild water bodies. The standardized seed production protocol can be popularized among the farming community to augment the fisheries production in massive scale and diversify the aquaculture sector of the state. The present studies will be helpful to improve the socio-economic status of the fisherman of Manipur and sustainable management of the endemic fish genetic resources of Manipur.

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REFERENCES

Vishwanath, W., Lakra, W. S., & Sarkar, U. K. (2007). *Fishes of North East India*. National Bureau of Fish Genetic Resources, Indian Council of Agricultural Research.

Behera, B. K., Das, P., Singh, N. S., &Sahu, A. K. (2010). Captive breeding of an endemic medium carp Pengba, Osteobramabelangeri (Val.) with Wova-FH in Manipur. *Journal of Aquaculture*, *18*, 23-29.

Behera, B. K., Das, P., Singh, N. S., &Sahu, A. K. (2009). Breeding and seed production of Labeogonius (Hamilton) under captive condition in Manipur. *Journal of Aquaculture*, *17*, 1-6.

Basudha, C. H., Singh, N. G., Devi, N. S., &Sinthoileima, C. H. (2017). Induced breeding and embryonic development of an indigenous fish Banganadero (Hamilton) in captivity using wova FH. *Int J Fish Aquat*, *5*(1), 428-432.

Routray, P., Verma, D. K., Sarkar, S. K., & Sarangi, N. (2007). Recent advances in carp seed production and milt cryopreservation. *Fish Physiology and Biochemistry*, *33*(4), 413-427.

Pandey, A. K., Mohapatra, C. T., Kanungo, G., Sarkar, M., Sahoo, G. C., & Singh, B. N. (2002). Ovatide induced spawning in the Indian major carps, Labeorohita (Hamilton-Buchanan). *Aquaculture*, *3*(1), 1-4.

Singh, Y. L. Ichthyofaunal Resources of Manipur. *FOOD BIORESOURCES AND ETHNIC FOODS OF MANIPUR, NORTH EAST INDIA*, 16.

EXPLORATION AND EVALUATION OF FISH FAUNAL DIVERSITY OF DUDHNOI AND JINARI RIVERS OF GARO HILLS, MEGHALAYA

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ABSTRACT

Explorations were made between October 2012 to March 2015 to study the ichthyofaunal richness of two south bank tributaries of the Brahmaputra in Meghalaya, Dudhnoi and Jinari rivers. No prior records on the fish fauna of these two rivers are available. A total of 36 fish species of 28 genera under 16 families and 58 fish species of 45 genera under 21 families were caught during the study period from the Dudhnoi and Jinari rivers, respectively. Dominance of Cyprinids was observed in both rivers. The course of Dudhnoi and Jinari, both originating from the Garo Hills, Meghalaya, is highly varied and hence, these rivers support immense ichthyofaunal diversity in the form of both torrential and plain water species. Species like *Glyptothorax cavia*, *Tor tor*, *Opsarius tileo*, *Schistura savona*, *Batasio batasio*, *Olyra kempi*, etc were restricted to the upper stretches, these species being specially adapted in the form of structural modifications to sustain the harsh flow of water. Of the total sampled fish species from both the rivers, 82.3% belong to the Least Concern category, 4.8% under Near Threatened, 3.2% under Data Deficient, and 1.6% as Vulnerable. However, the less richness of fish species of the Dudhnoi River may be attributed to the Acid Mine Drainage (AMD) of coal mining being practiced in the bank of the river in its upper stretches. The present findings indicate that the both the tributaries of the Brahmaputra are rich in fish species and can provide huge prospects of economic development of the nearby areas including livelihood generation of the associated fisherfolk and rural communities.

Keywords: Freshwater fish, species richness, hill stream, northeast India

INTRODUCTION

Over the last century, riverine ecosystems have suffered from intense human interventions, which has resulted in habitat loss and degradation. Consequently, several species of fish are now endangered, specifically those in freshwaters where heavy demand is placed. Freshwater fish is one of the most threatened taxonomic groups because of its high sensitivity to the quantitative and qualitative alteration of aquatic habits. Thus, understanding biodiversity distribution patterns is a central issue for scientists and managers concerned with the current extinction processes.

The present investigation is a study on the fish faunal diversity and associated habitat of two southern tributaries of the Brahmaputra River, Dudhnoi and Jinari. The Dudhnoi River originates in the East Garo Hills District of Meghalaya. After flowing about 50 km through hilly terrain of East Garo Hills, the river enters in Assam at Dainadubi in the name of Dudhnoi. It then joins the Krishnai River and takes the name of Domoni and finally meets the Brahmaputra River. The approximate length of the river from its origin in Meghalaya plateau to River Brahmaputra is about 130 km. The Jinari River originates from Nokrek Peak (about 1400 MSL, now declared as Nokrek Biosphere Reserve). After flowing through areas of West Garo Hills and East Garo Hills via Bajengdoba, it enters the plain of Assam at Goalpara District. Before joining with River Brahmaputra at Goalpara, the river re-routes through a wetland called Urpod Beel. The approximate length of the river from its origin to River Brahmaputra is 140 km. To the best of knowledge, no previous information is available on the fish faunal diversity of these rivers.

MATERIALS AND METHODS

The investigation was carried out from October 2012 to March 2015. In the initial period of the survey, tracing of the rivers was carried out physically and with the help of fringe villagers of both the rivers.

For collection of fish samples, an electric fishing device had been fabricated using a 12V battery to catch the fishes in various sampling sites of the rivers as well as the sites as indicated by the fringe villagers. Also, fishing nets (caste nets, gill nets) were used. To examine fish faunal diversity of the rivers, experimental fishing was carried out on a monthly basis with the help of local fishers. Fishes were also collected regularly from local collaborator appointed in all selected sampling site. Efforts were also made to collect the fish specimen from all possible sites of the selected river throughout its length. Collected species were preserved in 10% formalin for initial one week and then transferred to 70% alcohol for permanent preservation. Fishes were subsequently identified by following Talwar and Jhingran (1991), Jayaram (1999), Jayaram (2006), and Vishwanath *et al*. (2014). The conservation status of the fish species was assessed following IUCN (2022). The identification of fishes was done by using morphological features and morphometric analysis. Current updated names of fishes were validated from the online database of Fricke *et al.* (2022). Evaluation of habitat ecology of the rivers, diversity pattern of the species, and taxonomic status of the collected species had been carried out through direct observations and standard method. The relative abundance (RA) of individual species in each sampling stations was calculated by the following formula:

$$RA = \frac{\text{Number of samples of particular species}}{\text{Total number of samples}} \times 100$$

Early history of the rivers, secondary information on species diversity, Indigenous Technological Knowledge and demographic data of fringe villages were collected from the villagers through interview and focused group discussions. At each site, the basic field data, including latitude, longitude and elevation, were taken with a GPS recorder. Photographs of live and preserved specimens were taken with a canon 550-D camera.

Details of sampling sites of Dudhnoi River

Five sampling sites (Fig. 1) were selected for collection of fishes and water sample for assessment of certain water quality parameters. The distance from one sampling site to another was approximately 30 km. Brief description of all the sampling sites are as follows in Table 1 –

S.No.	**Name of the site**	**GPS coordinates (Latitude & Longitude)**	**Altitude (m)**	**No. of fish species recorded from that site**	**Characteristics of the site in brief**	**Any specific issue/threat of significance to biodiversity**
1	Site. 1 (S_1)	E 90°48′30.61″ N 25°40′09.54″	1120	6	Riverbed is rocky. Average depth of the site was 0.53 m. Both the bank is covered by dense rain forest	Coal mining activities are being practiced in the hills of the vicinity.
2	Site. 2 (S_2)	E 90°47′15.19″ N 25°49′10.28″	813	23	Riverbed is covered with boulders and pebbles. Average depth of the site was 0.61m. Both the bank is covered by dense rain forest	Herbal Poison is being practiced by the fringe villagers to catch the fish.
3	Site. 3 (S_3)	E. 90°46′51.24″ N.25°52′03.78″	521	30	Riverbed is covered with boulders, pebbles and sand. Comparatively wider than the preceding site. Average depth of the site was 0.89 m.	Gill net along with herbal poison is being used by Garo tribes for fishing.
4	Site. 4 (S_4)	E 90°46′31.99″ N 25°56′27.58″	314	23	Riverbed is covered with pebbles and sand. Average depth of the site was 1.06 m.	Excessive fishing is being practiced with traditional fishing gear

S.No.	Name of the site	GPS coordinates (Latitude & Longitude)	Altitude (m)	No. of fish species recorded from that site	Characteristics of the site in brief	Any specific issue/threat of significance to biodiversity
5	Site. 5 (S_5)	E 90°47′42.05″ N 25°58′37.77″	150	24	Riverbed is covered with sand. Average depth of the site was 1.06 m.	Excessive fishing is being practiced with traditional fishing gear

Details of sampling sites of Jinari River

Five sampling sites (Fig. 1) were selected for collection of fish and water sample for assessment of certain water quality parameters. The distance from one sampling site to another was approximately 25 km. Brief description of all the sampling sites is as follows in Table 2 –

S.No.	Name of the site	GPS coordinates (Latitude & Longitude)	Altitude (m)	No. of fish species recorded from that site	Characteristics of the site in brief	Any specific issue/threat of significance to biodiversity
1	Site. 1 (S_1)	E 90°22′00.21″ N 25°43′24.46″	1028	14	Width of the River is less and Riverbed is covered with boulders and pebbles. Average depth of the site was 0.51 m.	Fishing is done by Herbal poison only
2	Site. 2 (S_2)	E 90°24′47.86″ N 25°46′17.86″	704	24	Riverbed is covered with boulders and pebbles. Average depth of the site was 0.61 m.	Herbal Poison is being practiced by the fringe villagers to catch the fish.
3	Site. 3 (S_3)	E 90°26′28.41″ N 25°49′29.31″	468	33	Riverbed is covered with boulders, pebbles and sand. Average depth of the site was 0.75 m.	Excessive fishing is being practiced with traditional fishing gear
4	Site. 4 (S_4)	E 90°33′45.85″ N 25°58′51.92″	221	30	Riverbed is covered with pebbles and sand. Average depth of the site was 1.22 m.	Excessive fishing is being practiced with traditional fishing gear
5	Site. 5 (S_5)	E 90°04′32.86″ N 26°04′52.54″	123	32	Riverbed is covered with sand. Average depth of the site was 2.50 m.	Excessive fishing is being practiced with traditional fishing gear

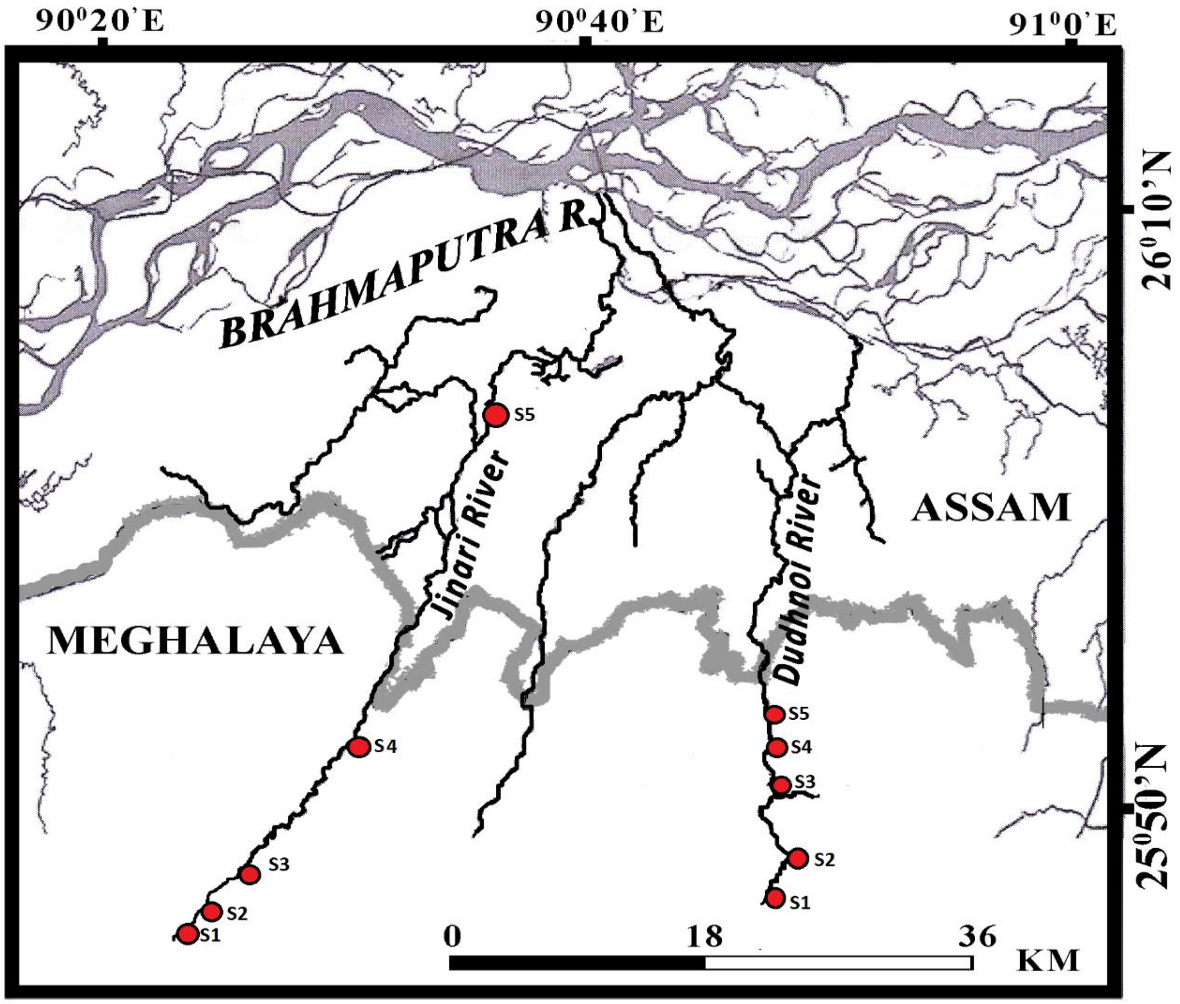


Figure 1 Drainage map showing sampling sites of Dudhnoi and Jinari rivers, Northeast India

RESULTS

A total of 36 fish species of 28 genera under 16 families were collected during the period of investigation from the Dudhnoi River. Three species (*Parambassis lala*, *Ailia coila* and *Bagarius bagarius*) as Near Threatened, three species (*Eutropichthys vacha, Ctenopharyngodon idella* and *Glossogobius gutum*) as Not Evaluated, one species (*Devario assamensis*) as Vulnerable, two species (*Anabas testudineus* and *Badis assamensis*) as Data Deficient, and the rest as Least Concern. Relative abundance of Cyprinidae was estimated maximum (35.29) in S_1 and minimum relative abundance was found in Psilorhynchidae (1.07) and has been reported from S_3 only. The abundance of Badidae was recorded from S_3 to S_5. One species of the Badidae family has not yet been identified. Species of family Belonidae, Channidae, Clupeidae, Engraulididae, Gobiidae, Heteropneustidae, Mastacembelidae, Mugilidae, Nandidae, Notopteridae and Psilorhynchidae were not recorded in S_1. Species of Balitoridae family were found abundant in S_1 to S_3, however, not collected from S_4 and S_5.

Table 3 Relative abundance (in %) of fish species in five sampling sites of Dudhnoi River (2012-2015) (N represents species richness under each family)

Family	Sampling Sites									
	S_1		S_2		S_3		S_4		S_5	
	N	%	N	%	N	%	N	%	N	%
Ambassidae	3	17.65	5	8.47	8	9.41	10	10.20	15	13.04
Anabantidae	-	-	2	3.39	-	-	5	5.10	-	-
Badidae	-	-	5	8.47	6	7.06	-	-	9	7.83

Family	Sampling Sites									
	S_1		S_2		S_3		S_4		S_5	
	N	%	N	%	N	%	N	%	N	%
Bagridae	4	23.53	7	11.86	9	10.59	12	12.24	16	13.91
Balitoridae	2	11.76	4	6.78	6	7.06	-	-	-	-
Belonidae	-	-	3	5.08	8	9.41	11	11.22	-	-
Channidae	-	-	2	3.39	4	4.71	7	7.14	-	-
Cyprinidae	6	35.29	12	20.34	16	18.82	21	21.43	28	24.35
Gobiidae	2	11.76	5	8.47	3	3.53	7	7.14	11	9.57
Mastacembelidae	-	-	3	5.08	5	5.88	7	7.14	5	4.35
Nandidae	-	-	3	5.08	6	7.06	-	-	7	6.09
Osphronemidae	-	-	6	10.17	7	8.24	11	11.22	9	7.83
Psilorhynchidae	-	-	-	-	2	2.35	-	-	-	-
Schilbeidae	-	-	-	-	5	5.88	5	5.10	5	4.35
Siroridae	-	-	4	6.78	-	-	2	2.04	7	6.09
Sisoridae	-	-	-	-	-	-	-	-	3	2.61
	17	**100.00**	**61**	**100.00**	**85**	**100.00**	**98**	**100.00**	**115**	**100.00**

A total of 58 fish species of 45 genera under 21 families were collected from the Jinari River. Four species (*Parambassis lala*, *Tor tor, Ailia coila* and *Bagarius bagarius*) as Near Threatened, two species (*Glossogobius gutum* and *Oreichthys crenuchoides*) as Not Evaluated, one species (*Devario assamensis*) as Vulnerable, two species (*Anabas testudineus* and *Badis assamensis*) as Data Deficient, rest are recorded as Least Concern. In the present findings, relative abundance of Cyprinidae was estimated as maximum (17.11) in S_1 and minimum relative abundance was estimated in Badidae (1.07) in S_5. The abundance of Badidae was recorded in S_3 to S_5. One species of the Badidae family has not yet been identified. Species of the family Belonidae, Channidae, Clupeidae, Engraulididae, Gobiidae, Heteropneustidae, Mastacembelidae, Mugilidae, Nandidae, Notopteridae and Psilorhynchidae were also not recorded in S_1. Species of Balitoridae family were found abundant in S_1 & S_2. One specimen of *Oreichthys crenuchoides* was collected in S_5 in retreating monsoon, which was previously described from Sonkosh River (tributary of Brahmaputra) in West Bengal. The abundance of *Opsarius tileo* was also found very less and only reported from S_2. One species of *Lepidocephalicthys* is yet to be identified.

Table 5 Relative abundance (in %) of fish species in five sampling sites of Jinari River (2012-2015) (N represents species richness under each family)

Family	Sampling Sites									
	S_1		S_2		S_3		S_4		S_5	
	N	%	N	%	N	%	N	%	N	%
Ambassidae	1	3.57	2	3.39	5	4.31	8	6.67	12	6.42
Anabantidae	2	7.14	0	-	3	2.59	4	3.33	6	3.21
Badidae	-	-	0	-	4	3.45	2	1.67	2	1.07
Bagridae	3	10.71	2	3.39	5	4.31	7	5.83	8	4.28
Balitoridae	1	3.57	2	3.39	5	4.31	-	-	-	-
Belonidae	-	-	3	5.08	-	-	-	-	4	2.14
Channidae	-	-	2	3.39	6	5.17	7	5.83	14	7.49
Clupeidae	-	-	4	6.78	7	6.03	11	9.17	16	8.56
Cobitidae	3	10.71	8	13.56	10	8.62	13	10.83	17	9.09
Cyprinidae	9	32.14	17	28.81	24	20.69	26	21.67	32	17.11
Engraulididae	-	-	-	-	3	2.59	-	-	6	3.21
Gobiidae	-	-	4	6.78	8	6.90	11	9.17	16	8.56
Heteropneustidae	-	-	-	-	3	2.59	-	-	4	2.14
Mastacembelidae	-	-	3	5.08	9	7.76	6	5.00	11	5.88
Mugilidae	-	-	2	3.39	-	-	-	-	-	-
Nandidae	-	-	-	-	-	-	6	5.00	9	4.81
Notopteridae	-	-	-	-	4	3.45	6	5.00	9	4.81

Family	Sampling Sites									
	S_1		S_2		S_3		S_4		S_5	
	N	%	N	%	N	%	N	%	N	%
Osphronemidae	4	14.29	-	-	2	1.72	3	2.50	7	3.74
Psilorhynchidae	-	-	4	6.78	7	6.03	-	-	3	1.60
Schilbeidae	3	10.71	-	-	8	6.90	6	5.00	-	-
Sisoridae	2	7.14	6	10.17	3	2.59	4	3.33	11	5.88
	28	**100.00**	**59**	**100.00**	**116**	**100.00**	**120**	**100.00**	**187**	**100.00**

DISCUSSION

The level of endemism in Northeast India is strikingly higher in the mountain tributaries of the Brahmaputra with large number of hill stream species with highly localized distributions from different families like Balitoridae, Psilorhynchidae, Cyprinidae and Sisoridae (Vishwanath *et al*., 2010). Fish species like *Oreichthys crenucoides*, *Devario assamensis*, *Channa stewartii*, *Badis assamensis*, etc. are restricted to the Brahmaputra basin in Northeast India. This endemicity or restricted distribution along with various threats (both natural and man-made) has been a major problem for the fish fauna of the region (Sarkar and Ponniah, 2000; Vishwanath *et al*., 2010; Goswami *et al*., 2014). The course of Dudhnoi and Jinari, both originating from the Garo Hills, Meghalaya, is highly varied and hence, these rivers support immense ichthyofaunal diversity in the form of both torrential and plain water species. Species like *Glyptothorax cavia*, *Tor tor*, *Opsarius tileo*, *Schistura savona*, *Batasio batasio*, *Olyra kempi*, etc. were restricted to the upper stretches, these species being specially adapted in the form of structural modifications to sustain the harsh flow of water. Of the total sampled fish species from both the rivers, 82.3% belong to the Least Concern category, 4.8% under Near Threatened, 3.2% under Data Deficient, and 1.6% as Vulnerable. Fish species belonging to the threatened criteria thereby require special attention in the form of proper sustainable management approaches, initiatives to be taken from both government and non-government bodies, is essential for preservation of these indigenous germplasm of Northeast India.

However, the less richness of fish species of the Dudhnoi River may be attributed to the Acid Mine Drainage (AMD) of coal mining being practiced in the bank of the river in its upper stretches. Acid Mine Drainage (AMD) is the key factor that causes low pH, and fishes die due to acute acidemia and increased heavy metal concentration (Mallik *et al*., 2015). It is evident from the survey that the gill nets (*Langi jal*, *Phansi jal*) along with cast net and *Ber jal* are most extensively used in the fishing processes in lower reaches of both the rivers. However, fishing with these gears is banned from 1st May to July 15th of every year vide the Assam Fishery Rules, 1953 (Sharma, 2001), and therefore, use of these fishing gears is limited to pre monsoon, retreating monsoon and winter only. The specified banned period falls within the monsoon season and more particularly, most of the fish species breed during this period. It has also been observed that the cast net and *Khewali jal* were being employed throughout the year in certain sampling sites (4 and 5). The only scooping gear observed during the study period was the *Dheki jal* or *Khora jal* generally operated in lower reaches of both the rivers. This gear is also used all throughout the year except in stormy weathers. In addition to these, different types of nets, fishing gears like hooks and lines (*Nal barshi* and *Sip barshi*) are also observed to be used throughout the entire stretch of the studied rivers. It was also observed that only one type of fishing trap namely *Chepa* and certain basket traps have been found to be in operation in the upper stretches of the studied rivers. Traps are unique of their own as they are designated and fabricated taking into consideration the area, location and behaviour of the fishes. Thus, the study shows seasonal variation in the usages of fishing gears in the river system. At least 3 to 4 types of herbal poisons are used by *Garo* tribes in the upper reaches of both the rivers. Community fishing through herbal poison, electric fishing (and occasionally through dynamiting) in receding season is the significant feature in *Garo* dominated areas. Hand picking is another method being executed by *Garo* tribes in the upper reaches of both rivers. This free hand fish capturing method is done by lifting boulders. A boulder is lifted and striked over the boulder where fishes remain hidden. *Glyptothorax* sp., *Channa* sp., and eels are also caught by this method. Efficiency in fish harvesting technology among the *Garo* people is also significant as they have modified and upgraded various indigenous gears that are being locally fabricated to catch fish. Their traditional methods reflect the dependency on nature for livelihood support which has succeeded over the years by revering nature and using its resources in a sustainable way (Brandt, 2005; Baruah *et al*., 2013). But certain destructive fishing practices (poisoning, dynamiting, etc) should be checked so that these do not hamper the fisheries resources.

CONCLUSION

The findings of the study indicate that the both the tributaries of River Brahmaputra are still very rich in terms of fish species diversity. Though the feeder channels of the rivers are subjected to varied pressures (anthropogenic and natural) they are still rich aquatic ecosystems. Therefore, conservation of these indigenous fish species, various strategies are the need of the hour, which may be halting of siltation, promoting controlled harvest and control of herbal poisoning or dynamiting. Effective conservation strategies can be taken up by the conservation agencies for sustaining biodiversity. A comprehensive biotic assessment program is required for effective protection of freshwater fish resources in both the rivers.

REFERENCES

Baruah D, Dutta A & Pravin P, 2013. Traditional fish trapping devices and methods in the Brahmaputra valley of Assam, *Indian Journal of Traditional Knowledge*, 12 (1): 123–129.

Brandt, A. V., 2005. Catching Methods in Fisheries: an Introduction, In: *Fish catching methods of the world*, 4th ed., pp. 1–11. Edited by O Gabriel, K Lange, E Dahm & T Wendt, (Blackwell Publishing Limited, UK).

Fricke, R., Eschmeyer, W. N. and Van der Laan, R. (eds.), 2022. *Catalog of fishes*: *genera, species, references*. Electronic version of 02 July 2022. Available from: http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. Accessed 07 July 2022.

IUCN, 2022. *The IUCN Red List of Threatened Species*. Version 2022-1. http://www.iucn.org. Accessed 07 July 2022.

Jayaram, K. C., 1999. *The freshwater fishes of the Indian Region*. Narendra Publishing House, Delhi.

Jhingran, V. G., 1991. *Fish and fisheries of India*. 3rd ed. Hindustan Publishing Corporation, Delhi, India. pp. 727.

Mallik, S. K., Sarma, D., Sarma, D. and Shahi, N. 2015. Acid mine drainage, a potential threat to the fish fauna of Simsang River, Meghalaya. *Current Science*. 109 (4): 687–690.

Sarkar, U. K. and Ponniah, A.G. 2000. Evaluation of North East Indian Fishes for their Potential as Cultivable, Sport and Ornamental Fishes along with their Conservation and Endemic Status p.11–30 In: A.G. Ponniah and U. K. Sarkar edited. *Fish Biodiversity of North-East India*. NBFGR, NATP Pub 2, Lucknow.

Sarma, K. and Barik, S. K., 2010. Geomorphological risk and conservation imperatives in Nokrek Biosphere Reserve, Meghalaya Using Geoinformatics. *NeBIO.* 1(2): 14–24.

Sharma, R. 2001. Traditional fishing methods and fishing gears of Assam. *Fishing Chimes*. 20 (12): 23–26.

Talwar, P. K. and Jhingran, A. G., 1991. *Inland fishes of India and adjacent countries*. Vol I & II. Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi.

Tripathi, O. P., Pandey, H. N. and Tripathi, R. S., 2008. Effects of human activities on structure and composition of woody species of the Nokrek Biosphere Reserve of Meghalaya, North-east India. *Journal of Plant Ecology* (Chinese Version). 73–79.

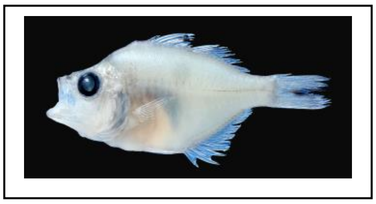
Vishwanath W, Ng H. H., Britz, R., Singh, L. K., Chaudhry, S. and Conway, K. W. 2010. The status and distribution of freshwater fishes of the Eastern Himalaya region p.22–39 In: D. J. Allen, S. Molur and B. A. Daniel compiled. *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalayas*. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Vishwanath, W., Nebeshwar, K., Lokeshwar, Y., Shangningam, B. D. and Rameshori, Y., 2014. *Freshwater fish taxonomy and a manual for identification of fishes of North-East India*. Manipur University & National Bureau of Fish Genetic Resources. Imphal, Manipur, India. pp. 1–116.

APPENDIX

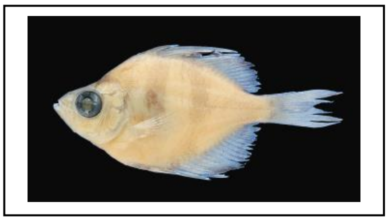
A checklist of the fish species of Dudhnoi and Jinari Rivers is provided below –

1. Scientific name: ***Chanda nama* (Hamilton, 1822)**



Common name: Elongate glass-perchlet
Local name: Chanda
Distribution: India, Nepal, Pakistan and Bangladesh
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4, S_5; Dudhnoi River—S_2, S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_2= 6, S_3=7, S_4=9, S_5=7; Dudhnoi River—S_2= 10, S_3= 6, S_4= 4, S_5=9.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

2. Scientific name: ***Parambassis lala* (Hamilton, 1822)**



Common name: Highfin glassy perchlet
Local name: Chanda
Distribution: India: Orissa, Tripura, Assam, Bengal and Bihar, and Myanmar.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_5; Dudhnoi River—S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_3=4, S_5= 6; Dudhnoi River—S_3= 2, S_4= 6, S_5= 7.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Near Threatened**

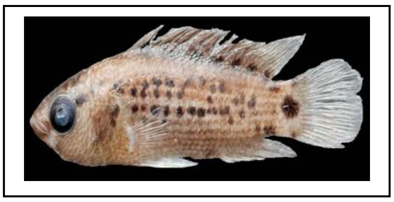
3. Scientific name: ***Parambassis baculis* (Hamilton, 1822)**

Common name: Himalayan Glassy Perchlet
Local name: Chanda
Distribution: Bangladesh, India and Myanmar.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_4; Dudhnoi River—S_1, S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_1=3, S_3=1 , S_4= 4; Dudhnoi River—S_1= 2, S_3=1, S_4=1, S_5=3.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

4. Scientific name: ***Anabas testudineus* (Bloch, 1792)**

Common name: Climbing perch
Local name: Kawai
Distribution: Pakistan, India, Bangladesh, Nepal, Bhutan, Sri Lanka, Myanmar, Thailand, Cambodia, Laos, Vietnam, Southern China, Malaysia, Indonesia, Brunei and Singapore.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_4, S_5; Dudhnoi River—S_2, S_4.
Number of samples recorded from each site: Jinari River— S_1=10, S_3=17, S_4=8, S_5=10; Dudhnoi River—S_2=9, S_4=7.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Data deficient**

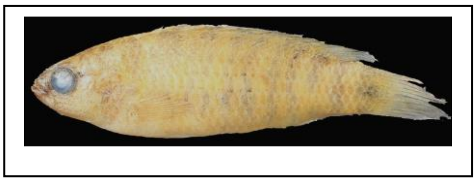
5. Scientific name: ***Badis assamensis* (Ahl, 1937)**



Common name: Assam badis
Local name: Randhoni maas
Distribution: India: Assam, Arunachal Pradesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4; Dudhnoi River—S_2, S_3, S_5.
Number of samples recorded from each site: Jinari River— S_2=1, S_3=2, S_4=3; Dudhnoi River—S_2=3, S_3=2, S_5=6.

Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Data Deficient**

6. Scientific name: ***Badis badis*** (**Hamilton, 1822)**
Common name: Dwarf chameleon fish.
Local name: Randhoni maas
Distribution: India, Bhutan, Bangladesh, Pakistan and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Dudhnoi River—S_2, S_3, S_5.



Number of samples recorded from each site: Dudhnoi River—S_2=8, S_3=9, S_5=7.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

7. Scientific name: ***Batasio batasio*** **(Hamilton, 1822)**
Common name: Tista batasio
Local name: Batasi mass
Distribution: Bangladesh; India: Arunachal Pradesh, Assam, Mizoram, Tripura and West Bengal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3.

Number of samples recorded from each site: Jinari River-S_3=2.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

8. Scientific name: ***Mystus cavasius*** **(Hamilton, 1822)**
Common name: Gangetic mystus
Local name: Singorah
Distribution: Bangladesh, India and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_4, S_5; Dudhnoi River— S_3, S_4, S_5.

Number of samples recorded from each site: Jinari River— S_2=4, S_4=7, S_5=3; Dudhnoi River— S_3=4, S_4=5, S_5=8.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

9. Scientific name: ***Mystus tengara*** **(Hamilton, 1822)**
Common name: Stripped dwarf catfish.
Local name: Tingorah
Distribution: India and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_4; Dudhnoi River— S_3, S_4, S_5.

Number of samples recorded from each site: Jinari River— S_1=8, S_3=7, S_4=7; Dudhnoi River— S_3=9, S_4=4, S_5=7.
Local fishery/ economic importance: Food and ornamental fish.
Conservation/threatened status: **Least concern**

10. Scientific name: ***Mystus bleekeri*** **(Day, 1877)**
Common name: Day's mystus.
Local name: Singorah
Distribution: Bangladesh, India, Nepal, Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5; Dudhnoi River— S_3, S_4, S_5.

Number of samples recorded from each site: Jinari River— S_4=6, S_5=3; Dudhnoi River— S_3=4, S_4=2, S_5=5.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

11. Scientific name: ***Olyra kempi* Chaudhuri, 1912**
Common name: Himalayan Olyra
Local name: Botsinghi
Distribution: India: Arunachal Pradesh, Assam, Darjeeling, Manipur and West Bengal.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1; Dudhnoi River— S_2.
Number of samples recorded from each site: Jinari River— S_1=5; Dudhnoi River— S_2=7.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

12. Scientific name: ***Paracanthocobitis botia* (Hamilton, 1822)**
Common name: Striped loach
Local name: Botia
Distribution: Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan and Thailand.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3; Dudhnoi River— S_1.
Number of samples recorded from each site: Jinari River— S_3=; Dudhnoi River— S_1=.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

13. Scientific name: ***Schistura savona* (Hamilton, 1822)**
Common name: Half-banded loach
Local name: Botia
Distribution: India: Uttar Pradesh; Nepal

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2; Dudhnoi River— S_1, S_3.
Number of samples recorded from each site: Jinari River— S_2=3; Dudhnoi River— S_1=2, S_3=3.
Local fishery/ economic importance: Ornamental fish
Conservation/threatened status: **Least concern**

14. Scientific name: ***Nemacheilus corica* (Hamilton, 1822)**
Common name: Stone Loach.
Local name: Botia
Distribution: India: Darjeeling, Himachal Pradesh, Punjab, Uttaranchal; Nepal.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1.
Number of samples recorded from each site: Jinari River— S_1=5.
Local fishery/ economic importance: Ornamental fish
Conservation/threatened status: **Least concern**

15. Scientific name: ***Xenentodon cancila* (Hamilton, 1822)**
Common name: Asian needlefish.
Local name: Kakila
Distribution: Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_5; Dudhnoi River— S_2.
Number of samples recorded from each site: Jinari River— S_2=6, S_5=5; Dudhnoi River— S_2=7.
Local fishery/ economic importance: Food and ornamental fish
Conservation/threatened status: **Least concern**

16. Scientific name: ***Channa gachua* (Hamilton, 1822)**

Common name: Dwarf Snakehead
Local name: Cheng
Distribution: Afghanistan, Bangladesh, Bhutan, Cambodia, China, Hong Kong, India, Indonesia, Iran, Iraq, Malaysia, Myanmar, Nepal, Singapore, Sri Lanka, Thailand and Vietnam.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5; Dudhnoi River— S_2, S_3, S_4.
Number of samples recorded from each site: Jinari River— S_4=6, S_5=7; Dudhnoi River— S_2=8, S_3=5, S_4=4.
Local fishery/ economic importance: Food and ornamental fish.
Conservation/threatened status: **Least concern**

17. Scientific name: ***Channa stewartii* (Playfair, 1867)**

Common name: Assamese snakehead
Local name: Chengeli
Distribution: India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Tripura; Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4.
Number of samples recorded from each site: Jinari River— S_2=4, S_3=3, S_4=5.
Local fishery/ economic importance: Food and ornamental fish.
Conservation/threatened status: **Least concern**

18. Scientific name: ***Channa striata* (Bloch, 1793)**

Common name: Snakehead murrel.
Local name: Sol
Distribution: Pakistan, India, Nepal, Sri Lanka, Bangladesh, Myanmar, Malaysia, Indonesia, Laos, Cambodia, Viet Nam, Thailand and China.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_3=6, S_4=7, S_5=5.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

19. Scientific name: ***Channa punctata* (Bloch, 1793)**

Common name: Spotted snakehead.
Local name: Goroi
Distribution: Afghanistan, Pakistan, India, Nepal, Sri Lanka, Bangladesh and Myanmar.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5; Dudhnoi River— S_2, S_3, S_4.
Number of samples recorded from each site: Jinari River— S_4=6, S_5=7; Dudhnoi River— S_2=5, S_3=4, S_4=5.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

20. Scientific name: ***Gudusia chapra* (Hamilton, 1822)**

Common name: Indian River shad
Local name: Karoti
Distribution: Afghanistan, Bangladesh, India, Myanmar, Nepal, Pakistan and Sri Lanka.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_2=5, S_3=4, S_4=7, S_5=6.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Least concern**

21. Scientific name: ***Botia dario*** **(Hamilton, 1822)**
Common name: Queen Loach
Local name: Rani botia
Distribution: India and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_5.

Number of samples recorded from each site: Jinari River— S_1=9, S_3=7, S_5=10.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

22. Scientific name: ***Cantophrys gongota*** **(Hamilton, 1822)**
Common name: Gongota Loach
Local name: Botia
Distribution: Bangladesh, India and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3.

Number of samples recorded from each site: Jinari River— S_2=9, S_3=7.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

23. Scientific name: ***Lepidocephalichthys goalparensis*** **Pillai & Yazdani, 1976**
Common name: Pillai loach
Local name: Botia
Distribution: Bangladesh, India and Myanmar.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4.

Number of samples recorded from each site: Jinari River— S_4=6.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

24. Scientific name: ***Lepidocephalichthys guntea*** (**Hamilton, 1822)**
Common name: Guntea loach
Local name: Botia
Distribution: Bangladesh, India, Myanmar and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_5.

Number of samples recorded from each site: Jinari River— S_2=12, S_3=10, S_5=16.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

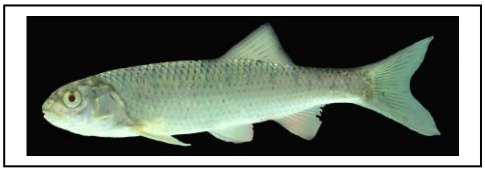
25. Scientific name: ***Amblypharyngodon mola*** **(Hamilton, 1822)**
Common name: Pale carplet
Local name: Moah
Distribution: Bangladesh, India and Pakistan
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_2, S_4, S_5; Dudhnoi River— S_2, S_3, S_4.

Number of samples recorded from each site: Jinari River— S_1=10, S_2=12, S_4=16, S_5=17; Dudhnoi River— S_2=12, S_3=10, S_4=11.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Least concern**

26. Scientific name: ***Barilius barila*** **(Hamilton, 1822)**
Common name: Barred baril
Local name: Korang
Distribution: Bangladesh, China, India, Myanmar and Nepal.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_2=7, S_4=4, S_5=6.
Local fishery/ economic importance: Ornamental as well as game fish.
Conservation/threatened status: **Least concern**

27. Scientific name: ***Barilius bendelisis* (Hamilton, 1807)**
Common name: Hamilton's barila
Local name: Korang
Distribution: India, Bangladesh, Nepal, Myanmar, Pakistan, Thailand and Sri Lanka.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4; Dudhnoi River— S_2, S_3.



Number of samples recorded from each site: Jinari River— S_2=6, S_3=7, S_4=7; Dudhnoi River— S_2=4, S_3=7.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

28. Scientific name: ***Barilius shacra* (Hamilton, 1822)**
Common name: Shacra baril.
Local name: Korang
Distribution: Bangladesh, India and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Dudhnoi River— S_2, S_3, S_4, S_5.
Number of samples recorded from each site: Dudhnoi River— S_2=2, S_3=4, S_4=3, S_5=6.

Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

29. Scientific name: ***Cabdio morar* (Hamilton, 1822)**
Common name: Aspidoparia
Local name: Bariala
Distribution: Iran, Pakistan, India, Nepal, Bangladesh, Myanmar and Thailand.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_5; Dudhnoi River— S_2, S_3, S_4.
Number of samples recorded from each site: Jinari River— S_1=6, S_3=3, S_5=5; Dudhnoi River— S_2=3, S_3=4, S_4=3.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

30. Scientific name: ***Chagunius chagunio* (Hamilton, 1822)**
Common name: Chenguni
Local name: Keinath puthi
Distribution: India, Nepal and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4.
Number of samples recorded from each site: S_4=3.

Local fishery/ economic importance: Game fish.
Conservation/threatened status: **Least concern**

31. Scientific name: ***Tariqilabeo latius* (Hamilton, 1822)**
Common name: Gangetic latia
Local name: Lurali
Distribution: India, Nepal and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4, S_5; Dudhnoi River— S_3, S_4, S_5.

Number of samples recorded from each site: Jinari River— S_2=3, S_3=6, S_4=2, S_5=6; Dudhnoi River— S_3=7, S_4=6, S_5=6.
Local fishery/ economic importance: No interest in fisheries.
Conservation/threatened status: **Least concern**

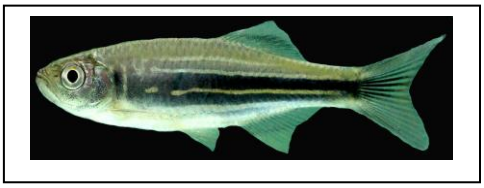
32. Scientific name: ***Oreichthys crenuchoides* Scäfer, 2009**
Common name: N/A
Local name: Puthi
Distribution: India: West Bengal and Assam.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_5.
Number of samples recorded from each site: Jinari River— S_5=2.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Not Assessed**

33. Scientific name: ***Ctenopharyngodon idella* (Valenciennes, 1844)**
Common name: Grass carp
Local name: Grass carp
Distribution: Flatland rivers of China and the Middle and lower reaches of river Amur in the USSR; introduction into many countries including India.
Local occurrence/ Names of rivers & sites from which recorded: Dudhnoi River— S_1, S_3, S_5.
Number of samples recorded from each site: Dudhnoi River— S_1=7, S_3=8, S_5=6.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Not Assessed**

34. Scientific name: ***Devario assamensis* (Barman, 1984)**
Common name: Assami devario
Local name: Laupati
Distribution: India: Assam and Arunachal Pradesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_4; Dudhnoi River— S_3, S_4.
Number of samples recorded from each site: Jinari River— S_2=6, S_4=7; Dudhnoi River— S_3=5, S_4=3.
Local fishery/ economic importance: Food as well as Ornamental fish
Conservation/threatened status: **Vulnerable**

35. Scientific name: ***Devario devario* (Hamilton, 1822)**
Common name: Sind danio.
Local name: Laupati
Distribution: India, Nepal and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5; Dudhnoi River— S_4, S_5.
Number of samples recorded from each site: Jinari River— S_4=4, S_5=6; Dudhnoi River— S_4=7, S_5=5.
Local fishery/ economic importance: Food and Ornamental fish.
Conservation/threatened status: **Least concern**

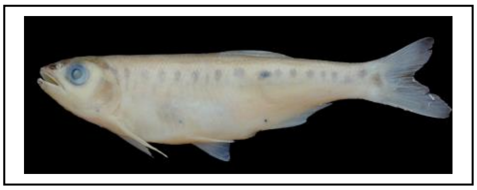
36. Scientific name: ***Devario aequipinnatus* (McClelland, 1839)**
Common name: Giant danio
Local name: Saldarikana
Distribution: India, Nepal and Sri Lanka.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_5.
Number of samples recorded from each site: Jinari River— S_5=7.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**



37. Scientific name: ***Danio* cf. *dangila* (Hamilton, 1822)**
Common name: Moustache danio
Local name: Dorikona
Distribution: India and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3.
Number of samples recorded from each site: Jinari River— S_3=4.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

38. Scientific name: ***Garra* cf. *nasuta* (McClelland, 1838)**
Common name: Khasi garra
Local name: N/A
Distribution: Chin, Burma, Vietnam and India
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_4.
Number of samples recorded from each site: Jinari River— S_1=6, S_4=3.
Local fishery/ economic importance: No interest in fisheries.
Conservation/threatened status: **Least concern**

39. Scientific name: ***Opsarius tileo* (Hamilton, 1822)**
Common name: Tileo baril
Local name: Selling
Distribution: India, Nepal and Bangladesh.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2.
Number of samples recorded from each site: Jinari River— S_2=3.
Local fishery/ economic importance: Ornamental as well as game fish.
Conservation/threatened status: **Least concern**



40. Scientific name: ***Pethia ticto* (Hamilton, 1822)**
Common name: Two spot barb
Local name: Puthi
Distribution: Bangladesh, India, Nepal, Pakistan and Sri Lanka.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_5; Dudhnoi River— S_3, S_4.
Number of samples recorded from each site: Jinari River— S_3=4, S_5=6; Dudhnoi River— S_3=7, S_4=.5
Local fishery/ economic importance: Food and ornamental fish
Conservation/threatened status: **Least concern**

41. Scientific name: ***Puntius chola* (Hamilton, 1822)**
Common name: Swamp barb
Local name: Puthi
Distribution: India, Nepal, Bangladesh, Sri Lanka, Myanmar and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_5; Dudhnoi River— S_3, S_5.
Number of samples recorded from each site: Jinari River— S_2=6, S_3=7, S_5=5; Dudhnoi River— S_3=6, S_5=5.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

42. Scientific name: ***Puntius sophore* (Hamilton, 1822)**
Common name: Spotfin Swamp Barb.
Local name: Puthi
Distribution: Bangladesh, China, India, Myanmar, Nepal, Pakistan and Thailand.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_5; Dudhnoi River— S_1, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_2=4, S_3=6, S_5=5; Dudhnoi River— S_1=7, S_4=6, S_5=8.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

43. Scientific name: ***Puntius terio*** **(Hamilton, 1822)**
Common name: Onespot Barb
Local name: Puthi
Distribution: Bangladesh, India, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3; Dudhnoi River— S_2, S_3, S_5.
Number of samples recorded from each site: Jinari River— S_3=7; Dudhnoi River— S_2=4, S_3=6, S_5=6.

Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

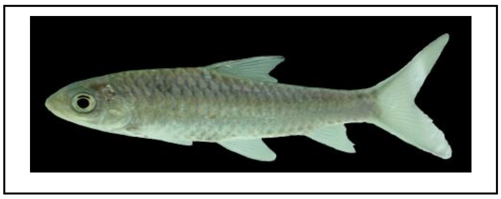
44. Scientific name: ***Raiamas bola*** **(Hamilton, 1822)**
Common name: N/A
Local name: N/A
Distribution: Bangladesh, India, Myanmar and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2.
Number of samples recorded from each site: Jinari River— S_2=5.

Local fishery/ economic importance: Food as well as game fish.
Conservation/threatened status: **Least concern**

45. Scientific name: ***Systomus sarana*** **(Hamilton, 1822)**
Common name: Olive barb.
Local name: Cheniputhi
Distribution: Bangladesh, India, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4; Dudhnoi River— S_3, S_4.
Number of samples recorded from each site: Jinari River— S_4=3; Dudhnoi River— S_3=4, S_4=3.

Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

46. Scientific name: ***Tor tor*** **(Hamilton, 1822)**
Common name: Mahseer
Local name: Makhula
Distribution: Bangladesh, Bhutan, India, Myanmar, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1.
Number of samples recorded from each site: Jinari River— S_1=3.



Local fishery/ economic importance: Food as well as game fish.
Conservation/threatened status: **Near Threatened**

47. Scientific name: ***Setipinna brevifilis*** **(Valenciennes, 1848)**
Common name: Short-hairfin anchovy
Local name: Phansa
Distribution: India: Ganga river system (at Kolkata and Allahabad), Jamuna river at Delhi and Brahmaputra river system in Assam.

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_5.
Number of samples recorded from each site: Jinari River— S_3=6, S_5=8.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Least concern**

48. Scientific name: ***Glossogobius giuris* (Hamilton, 1822)**
Common name: Tank Goby
Local name: Patimutura
Distribution: Widespread throughout Indo-west Pacific along the coast of Pakistan, India, China, Sri Lanka to Japan, Australia
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_4, S_5; Dudhnoi River— S_5.

Number of samples recorded from each site: Jinari River— S_2=7, S_3=8, S_4=8, S_5=7; Dudhnoi River— S_5=6.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Least concern**

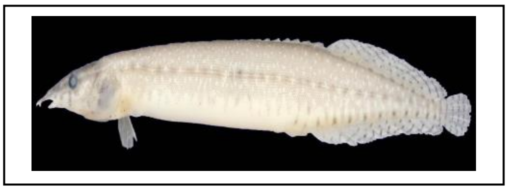
49. Scientific name: ***Heteropneustes fossilis* (Muller, 1840)**
Common name: Stinging catfish
Local name: Singhi
Distribution: Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_5.

Number of samples recorded from each site: Jinari River— S_3=7, S_5=6.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Least concern**

50. Scientific name: ***Macrognathus aral* (Schneider, 1801)**
Common name: One-striped spiny eel
Local name: Tura
Distribution: Bangladesh, India, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3; Dudhnoi River— S_2, S_4, S_5.

Number of samples recorded from each site: Jinari River— S_2=6, S_3=4; Dudhnoi River— S_2=3, S_4=7, S_5=8.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

51. Scientific name: ***Macrognathus pancalus* (Hamilton, 1822)**
Common name: White spotted spiny eel
Local name: Tura
Distribution: Bangladesh, India, Nepal and Pakistan
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5.



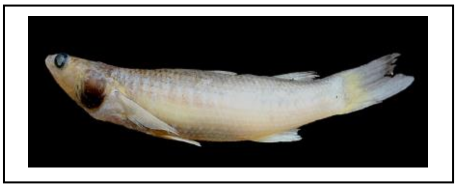
Number of samples recorded from each site: Jinari River— S_4=9, S_5=7.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

52. Scientific name: ***Mastacembelus armatus* (La Cepede, 1800)**
Common name: Tire track spiny eel
Local name: Bami
Distribution: Bangladesh, Cambodia, China, India, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Vietnam

Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_4, S_5.

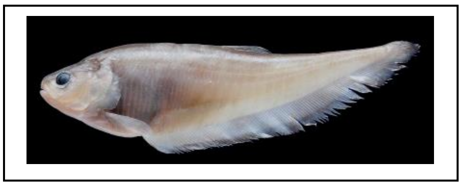
Number of samples recorded from each site: Jinari River— S_2=9, S_4=6, S_5=6.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

53. Scientific name: ***Rhinomugil corsula*** **(Hamilton, 1822)**
Common name: Corsula Mullet
Local name: Corsula
Distribution: Bangladesh, India, Myanmar and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinar River— S_2.
Number of samples recorded from each site: Jinar River— S_2=7.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**



54. Scientific name: ***Nandus nandus*** **(Hamilton, 1822)**
Common name: Mottled nandus
Local name: Gedgedi
Distribution: Bangladesh, India, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_4, S_5; Dudhnoi River— S_2, S_3.
Number of samples recorded from each site: Jinari River— S_4=9, S_5=8; Dudhnoi River— S_2=7, S_3=4.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

55. Scientific name: ***Notopterus notopterus*** **(Pallas, 1769)**
Common name: Feather back
Local name: Kanduli
Distribution: Bangladesh, Cambodia, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Thailand, Viet Nam, and Laos.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_3=6, S_4=8, S_5=7.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**



56. Scientific name: ***Trichogaster fasciata*** **(Bloch & Schneider, 1801)**
Common name: Striped gourami
Local name: Kholihona
Distribution: Bangladesh, India, Myanmar, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_4, S_5; Dudhnoi River— S_2, S_3, S_5.
Number of samples recorded from each site: Jinari River— S_1=7, S_3=8, S_4=6, S_5=4; Dudhnoi River— S_2=6, S_3=5, S_5=4.
Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

57. Scientific name: ***Psilorhynchus balitora*** **(Hamilton, 1822)**
Common name: Balitora minnow
Local name: N/A
Distribution: Bangladesh, India and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_5; Dudhnoi River— S_2, S_3, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_2=2, S_3=5, S_5=3; Dudhnoi River— S_2=4, S_3=3, S_4=3, S_5=2.
Local fishery/ economic importance: Ornamental fish.
Conservation/threatened status: **Least concern**

58. Scientific name: ***Ailia coila* (Hamilton, 1822)**
Common name: Gangetic ailia
Local name: Kadali
Distribution: Bangladesh, India, Nepal and Pakistan.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_4; Dudhnoi River— S_3.

Number of samples recorded from each site: Jinari River— S_1=9, S_3=10, S_4=8; Dudhnoi River— S_3=12.
Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Near Threatened**

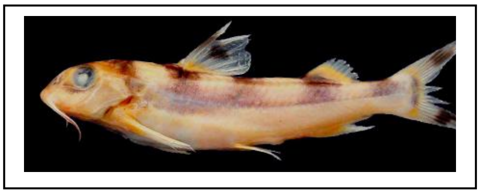
59. Scientific name: ***Bagarius bagarius* (Hamilton, 1822)**
Common name: Gangetic goonch
Local name: Garua
Distribution: Bangladesh, Bhutan, India and Nepal
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_5; Dudhnoi River— S_2, S_4, S_5.
Number of samples recorded from each site: Jinari River— S_5=6; Dudhnoi River— S_2=4, S_4=3, S_5=4.

Local fishery/ economic importance: Food fish
Conservation/threatened status: **Near Threatened**

60. Scientific name: ***Eutropichthys vacha* (Hamilton, 1822)**
Common name: Batchwa Vacha
Local name: Bacha
Distribution: Pakistan, India, Bangladesh, Burma and Thailand

Local occurrence/ Names of rivers & sites from which recorded: Dudhnoi River— S_4, S_5.
Number of samples recorded from each site: Dudhnoi River— S_4=7, S_5=8.
Local fishery/ economic importance: Food fish
Conservation/threatened status: **Not Assessed**

61. Scientific name: ***Gagata cenia* (Hamilton, 1822)**
Common name: Indian gagata
Local name: Keyakatta
Distribution: India, Pakistan and Burma
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_1, S_3, S_5; Dudhnoi River— S_3, S_4.
Number of samples recorded from each site: Jinari River— S_1=4, S_3=3, S_5=7; Dudhnoi River— S_3=5, S_4=3.



Local fishery/ economic importance: Ornamental as well as food fish.
Conservation/threatened status: **Least concern**

62. Scientific name: ***Glyptothorax cavia* (Hamilton, 1822)**
Common name: N/A
Local name: N/A
Distribution: Bangladesh, India, Burma and Nepal.
Local occurrence/ Names of rivers & sites from which recorded: Jinari River— S_2, S_3, S_5.
Number of samples recorded from each site: Jinari River— S_2=1, S_3=1, S_5=3.

Local fishery/ economic importance: Food fish.
Conservation/threatened status: **Least concern**

ICHTHYOFAUNAL RICHNESS OF THE DIMA HASAO DISTRICT, ASSAM, NORTHEAST INDIA

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ABSTRACT

Dima Hasao District is one of the twin hills districts of Assam, northeast India, with the headquarter at Haflong. However, studies on the ichthyofaunal assemblage, and habitat structuring and mapping of the region are deficient. In view of this, a survey was carried out from January 2012 to December 2015 to analyze the pattern of distribution, taxonomic richness and abundance of fish species of the major river systems, viz. Diyung, Mahur and Jatinga rivers of Dima Hasao. To examine the fish fauna, experimental fishing was carried out on a monthly basis with the help of local fishers. Efforts were made to collect the fishes at different hours, including morning, daylight, evening and night, from all sites. A total of 50 fish species were collected under 8 orders and 20 families comprising torrential, semi-torrential, migratory and plain water forms. Seasonal variation of fish abundance was observed with least collection in the monsoon season. Occurrence of hill stream fishes of the genera *Garra*, *Glyptothorax*, *Psilorhynchus* and *Pseudolaguvia* suggested linkage with the habitat morphology of fast-flowing rivers and streams, with rocky bed and shallow depth; whereas plain-water species like *Chitala chitala*, *Sperata aor* and *Rita rita* were found in deep pools of the rivers. Species like *Badis tuivaiei*, *Glyptothorax scrobiculus* and *Amblyceps laticeps* were restricted to the Jatinga River of the Barak drainage. Proper taxonomic identification along with studies on biology and phylogeny among certain endemic species from the region for asserting conservation is demanding. Notably, stone quarrying and sand mining in the Diyung, Mahur, and Jatinga rivers is another man-made activity responsible for water pollution and as well as habitat destruction of fish species. The Diyung, Mahur and Jatinga rivers are torrential water bodies flowing through undulating hills and dense tropical deciduous forests. These rivers may still harbour many rare fish species, possibly undescribed yet, that demands further exploration, taxonomic identification, and validation for proper management of these indigenous resources of Northeast India.

Keywords: Freshwater fishes, hillstreams, explorations, abundance, distribution

INTRODUCTION

Inventorying of freshwater fishes of northeast India has been done by many workers in the recent past. The Brahmaputra and the Barak River systems, which drains the Brahmaputra and Barak valleys of Assam, Northeast India, respectively, harbour a rich fish fauna of torrential stream especially in the upper reaches. The Brahmaputra and Barak with their tributaries originating from hills, and consequently, these torrential hill streams of both the river basin harbour rich diversity of fish species, cold water, mid-altitude and plain water species. The Dima Hasao District is situated at southern part of Assam between 92°37′ – 93°17′ E longitudes and 23°30′ – 25°47′ N latitudes at an elevation of about 2131 feet msl & is bounded by Nagaland and Manipur states in the east, Cachar district of Assam in the south, Meghalaya state and part of Karbi-Anglong district in the west, and another part of Karbi-Anglong and Nagaon district in the north. The major portion of the district is covered by hills. The main hill range is Borail (GUIDAI in Dimasa) of which Thumjang is the highest peak at 1866 m and Hempeupet is the second highest peak at 1748 m. The main river systems are the Kopili, Diyung, Jatinga, Jenam, Mahur and Langting, of which, the Diyung River is the longest river having a length of 240 km. Almost all rivers originate from Borail. This area supports a lucrative indigenous fauna comprising Nemacheilidae, Sisoridae, Psilorhynchidae, Balitoridae etc. Most of the hill districts of Assam are inhabited by various ethnic groups. The hill districts are the potential hub for beautiful stream and rivers which nurture heterogeneous groups of cold-water fish species including mahseers. But, due to the absence of modernized socio-economic and public health-care systems along with lack of employment and good infrastructure facility, the poor people of this region are compelled to depend on fish-resources for their livelihood.

Studies on the ichthyospecies assemblage, structure and their habitat requirements and mapping in the streams of northeast India are very few and nothing has been reported in the Dima Hasao District of Assam, with few initiatives in

Jatinga River (Kar & Sen, 2007). This dismal situation necessitated the present study, hitherto remained unattended, to undertake with utmost rigor and service. The present study to initiate the exercise embodies the systematics, taxonomy, and habitat mapping of the fish species of the streams and rivers of the Dima Hasao District, Assam, northeast India.

MATERIALS AND METHODS

Study area

The Diyung River, (the longest river with a total length of 240km; source: Department of Information and Public Relations [JANASANYOG]) with its source at Barail range near a Naga village called Longkhai, is in close proximity to the highest peak of the district as well as Assam the Hempeo peak with a height of 1736 m. Its tributaries include Brashang, Didaola, Kholong, Rubi, Abhung, Dihamlai, Dilaima and Mahur. Further downstream at nearby Mojowari (name of a village coined from the pool formed in the Diyung river), the river bed is completely sandy Finally, it joins the Kopili (a major south bank tributary of the Brahmaputra) at Diyungmukh.

The Mahur River has its origin from the Barail range. Mahur joins with Diyung near Thaisaling Hawar. Mahur is the tributary on the eastern bank of Diyung. Mupa is the first tributary which joins with Mahur near Thaisaling Hawar. The stream demarcates the southern boundary of Langting Mupa Reserved Forest. After the Langlai and Mahur on the upstream side of Longmaisa Dikhereng or Dihangi confluence of Dikhongma is there. Dihangi is an area where Diyung starts its middle course. To the upstream side of Dikhongma confluence, Dilaima, Dihamlai, Aghong, Rubi, Kholon Didaola Brashang are the tributaries of the Diyung River.

The Jatinga River is a major north bank tributary of the Barak, which originates from the Barail hill range in the village Jatinga (N 25°7′29.0″; E 93°1′36.0″), 26 kms from Haflong town, but becomes traceable from village Kaparsola (N 25°6′ 42.0″; E 92°56′2.0″) 11.5 km downstream, after joining with several other small tributaries like “Cherra”. The river Jatinga then flows all the way through the western boundary of the Barail Wildlife Sanctuary and after joining with several other tributaries like Chhotarekha, Bororekha, Daku, Chhoto Lokha, Dimru, Ditokcherra, Kayang, Dolu, Badri etc merge with Barak river at a place called Jatingamukh below Barkhala village near Chandpur travelling a distance of 71.5 km. But, within the Dima Hasao district, the length of the river is only about 30 km.

Fish sampling and collection

In the initial period of the survey, tracing of the rivers was carried out physically and also with the help of bank dwellers along both the rivers. For collection of fish sample, an electric fishing device was fabricated (20 V battery) to catch the fishes in six sampling sites (Figure 1). To examine fish faunal diversity of the rivers, experimental fishing was carried out on a monthly basis from 2013 to 2016. Fishes were also collected regularly from local collaborators appointed at each sampling site. Details of sampling sites are provided in Table 1. Efforts were also made to collect the fish specimen from all possible sites of the selected rivers throughout their lengths. Fishes were identified following Talwar and Jhingran (1991), Jayaram (1999), Jayaram (2006) and Vishwanath *et al*. (2014). For verification of species identifications, the data were compared with earlier reports and publication on the same or similar taxa. For current validity of taxonomic names, Fricke *et al.* (2021) was followed. Collected species were preserved in 10% formalin for initial one week and then transferred to 70% alcohol for permanent preservation. Evaluation of pattern of diversity of fish species and taxonomic status out following standard method. The relative abundance (RA) of individual species in each sampling stations was calculated by the following formula:

$$RA = \frac{\text{Number of samples of particular species}}{\text{Total number of samples}} \times 100$$

Early history of the rivers, secondary information on species diversity, Indigenous Technological Knowledge (ITK) and demographic data of fringe villages were collected from the villagers through interview and by Focused Group Discussions (Townsley, 1993; Schonut & Kieveltiz, 1994).

Table 1 summarizing the details of sampling sites in Dima Hasao district, Assam for ichthyofaunal explorations

S. No.	Name of site	GPS coordinates	Elevation (msl)	Characteristics of the site in brief
1	Samparidisa (S_1)	25°22′86″ N 92°55′97″ E	307	Riffles, deep pools
2	Dihangi (S_2)	25°25.5′45″ N 92°59.6′30″ E	129	Riffles
3	Maibang (S_3) (Kolabari)	25°17.9′50″ N 93°08.4′10″ E	280	Riffles
4	Thaisaling Howar (S_4)	25°27′45″ N 92°59.3′10″ E	136	Shallow pools
5	Harangjao (S_5)	25°06′42.6″ N 92°56′2.0″ E	417	Riffles
6	Banderkhal (S_6)	25°6′35.0″ N 92°51′2.0″ E	228	Shallow pools, runs

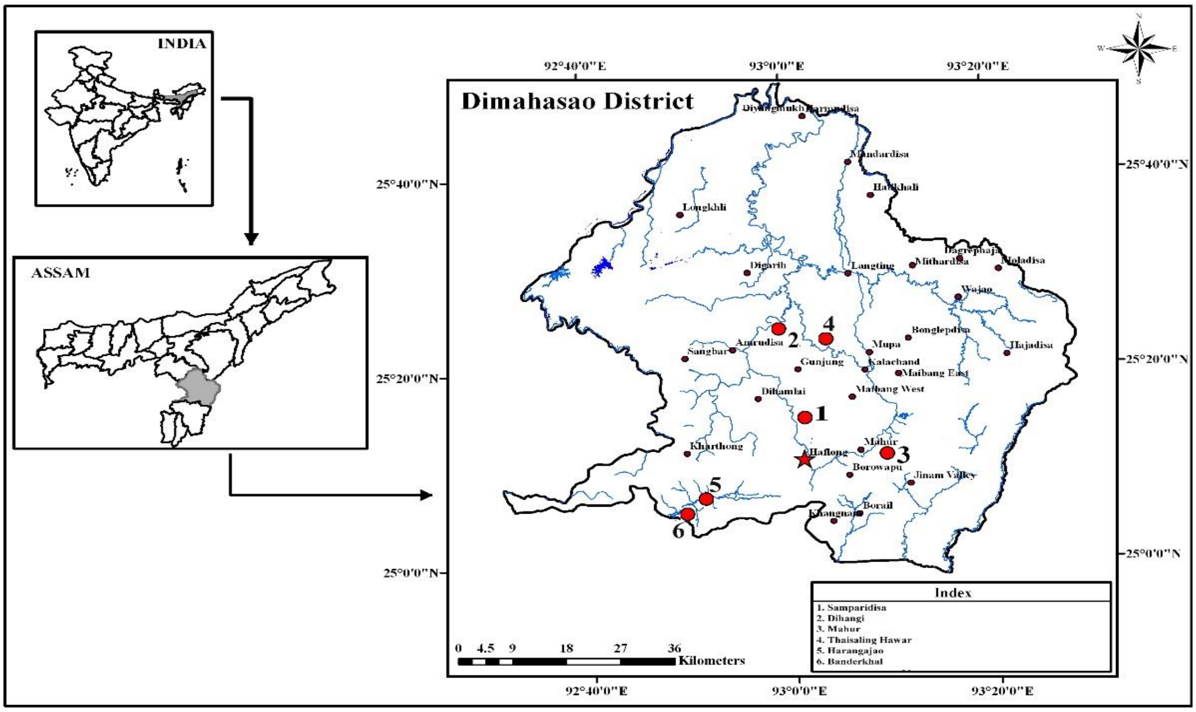

Figure 1 Drainage map of Dima Hasao district, Assam, northeast India showing Diyung, Mahur and Jatinga river systems along with the sampling sites

RESULTS

A total of 50 species under 28 families were recorded in the three river systems, Diyung, Mahur and Jatinga of Dima Hasao. Family Cyprinidae was found to be the most abundant, contributing 22 species, followed by Sisoridae with 7 species; Psilorhynchidae, Nemacheilidae and Schilbeidae with 3 species each; Notopteridae, Bagridae and Channidae with 2 species each and Anguillidae, Botiidae, Siluridae, Mastacembelidae and Gobiidae with 1 species each respectively.

According to IUCN (2016), about 70% of the total fish species have been categorized as Least Concern, 12% as Near Threatened, 2% both as Endangered and Vulnerable, and 10% as Not Evaluated, and 4% as Data Deficient. It is noteworthy that species like *Psilorhynchus nudithoracicus*, *Schistura fasciata*, *Glyptothorax*, *Pseudolaguvia*, etc. have not yet been accessed by IUCN which demands urgent actions for conserving their valuable germplasm.

Table 2 Fish fauna of Diyung River with site wise species richness and Relative Abundance (RA; in %)

S No.	Family	Fish species	Sampling sites			
			S_1	RA	S_2	RA
1	Notopteridae	*Chitala chitala*	3	1.13	0	0.00
2		*Notopterus notopterus*	5	1.88	1	0.47
3	Anguillidae	*Anguilla bengalensis*	2	0.75	0	0.00
4	Cyprinidae	*Chagunius chagunio*	8	3.01	2	0.95
5		*Osteobrama cotio*	3	1.13	1	0.47
6		*Tor putitora*	6	2.26	2	0.95
7		*Tor tor*	3	1.13	3	1.42
8		*Neolissochilus heaxagonolepis*	8	3.01	3	1.42
9		*Pethia conchonius*	5	1.88	8	3.79
10		*Pethia ticto*	4	1.50	6	2.84
11		*Puntius chola*	8	3.01	7	3.32
12		*Cirrhinus reba*	4	1.50	1	0.47
13		*Garra naganensis*	15	5.64	14	6.64
14		*Garra lissorhynchus*	20	7.52	18	8.53
15		*Garra nasuta*	4	1.50	12	5.69
16		*Tariqilabeo latius*	7	2.63	9	4.27
17		*Labeo bata*	2	0.75	1	0.47
18		*Labeo dyocheilus*	7	2.63	4	1.90
19		*Amblypharyngodon mola*	12	4.51	10	4.74
20		*Opsarius tileo*	18	6.77	12	5.69
21		*Opsarius bendelisis*	25	9.40	18	8.53
22		*Opsarius barna*	8	3.01	12	5.69
23		*Devario aequipinnatus*	5	1.88	8	3.79
24		*Danio dangila*	3	1.13	2	0.95
25		*Salmostoma bacaila*	1	0.38	2	0.95
26	Psilorhynchidae	*Psilorhynchus arunachalensis*	3	1.13	9	4.27
27		*Psilorynchus amphicephalus*	4	1.50	7	3.32
28		*Psilorynchus nudithoracicus*	5	1.88	7	3.32
29	Botiidae	*Botia dario*	3	1.13	0	0.00
30	Nemacheilidae	*Paracanthocobitis botia*	3	1.13	4	1.90
32		*Schistura chindwinica*	6	2.26	7	3.32
33	Sisoridae	*Bagarius bagarius*	1	0.38	0	0.00
34		*Glyptothorax botius*	2	0.75	2	0.95
35		*Glyptothorax radiolus*	2	0.75	0	0.00
36		*Glyptothorax striatus*	5	1.88	2	0.95
37		*Pseudocheneis sulcata*	3	1.13	0	0.00
38		*Pseudolaguvia viriosa*	3	1.13	0	0.00
39	Siluridae	*Ompok bimaculatus*	2	0.75	1	0.47
40	Schilbeidae	*Clupeisoma garua*	4	1.50	0	0.00
41		*Eutropiichthys vacha*	3	1.13	1	0.47
42		*Eutropiichthys murius*	1	0.38	1	0.47
43	Bagridae	*Sperata aor*	1	0.38	0	0.00
44		*Rita rita*	4	1.50	2	0.95
45	Belonidae	*Xenentodon cancila*	5	1.88	3	1.42
46	Mastacembelidae	*Mastacembelus armatus*	8	3.01	2	0.95
47	Gobiidae	*Glossogobius giuris*	2	0.75	0	0.00
48	Channidae	*Channa marulius*	4	1.50	0	0.00
49		*Channa gachua*	2	0.75	1	0.47
	Total		**266**	**100.00**	**211**	**100.00**

Table 3 Fish fauna of Mahur River with site wise species richness and relative abundance (RA; in %)

S. No.	Family	Name of fish species	Sampling sites			
			S_3	RA	S_4	RA
1	Notopteridae	*Notopterus notopterus*	0	0.00	3	2.56
2	Anguillidae	*Anguilla bengalensis*	0	0.00	1	0.85
3	Cyprinidae	*Chagunius chagunio*	0	0.00	2	1.71
4		*Osteobrama cotio*	0	0.00	2	1.71
5		*Tor putitora*	0	0.00	2	1.71
6		*Tor tor*	0	0.00	2	1.71
7		*Neolissochilus hexagonolepis*	0	0.00	2	1.71
8		*Pethia conchonius*	3	3.00	6	5.13
9		*Pethia ticto*	7	7.00	3	2.56
10		*Puntius chola*	5	5.00	6	5.13
11		*Cirrhinus reba*	0	0.00	2	1.71
12		*Garra naganensis*	9	9.00	4	3.42
13		*Garra lissorhynchus*	12	12.00	9	7.69
14		*Garra* cf. *nasuta*	6	6.00	2	1.71
15		*Tariqilabeo latius*	2	2.00	5	4.27
16		*Labeo bata*	0	0.00	1	0.85
17		*Amblypharyngodon mola*	12	12.00	9	7.69
18		*Opsarius tileo*	5	5.00	8	6.84
19		*Opsarius bendelesis*	7	7.00	3	2.56
20		*Opsarius barna*	4	4.00	3	2.56
21		*Devario aequipinnatus*	3	3.00	3	2.56
22		*Danio dangila*	1	1.00	4	3.42
23		*Salmostoma bacaila*	1	1.00	3	2.56
24	Psilorhynchidae	*Psilorynchus arunachalensis*	4	4.00	2	1.71
25		*Psilorynchus amphicephalus*	3	3.00	0	0.00
26		*Psilorynchus nudithoracicus*	2	2.00	0	0.00
27	Nemacheilidae	*Paracanthocobitis botia*	2	2.00	4	3.42
29		*Schistura chindwinica*	3	3.00	2	1.71
30	Sisoridae	*Glyptothorax botius*	1	1.00	1	0.85
31		*Glyptothorax striatus*	1	1.00	0	0.00
32		*Pseudocheneis sulcata*	0	0.00	1	0.85
33	Schilbeidae	*Eutropiichthys murius*	0	0.00	1	0.85
34	Bagridae	*Rita rita*	0	0.00	1	0.85
35	Belonidae	*Xenentodon cancila*	0	0.00	3	2.56
36	Mastacembelidae	*Mastacembelus armatus*	0	0.00	9	7.69
37	Gobiidae	*Glossogobius giuris*	3	3.00	2	1.71
38	Channidae	*Channa marulius*	0	0.00	2	1.71
39		*Channa gachua*	1	1.00	2	1.71
	Total		**100**	**100.00**	**117**	**100.00**

Table 4 Fish fauna of Jatinga River with site wise species richness and relative abundance (RA; in %)

S. No.	Family	Name of fish species	Sampling sites			
			S_5	RA	S_6	RA
1	Notopteridae	*Chitala chitala*	0	0.00	1	0.71
2		*Notopterus notopterus*	0	0.00	3	2.13
3	Anguillidae	*Anguilla bengalensis*	0	0.00	1	0.71
4	Cyprinidae	*Chagunius chagunio*	0	0.00	2	1.42
5		*Osteobrama cotio*	0	0.00	2	1.42
6		*Tor putitora*	0	0.00	3	2.13
7		*Tor tor*	0	0.00	3	2.13
8		*Neolissochilus heaxagonolepis*	0	0.00	4	2.84
9		*Pethia conchonius*	4	4.40	7	4.96

S. No.	Family	Name of fish species	Sampling sites			
			S_5	RA	S_6	RA
10		*Pethia ticto*	3	3.30	3	2.13
11		*Puntius chola*	9	9.89	3	2.13
12		*Cirrhinus reba*	0	0.00	3	2.13
13		*Garra naganensis*	0	0.00	6	4.26
14		*Garra lissorhynchus*	3	3.30	8	5.67
15		*Garra* cf. *nasuta*	2	2.20	0	0.00
16		*Tariqilabeo latius*	7	7.69	2	1.42
17		*Labeo bata*	0	0.00	6	4.26
18		*Labeo dyocheilus*	0	0.00	2	1.42
19		*Amblypharyngodon mola*	5	5.49	16	11.35
20		*Opsarius tileo*	3	3.30	4	2.84
21		*Opsarius bendelesis*	5	5.49	12	8.51
22		*Opsarius barna*	7	7.69	6	4.26
23		*Devario aequipinnatus*	2	2.20	5	3.55
24		*Danio dangila*	1	1.10	2	1.42
25		*Salmostoma bacaila*	4	4.40	1	0.71
26	Psilorhynchidae	*Psilorynchus arunachalensis*	8	8.79	1	0.71
27		*Psilorynchus amphicephalus*	4	4.40	0	0.00
28		*Psilorynchus nudithoracicus*	3	3.30	0	0.00
29	Nemacheilidae	*Acanthocobitis botia*	3	3.30	6	4.26
30		*Schistura fasciata*	6	6.59	2	1.42
31		*Schistura chindwinica*	4	4.40	0	0.00
32	Sisoridae	*Bagarius bagarius*	0	0.00	1	0.71
33		*Glyptothorax botius*	2	2.20	1	0.71
34		*Glyptothorax scrobiculus*	1	1.10	0	0.00
35		*Glyptothorax striatus*	2	2.20	0	0.00
36		*Pseudocheneis sulcata*	1	1.10	0	0.00
37	Siluridae	*Ompok bimaculatus*	0	0.00	3	2.13
38	Schilbeidae	*Clupisoma garua*	0	0.00	2	1.42
39		*Eutropiichthys vacha*	0	0.00	2	1.42
40	Bagridae	*Sperata aor*	0	0.00	1	0.71
41		*Rita rita*	0	0.00	3	2.13
42	Belonidae	*Xenentodon cancila*	0	0.00	5	3.55
43	Mastacembelidae	*Mastacembelus armatus*	0	0.00	2	1.42
44	Gobiidae	*Glossogobius giuris*	1	1.10	2	1.42
45	Channidae	*Channa marulius*	0	0.00	4	2.84
46		*Channa gachua*	1	1.10	1	0.71
	Total		**91**	**100.00**	**141**	**100.00**

DISCUSSION

The occurrence of 50 different fish species from the studied river drainages within Dima Hasao may be interlinked with the suitability of the habitat. The rivers and their streams, encompassing the district, constitutes the ichthyofauna of two main river basins viz. the Brahmaputra and Barak; of which the Diyung and Mahur form the sub-basins of Kopili (a southern tributary of Brahmaputra), while the Jatinga River forms the north bank tributary of Barak. As such, variation in the occurrences of fish among them can be immediately identified. Fishes like *Glyptothorax scrobiculus*, *Schistura fasciata* are available only from the Barak basin; whereas species like *Glytptothorax radiolus*, *Pseudolaguvia viriosa* have been found only from the Brahmaputra basin. Fish species like *Psilorhynchus arunachalensis*, *Glyptothorax radiolus*, *Schistura fasciata* are endemic to the northeastern region of India.

Unfortunately, the *Dimasa* also practice destructive fishing like poisoning, dynamiting, and electrofishing. Anthropogenic activities like crude destructive fishing methods viz. dynamiting, electrofishing, liming, use of ichthyotoxic plants, etc (authors' pers. obs.) along the rivers and streams are responsible in declining fish population in major Rivers of the district. Poisoning fishes to harvest fish by the large-scale native people from remote areas of the district still using plant derivatives known as sedative plant such as *Ru-gjao phang* (*Millettia pachycarpa*), *Ru panthao* (*Randia spinosa*), *Agurdukha (Croton caudatus), Suji (Acacia pinnata), Jengreng (Albizzia)* and *Mejen* (*Zanthoxylum alatum*), chemicals such as copper sulphate, bleaching powder and pesticides. Destructive method of fishing kills both target and non target fishes. This finding is in agreement with Tynsong and Tiwari (2008). Population of migratory species such as *N. hexagonolepis, T. tor* and *T. putitora* has found in declined trend in all the studied Rivers. As such, the entire aquatic ecology is disturbed by the use of such fishing methods. Popularization of these practices arose as a result of innovative ideas too, as fishing is quite difficult in the rocky terrain with strong water current. These "short-cut methods" are, however, very harmful causing overharvesting of both target species and as by-catch that may lead to severe population declines of some highly threatened and endemic fish species of the region. Moreover, the hill stream fishes, which are highly adapted to fast-flowing habitats, are much sensitive to any changes in their habitats (Biju, 2003).

Though Dima Hasao district of Assam is endowed with one of the richest riverine fish genetic resources and a network of rivers, streams, wetlands the contribution of riverine capture fisheries is declining sharply. Extraction of sand and gravel from river bed has direct and indirect negative impact on semi torrential migratory group of fishes such as *Schistura* sp, *Lepidocephalichthys* sp, etc. These species generally bury themselves under pebble and sand. Sand mining and damaging of riparian vegetation may cause habitat destruction for these species. Migratory species are also use sand bed as breeding grounds. Stone quarrying and Sand mining from the Diyung, Mahur, and Jatinga rivers is another man-made activity responsible for water pollution and as well as habitat destruction for fish species. Also, the two National projects viz. The East West Corridors (NAHAI) and the Broad Gauge Conversion of Railway line are ongoing which have indirectly affected the nearby rivers and streams. Semi torrential fishes of the genus *Lepidocephalicthys, Schistura, Paracanthocobitis, Gonorhynchus, Botia* are mostly at risk due to sand and pebble mining, because these fishes takes shelter under sand, pebble and crevices. Waters are becoming muddy and this situation is very common during monsoon, post monsoon and winter seasons when water level as well as flow are reducing to considerable level. Shifting agriculture commonly known as *jhuming* is practiced by the local communities in the district which led to deforestation. Since Dima Hasao receives high rainfall, so areas under *jhum* cultivation have shown maximum soil erosion. Deforestation also results in increased siltation and the resulting destruction of niche habitats, of particular concern for some habitat-specific species.

CONCLUSION

The Dima Hasao district represents a rich granary of ichthyofaunal resources for 50 different species have been identified so far, and these together, comprise a complex which has the potential to form an ichthyofaunal hub of freshwater fishes within the northeastern region of India. Fisheries in Dima Hasao district of Assam are still in the state of subsistence fishery. Thus, most of the catches are consumed locally and never reach the main markets. The Diyung, Mahur and Jatinga rivers are torrential water bodies flowing through undulating hills and dense tropical deciduous forests. These rivers may still harbour many rare fish species, possibly undescribed yet, that demands further exploration, taxonomic identification, and validation for proper management of these indigenous resources of Northeast India.

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REFERENCES

Biju, C. R. (2003). *Habitat and Distribution of Hillstream Fishes of Northern Kerala (North of Palghat Gap)*. PhD Thesis, Mahatma Gandhi University, Kerala, India.

Fricke, R., Eschmeyer, W. N., and Van der Laan, R. (eds.) (2021). *Catalog of fishes*: *genera, species, references*. Electronic version of 2 August 2021. Available from: http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. Accessed 20 August 2021.

IUCN. (2021). The IUCN Red List of Threatened Species. Available from: www.iucnredlist.org. Downloaded on 20 August 2021.

Jayaram, K.C. (1999). *The Freshwater Fishes of the Indian Region*. Narendra Publishing House (Delhi). pp.1–7, 68–450.

Jayaram, K.C. (2006). *Catfishes of India*. Narendra Publishing House (Delhi). pp.206–255.

Kar, D. & Sen, N. (2007). Systematic list and distribution of fishes in Mizoram, Tripura and Barak drainage of Northeastern India. *Zoos' Print Journal*. 22 (3): 2599-2607.

Schonhut, M. & Kieveltiz, V. (1994). *Participatory learning approaches– Rapid rural appraisal; Participatory appraisal–An introductory guide*, (Springer-Verlag, Berlin), 183.

Talwar, P.K. & Jhingran, A.G. (1991). *Inland Fishes of India and Adjacent Countries, Vol.I & II*. Oxford and IBH Publishing Co., Pvt. Ltd. (New Delhi). pp.94–1060.

Townsley, P. (1993). *Rapid appraisal methods for coastal communities*, (Bay of Bengal Programme, Madras), 110.

Tynsong, H. & Tiwari, B. K. (2008). Traditional knowledge associated with fish harvesting practices of War Khasi community of Meghalaya. *Indian Journal of Traditional Knowledge*. 7 (4): 618-623.

Vishwanath, W., Nebeshwar, K., Lokeswar, Y., Shangningam, B. D. & Rameshori, Y. (2014). *Freshwater Fish Taxonomy & A Manual for Identification of Fishes of Northeast India*. National Workshop on Freshwater Fish Taxonomy. Organized by Manipur University, Imphal & National Bureau of Fish Genetic Resources, Lucknow. pp.1–116.

DIVERSITY OF NEMACHEILINE LOACHES OF MANIPUR AND ITS CONSERVATION

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ABSTRACT

Manipur, a northeastern state of India, is a part of the Eastern-Himalaya Freshwater Biodiversity Hotspot. The present study shows the occurrence of 25 species of nemacheiline loaches belonging to five genera viz., *Mustura*, *Neonoemacheilus*, *Paracanthocobitis*, *Rhyacoschistura* and *Schistura*, of which 16 species are distributed in the Chindwin drainage while 9 species are distributed in the Barak drainage. Among these five genera, the genus *Schistura* accounts for 48% of all nemacheiline loaches in the state with 12 species. Conservation strategies for these fishes are also discussed.

Keywords Ichthyofaunal diversity, Nemacheilidae, Manipur, northeast India

INTRODUCTION

Loaches of the family Nemacheilidae are small benthic fishes typically inhabiting fast flowing water of small streams and creeks in hilly areas of south and Southeast Asia. Most of these fishes have small geographic ranges, restricted to a single or a few river systems (Kottelat, 2017). 578 nemacheiline loaches under 46 genera are recognized under the family Nemacheilidae (Kottelat, 2012).

Manipur, one of the northeastern states of India, have high ichthyofaunal diversity. The central valley and the eastern parts of Manipur are drained by the Chindwin drainage while the western parts are drained by the Barak River and its tributaries. *Rhyacoschistura manipurensis* (Chaudhuri, 1912) was the first nemacheiline loach reported from Manipur. Later, many workers have described many nemacheiline species new to science from Manipur (Hamilton, 1822; Hora, 1921; Hora, 1929; Menon, 1987; Tilak & Hussain, 1990; Arunkumar, 2000; Vishwanath & Shanta, 2004a, b; Vishwanath & Nebeshwar, 2004, 2005; Vishwanath & Shanta Kumar, 2006; Lokeshwor & Vishwanath, 2011; Lokeshwor & Vishwanath, 2012a, b; Lokeshwor *et al.* 2012; Lokeshwor & Vishwanath, 2013; Lokeshwor & Vishwanath, 2014; Singer & Page, 2015; Singer *et al.*, 2017; Shangningam *et al.* 2014). Recently, Chinglemba *et al.* (2021) described *Mustura taretensis* from the Chindwin drainage of Manipur. In the present study, an attempt has been made to record the diversity of Nemacheiline loaches of Manipur, northeast India.

MATERIAL AND METHODS

Fishes were collected from different water bodies of Manipur using electrofishing machine (Ultrasonic Inverter Electro Fisher, 24 Volts, and 4m), nets, traps and local fishing techniques. Collections were done during the period from May 2018 to September 2021. Images of freshly collected specimens were taken whenever possible to record the colour of the specimens. Fishes were fixed and preserved in 10% formalin. Identification of fish followed Kottelat (1990). The specimens are deposited in the Manipur University Museum of Fishes (MUMF). Conservation status was ascertained using Vishwanath *et al*. (2010).

RESULTS

The present study revealed the occurrence of 25 valid species of nemacheiline loaches under five genera viz., *Mustura*, *Neonoemacheilus*, *Paracanthocobitis*, *Rhyacoschistura* and *Schistura* in Manipur. 16 species are found in the Chindwin drainage while nine species are found in the Barak drainage. The maximum diversity of the species is observed in the genus *Schistura* which accounts for 48% of total species. One species each of *Neonoemacheilus* and *Rhyacoschistura* are classified as Near Threatened; one species of *Mustura* and three species of *Schistura* as Vulnerable; and four species of *Schistura* are listed under endangered category (Vishwanath *et al*., 2010). Table I shows the total number of nemacheiline loaches recorded from Manipur, northeast India and their conservation status.

Table 1. Nemacheilines of Manipur, northeast India, their distribution and IUCN status (NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered)

Genus	Species	Distribution		IUCN status
		Chindwin drainage	Barak drainage	
Mustura Kottelat	1. *M. chindwinensis* Lokeshwor & Vishwanath	+	-	NE
	2. *M. prashadi* (Hora)	+	-	VU
	3. *M. taretensis* Chinglemba *et al*.	+	-	NE
	4. *M. tigrina* Lokeshwor & Vishwanath	+	-	NE
	5. *M. tuivaiensis* Lokeshwor *et al*.	-	+	NE
Neonoemacheilus Zhu & Guo	6. *N. assamensis* (Menon)	-	+	NT
	7. *N. morehensis* Arunkumar	+	-	DD
	8. *N. peguensis* (Hora)	+	-	DD
Paracanthocobitis Grant	9. *P. botia* (Hamilton)	-	+	LC
	10. *P. marmorata* Singer *et al*.	+	-	NE
	11. *P. linypha* Singer & Page	+	-	NE
Rhyacoschistura Kottelat	12. *R. ferruginea* Lokeshwor & Vishwanath	-	+	NE
	13. *R. manipurensis* (Chaudhuri)	+	-	NT
Schistura McClelland	14. *S. chindwinica* (Tilak & Hussain)	-	+	VU
	15. *S. fasciata* Lokeshwor & Vishwanath	-	+	NE
	16. *S. kangjupkhulensis* (Hora)	+	-	EN
	17. *S. khugae* Vishwanath & Shanta	+	-	VU
	18. *S. liyaiensis* Lokeshwor & Vishwanath	-	+	NE
	19. *S. minuta* Vishwanath & Shanta Kumar	-	+	EN
	20. *S. nagaensis* (Menon)	+	-	VU
	21. *S. phamhringi* Shangningam *et al*.	+	-	NE
	22. *S. reticulata* Vishwanath & Nebeshwar	+	-	EN
	23. *S. rubrimaculata* Bohlen & Šlechtová	+	-	NE
	24. *S. sikmaiensis* (Hora)	+	-	LC
	25. *S. tigrina* Vishwanath & Nebeshwar	-	+	EN

DISCUSSION

The results of the study indicate that the diversity of nemacheiline loaches is very high in Manipur, northeast India. This is attributed to its varying topography and the presence of two important drainages of northeast India viz., the Chindwin and the Barak drainage. In the last two decades, Vishwanath and co-workers have described 12 new species of Nemacheiline from Manipur. Many new species are also awaiting discovery as several parts of Manipur remained out of reach for researchers due to difficult hill terrain, poor transport and communication facilities. Therefore, further exploration is needed in the future for proper documentation of the nemacheiline loaches of Manipur.

Many of these loaches are endemic to Manipur, yet threatened due to many anthropogenic activities. As these fishes prefer to inhabit under the stones, cobbles and rocks of fast flowing water, mining of sand and stones from the riverbed is a major threat faced by these loaches. Some other threats include using high voltage local dynamo for catching these fishes, water pollution and change in climate pattern globally. One way to conserve these fishes is through captive breeding. This will also lead to increase in farmer’s income as they have high ornamental value due to its attractive coloration and small sized. During our visit to Rivers of Manipur for collection of fishes, we found that some fishermen are using piscicides for catching fishes. This may have detrimental effect on the populations of fishes. These practices of using piscicides in Rivers should be strictly prohibited. Lastly, local communities should be actively engaged by conducting awareness programs about the value of conserving the fish diversity.

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REFERENCES

Arunkumar, L. (2000). *Neonoemacheilus morehensis*, a new species of Nemacheiline loach (Balitoridae: Nemacheilinae) from the Yu-River system of Manipur. *Indian Journal of Fisheries*, 47 (1), 43-47.

Chaudhuri, B. L. (1912). Descriptions of some new species of freshwater fishes from north India. *Records of the Indian Museum*, 7, 437-444.

Chinglemba, Y., Rameshori, Y., & Vishwanath, W. (2021). A new species of stone loach of the genus *Mustura* (Teleostei: Nemacheilidae) from Chindwin River drainage, Manipur, north-eastern India. *Zootaxa*, 5081 (4), 551–565. https://doi.org/10.11646/zootaxa.5081.4.6

Hamilton, F. (1822). *An Account of the Fishes found in the River Ganges and its Branches*. Archibald Constable & Company, Edinburgh, 405pp. https://doi.org/10.5962/bhl.title.6897

Hora, S. L. (1921). Fish and Fisheries of Manipur with some observations on those of Naga Hills. *Records of Indian Museum,* 22, 166–214. https://doi.org/10.5962/bhl.part.1473

Hora, S. L. (1929). Notes on fishes in the Indian Museum. VIII. On the loaches of the genus *Nemacheilus* from Burma. *Records of Indian Museum*, 31, 311–334.

Kottelat, M. (1990). *Indochinese nemacheilines: A revision of nemacheiline loaches (Pisces: Cypriniformes) of Thailand, Burma, Laos, Cambodia and southern Vietnam.* Verlag, Dr. Friedrich Pfiel, Munchen, 262 pp.

Kottelat, M. (2012). Conspectus cobitidum: an inventory of the loaches of the world (Teleostei: Cypriniformes: Cobitoidei). *The Raffles Bulletin of Zoology*, Supplement 26, 1–199.

Kottelat, M. (2017). A new genus and three new species of nemacheilid loaches from northern Irrawaddy drainage, Myanmar (Teleostei: Cypriniformes). *Raffles Bulletin of Zoology*, 65, 80-99.

Lokeshwor, Y., & Vishwanath, W. (2011). ***Schistura fasciata*, a new nemacheiline species (Cypriniformes: Balitoridae) from Manipur, India.** *Journal **of** Threatened Taxa,* 3, 1514–1519.

Lokeshwor, Y. & Vishwanath, W. (2012a) *Physoschistura chindwinensis*, a new balitorid loach from Chindwin basin, Manipur, India (Teleostei: Balitoridae). *Ichthyological Research*, 59, 230–234.

Lokeshwor, Y., & Vishwanath, W. (2012b) A new loach of the genus *Physoschistura* Bănărescu & Nalbant (Teleostei: Nemacheilidae) from Chindwin basin, Manipur, India. *Zootaxa,* 3586 (1), 95–102. https://doi.org/10.11646/zootaxa.3586.1.10

Lokeshwor, Y., Vishwanath, W., & Shanta, K. (2012) *Physoschistura tuivaiensis*, a new species of loach (Teleostei: Nemacheilidae) from the Tuivai River, Manipur, India. *Taprobanica*, 4, 5–11. https://doi.org/10.47605/tapro.v4i1.59

Lokeshwor, Y., & Vishwanath, W. (2013). *Schistura ferruginea*, a new species of loach from Northeast India (Teleostei: Nemacheilidae). *Ichthyological Exploration of Freshwaters*, 24, 49–56.

Lokeshwor, Y., & Vishwanath, W. (2014). *Schistura liyaiensis*, a new loach from Barak River, Manipur, India (Cypriniformes: Nemacheilidae). *Ichthyological Research*, 62, 313-319.

Menon, A. G. K. (1987). *The fauna of India and the adjacent countries. Pisces, Vol. 4, Teleostei: Cobitoidea, Part I, Homalopteridae.* Zoological Survey of India, Calcutta, 259 pp., 16 pls.

Shangningam, B. D., Lokeshwor, Y., & Vishwanath, W. (2014). *Schistura phamhringi*, a new stone loach from Chindwin Basin in Manipur, India (Cypriniformes: Nemacheilidae). *Zootaxa*, 3786, 181–191.

Singer, R. A., & Page, L. M. (2015). Revision of the zipper loaches, *Acanthocobitis* and *Paracanthocobitis* (Teleostei: Nemacheilidae), with descriptions of five new species. *Copeia* 103 (2), 378–401. https://doi.org/10.1643/ci-13-128

Singer, R. A., Pfeiffer, J. M., Page, L. M. (2017). A revision of the *Paracanthocobitis zonalternans* (Cypriniformes: Nemacheilidae) species complex with descriptions of three new species. *Zootaxa*, 4324(1), 85–107.

Tilak, R., & Husain, A. (1990). Description of a new loach, *Nemacheilus chindwinicus* sp. nov. (Homalolpteridae, Cypriniformes) from Manipur, India, with notes on the systematic status of the genus *Nemacheilus* and the subfamily Nemacheilinae. *Mitteilungen aus dem Zoologischen Museum in Berlin,* 66, 51–58.

Vishwanath, W., & Nebeshwar Sharma, K. (2004). *Schistura reticulata*, a new species of balitorid loach from Manipur, India with redescription of *S. chindwinica*. *Ichthyological Exploration of Freshwaters*, 15, 323–330.

Vishwanath, W., & Nebeshwar Sharma, K. (2005). A new nemacheiline fish of the genus *Schistura* McClelland (Cypriniformes: Balitoridae) from Manipur, India. *Journal of the Bombay Natural History Society,* 102 (1), 79-82.

Vishwanath, W., & Shanta, K. (2004a). A new nemacheiline fish of the genus *Schistura* McClelland (Cypriniformes: Balitoridae) from Manipur, India. *Journal of the Bombay Natural Historical Society*, 101, 138–140.

Vishwanath, W., & Shanta, K. (2004b). *Schistura khugae*, a new replacement name for S*. macrocephalus* Vishwanath & Shanta 2004 (Teleostei: Balitoridae). *Ichthyological Exploration of Freshwaters*, 15, 323–330.

Vishwanath, W., & Shanta Kumar, M. (2005). A new nemacheiline fish of the genus *Schistura* McClelland (Cypriniformes: Balitoridae) from Manipur, India. *Journal of the Bombay Natural History Society,* 102 (2), 210-213.

Vishwanath, W., Ng, H. H., Britz, R., Kosygin, L., Chaudhury, Sh., & Conway, K. W. (2010). *Chapter 3. The status and distribution of freshwater fishes of the Eastern Himalaya region*. In: The status and distribution of freshwater biodiversity in the Eastern Himalaya*.* (Eds.): Allen, Molur and Daniel, The IUCN Red List of Threatened species, pp. 1-88.

SESSION 2: THREATS FOR AQUATIC ECOSYSTEMS

PHYSICO-CHEMICAL ATTRIBUTES OF THE UPPER REACHES OF RIVER BRAHMAPUTRA, INDIA: ASSESSMENT, THREATS AND CONSERVATION ISSUES

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ABSTRACT

Assessment of the physico-chemical attributes of the upper reaches of River Brahmaputra (27°34′52.6″N; 95°18′58.2″E to 26°11′10.2″N; 91°45′03.6″E) in Assam, India has been carried out and examined for a period of three years from February, 2013 to January, 2016. Multivariate statistical techniques were applied to estimate the characteristics of water quality in the sampling sites. Student's t-test and z-test were applied at 0.05 level of significance and 95% confidence interval for checking the significance status. Intense human intervention viz., siltation; water abstraction, industrial and private use; pollution; and impacts of global climate change results in habitat loss and degradation of few fish species that have become highly endangered, particularly in the sampling sites. Despite this, the Pearson (n) Correlation matrix among the variables, water temperature (°C) with pH; FCO_2 (mg l^{-1}); DO (mg l^{-1}); total alkalinity (mg l^{-1}) and turbidity (NTU) showed positive correlation (R = 0.445, 0.049, 0.706, 0.561 and 0.437) at 5% significance level respectively. Thus, the study reveals that the physico-chemical variables of the upper stretches of River Brahmaputra is within the permissible limits. However, promotion of strong policies towards comprehensive monitoring program is imperative to prevent the upper River Brahmaputra basin contamination.

Keywords: Water quality; Correlation matrix; Principal Component Analysis; Cluster analysis; River Brahmaputra

INTRODUCTION

Rivers are ecological and geographical units with clear borders often turn in to true islands for the freshwater fauna and thus can be studied from an island biogeography point of view (Sepkoski and Rex, 1974; Hugueny and Léveque, 1994). They are the most important freshwater resources for humans. The water quality of rivers, streams and lakes change with the seasons and in turn has profound influence on the population density of aquatic organisms both plants and animals (Lawson, 2011; Adeyemo *et al*., 2008). Socio-economic and political development has, in the past, been largely related to the availability and distribution of freshwater riverine systems (Chapman, 1996). Freshwater ecosystem represents a major group of habitats around the world. It is not that, the habitats themselves are important for a wide variety of reasons, but also the freshwater medium itself is of fundamental significance (Nguyan, 1990).

Freshwater variables, in recent years, have suffered from intense human intervention resulting in habitat loss and degradation and therefore, many fish species have become highly endangered, particularly in rivers. The main causes are habitat destruction and de-fragmentation (Chovance *et al*., 2003), water abstraction, industrial and private use (Ricciardi and Rasmussen, 1999; Gibbs, 2000; Dawson *et al*., 2003), pollution (Lima-Junior *et al*., 2006) and impacts of global climate change (Leveque *et al*., 2005; Mas-Marti *et al*., 2010; Givan *et al*., 2018; Jaric *et al*., 2020).

The Brahmaputra drainage system in North Eastern India is one of the largest hydrographic basins in Southeast Asia with an average annual discharge of 510,450 million m^3 and covers an area of 580,000 km^2. This river is the fourth largest river in the world in terms of average water discharge at the mouth with a flow of 19,830 m^3s^{-1} and flows through Tibet, India (Arunachal Pradesh and Assam) and Bangladesh before reaching the delta with the Bay of Bengal. The mighty river, Brahmaputra with 103 important tributaries covering about 900 km in the state of Assam, India and is also the habitat for a large number of aquatic fauna. This mighty river has a very rich and diverse aquatic gene pool, particularly fishes and featured among the global hotspots of freshwater fish diversity (Kottelat and Whitten, 1996). Very few studies have been made on the ecology in relation to the fisheries of the river system (Singh *et al*., 1988; Biswas and Michael, 1992; Yadava and Chandra, 1994; Biswas *et al*., 1995; Biswas and Boruah, 2000; Boruah and Biswas, 2002).

Keeping in view the biogeography and freshwater fish biodiversity of the upper Brahmaputra River system, an effort has been made to determine the present status and interrelationship of the physico-chemical attributes of the upper river system. Four different multivariate statistical techniques [Agglomerative Hierarchical Clustering (AHC), Principal Component Analysis (PCA), one-sample t-test and z-test; and Pearson (n) correlation analysis] were applied to evaluate the efficiency and classifying the sampling sites of the upper Brahmaputra River in terms of water quality.

MATERIALS AND METHODS

The present study had been restricted to only the upper stretches of the river, Brahmaputra from Dibru-Saikhowa National Park (95°18′58.2″ E, 27°34′52.6″ N; elevation – 77 m) bordering Arunachal Pradesh to Guwahati 91°45′03.6″ E, 26°11′10.2″ N; elevation – 53 m), the capital of the state of Assam and the gateway to the North-Eastern India comprising about 550 km. Five locations for the study were selected along the stretch of upper river Brahmaputra *viz.*,

1. Guijan ghat, Tinsukia (S_1) (E 95°18′58.2″, N 27°34′52.6″)
2. Dibrugarh ghat, Dibrugarh (S_2) (E 94°54′45.4″, N 27°29′22.5″)
3. Nematighat, Jorhat (S_3) (E 94°15′01.7″, N 26°51′28.7″)
4. Bhairabi ghat, Tezpur (S_4) (E 92°52′08.28″, N 26°37′32.53″)
5. Kachari ghat, Guwahati (S_5) (E 91°45′03.6″, N 26°11′10.2″)

Sites were chosen on the basis of accessibility and similarity in physical habitat. The study was carried out from February, 2013 to January, 2016. The distance from one sampling site to another was approximately 100 km apart. The locations of sampling sites were documented by using global positioning system receiver (Fig. 1).

For analysis of physical and chemical parameters of water, samples were collected twice in a season from the above sites. In North Eastern India, seasons were classified as pre-monsoon (March-May), monsoon (June-August), post monsoon (September-November) & winter (December to February) followed after Barthakur (1986). Dissolved Oxygen [DO (mg l^{-1})], free carbon dioxide [FCO_2 (mg l^{-1})], total hardness as $CaCO_3$ (mg l^{-1}), total alkalinity as $CaCO_3$ (mg l^{-1}) and chloride (mg l^{-1}) were estimated adopting the method of APHA (2017). Water temperature (°C) was measured by mercury thermometer, turbidity (NTU) was measured by Systronics model Nephelometer. Salinity (ppt) and conductivity (mhos cm^{-1}) were measured by salinity and conductivity meter (Systronics). Total dissolved solid (ppm) was measured by TDS meter (Systronics). pH was also measured by pH meter (Systronics).

The Agglomerative Hierarchical Clustering (AHC), Principal Component Analysis (PCA), one-sample t-test and z-test; and Pearson (n) correlation matrix were estimated using software XLSTAT 2019 version 2019.1. 2. The PCA for estimating the correlation among the physico-chemical variables was followed after Gower (1966); Legendre and Legendre (2012).

RESULTS

Among the physico-chemical parameters, pH, Dissolved Oxygen (DO), Free carbon-dioxide (FCO_2), total hardness, total alkalinity, chloride, Total Dissolved Solid (TDS), conductivity and turbidity were found to be fluctuating significantly from one sampling site to another. The water temperature fluctuated moderately among all the stations and ranged between 16.7°C to 27.4°C with mean ± SD (22.61°C ± 3.60). The pH was found to be slightly acidic in **site S_3** during monsoon season. Besides **site S_3**, all others had alkaline pH. The pH value ranged from 6.18 to 10.1 with (± 0.79) SD, showing neutral to alkaline range in the entire upper basin of the river. The levels of FCO_2 in all the sampling sites ranged between 2.2 mg l^{-1} and 8.8 mg l^{-1} with minimum at **site S_5** in the winter and maximum in the retreating-monsoon. DO range between 8.3 mg l^{-1} and 12.1 mg l^{-1}. However, the level of DO was found to be minimum at **site S_5** in retreating-monsoon and maximum in pre-monsoon at **site S^2**. BOD values in all the sampling sites ranged from 2.6 mg l^{-1} to 3.8 mg l^{-1} with mean ± SD (3.27 ± 0.32). The minimum BOD value was found in winter at **site S_5** and maximum at **site S_1** in pre-monsoon. The estimated value of hardness in the entire sampling site ranged between 48 mg l^{-1} and 117 mg l^{-1}, with both lowest and highest value recorded at **site S_3** in pre-monsoon and retreating-monsoon respectively. The alkalinity values in all sampling sites ranged between 66 mg l^{-1} to 280 mg l^{-1} with (± 76.39) SD throughout the annual cycle. The highest value of alkalinity was recorded at **site S_4** in the monsoon while minimum value was recorded at **site S_1** in winter. Accordingly, the highest value of chloride was estimated at **site S_5** in retreating-monsoon whereas, the lowest value was recorded at **site S_1** in monsoon. However, the values of chloride ranged between 11.52 mg l^{-1} and 22.01 mg l^{-1} with mean ± SD (15.46 ± 2.86). The conductivity value ranged between 143 mhos cm^{-1} and 301 mhos cm^{-1} with (± 204.35) SD with both highest and lowest value recorded in winter at **sites S_5** and **site S_1** respectively. The level of TDS was estimated to be between 70.7 ppm and 162 ppm with mean ± SD (111.58 ± 26.61), with both highest and lowest value at **site S_5** in winter and monsoon seasons. The salinity values in all the sites ranged between 0.06 ppt to 0.19 ppt with mean ± SD (0.09 ± 0.04). Turbidity was moderate at **sites S_1**, **S_2** and **S_4** with highest in **site S_5** and lowest in site S3. Water transparency varied seasonally amongst all the study sites from highly turbid (37.3 NTU) to moderately clear (9.4 NTU) throughout the annual cycle. The minimum, maximum, mean and standard deviation of the physico-chemical parameters of water were estimated and presented in Table 1.

Amongst the important habitat attributes, pH, water temperature, DO, FCO_2, total alkalinity, total hardness and turbidity values varied considerably from one sampling site to another (Fig. 2). The seasonal variations of the important physico-chemical variables for water quality assessment showed minor fluctuating trends in the entire selected stations in all the seasons.

The Pearson (n) correlation matrix of the important physico-chemical variables of the water quality of the upper Brahmaputra river showed that the relationship between water temperature (°C) with pH, FCO_2 (mg l^{-1}), DO (mg l^{-1}),total alkalinity (mg l^{-1}), and turbidity (NTU) had positive correlation (R = 0.445, 0.049, 0.706, 0.561 and 0.437) at 5 % significance level respectively (Table-2). Similarly, pH value with total alkalinity (mg l^{-1}), chloride (mg l^{-1}), and turbidity (NTU) showed positive relationship (R = 0.131, R = 0.742 and R = 0.623). Further, DO (mg l^{-1}) with FCO_2 (mg l^{-1}) and BOD (mg l^{-1}); DO (mg l^{-1}) and total alkalinity (mg l^{-1}); FCO_2 (mg l^{-1}) and BOD (mg l^{-1}); BOD (mg l^{-1}) and total hardness (mg l^{-1}) also showed positive relationship (R = 0.327, R = 0.016, R = 0.162, R = 0.221, R = 0.490) respectively.

Whereas, the co-relation between the water temperature (°C) and BOD (mg l^{-1}); pH and FCO_2 (mg l^{-1}); pH and DO (mg l^{-1}); pH and BOD (mg l^{-1}); FCO_2 (mg l^{-1}) and turbidity (NTU); DO (mg l^{-1}) and turbidity (NTU) as well as BOD (mg l^{-1}) and turbidity (NTU) showed insignificant negative relationship (R = -0.579, R = -0.001, R = -0.217, R = -0.501, R = -0.640, R = -0.263 and R = -0.829) respectively (Table 2). This suggests that there was a minor fluctuation of water temperature, pH, DO, FCO_2 and BOD during entire seasons of the year.

The t-test and z-test of the mean value of the physical and chemical variables at 0.05 level of significance and 95 % confidence interval showed a varied t (Observed) value for the individual parameters. The p-value for water temperature, pH, DO, BOD, total hardness, conductivity and TDS was found to be < 0.0001. Except these variables, the p-value for FCO_2 (0.0002), total alkalinity (0.002), chloride (0.0001), salinity (0.009) and turbidity (0.002) were evaluated (Table 3).

The Agglomerative Hierarchical Clustering analysis of the important physico-chemical variables of the study sites (Fig. 3) revealed a comparable picture of similarities and association among the studied variables. There were altogether four clads, among which DO and water temperature; TDS, conductivity and FCO_2; turbidity, chloride, total alkalinity and pH; salinity, total hardness and BOD form a single clad and were more closely positioned and comparatively associated with each other. Salinity, total hardness and BOD were the farthest from all the clusters in the dendrogram.

The Principal Component Analysis (PCA) of the tested physical and chemical variables indicated that DO and water temperature, DO and FCO_2, water temperature and pH, pH and chloride as well as DO and chloride were positively correlated with each other. From the ordination diagram it becomes clear that FCO_2 and BOD show negative correlation with DO, pH and water temperature respectively. Of the 12 variables estimated, only four parameters showed significant correlation with each other in the ordination plotting (Fig. 4).

DISCUSSION

The present investigation reveals that most of the physico-chemical variables in the upper basin of river Brahmaputra have been estimated within the permissible limits at all the five surveyed stations. In the present investigation it was observed that among all the physico-chemical parameters, water temperature, pH, DO, FCO_2 and BOD were the key habitat features which determined the aquatic species distribution. Water temperature is considered as an immensely important factor, which has key role in biochemical interactions (Gangwar *et al.*, 2012). The estimated mean value of water temperature of the studied stations were found to be 22.61°C with ± 3.60 SD. Similar trend of fluctuating water temperature values of upper Brahmaputra basin was observed by Boruah and Biswas (2002).

The pH of the water showed no definite seasonal trend and it ranged between 6.18 and 8.4 with mean ± SD (7.84 ± 0.79). These values were within maximum permissible limit prescribed by WHO (1993). Changes in pH can be indicative of an industrial pollutant, photosynthesis or the respiration of algae that is feeding on a contaminant. Specific pH affects the chemical reaction in aquatic bodies and thus rewarded as crucial factor in riverine ecosystem (Wang *et al.*, 2002). Concentration of FCO_2 gives direct evidences for pollution status of water. Excess concentration of

FCO_2 resulted from deoxygenation tends to enhance the water temperature, leading to direct impact over aquatic biota, hence considered as limiting factor (Talling, 1957). Fluctuation in FCO_2 among the study sites ranged between 2.2 mg l^{-1} to 8.8 mg l^{-1} with mean ± SD (5.23 ± 1.67). Similar trend of fluctuating FCO_2 values were observed by Boruah and Biswas (2002) and Gaikwad and Kamble (2013).

In the upper basin of river Brahmaputra, DO values were slightly higher with mean ± SD (9.83 ± 1.16), possibly due to the faster current of water in the upstream. Dissolved oxygen concentrations of 5.0 mg l^{-1} or more are acceptable for most aquatic organisms (Stickney, 2000). BOD is often used as a measure of pollutants in natural and waste waters and to assess the strength of waste, such as sewage and industrial effluent waters (Zeb *et al*., 2011). BOD, therefore, is an important parameter of water indicating the health status of freshwater bodies (Bhatti and Latif, 2011). In the present investigation, BOD values varied from 2.6 mg l^{-1} to 3.8 mg l^{-1} with mean ± SD (3.27 ± 0.32). Both DO and BOD shows a significant correlation with FCO_2 (R = 0.327 and R = 0.221), but shows negative correlation with pH (R = 217 and R = 0.501).

Hard and alkaline water may be attributed to high planktonic growth to some extent (Sujitha *et al*., 2011). The levels of total hardness of the upper basin of river Brahmaputra were estimated within the permissible limit with mean ± SD (86.88 ± 20.82). According to Baruah *et al*. (1993), total hardness of water is not a pollution parameter, but indicates water quality mainly in terms of Ca^{2+} and Mg^{2+}. Total alkalinity of water is due to the presence of mineral salts present in it. It was primarily caused by the carbonate and bicarbonate ions. High alkalinity can be attributed to the rise in temperature and high planktonic growth (Sujitha *et al*., 2011) which also coincides with the concentration of nutrients and bicarbonates in particular. The value of conductivity estimated in all the sampling sites was within the permissible limit with mean ± SD (174.45 ± 76.39). The decomposition of the organic matter leads to the high alkalinity of the riverine waters (Venkateswarlu and Jayanti, 1968).

The content of chloride gave a concrete idea of organic matter and presence of nitrates in freshwater bodies. Excess chloride in water gives salty taste to water and has laxative effects on organisms (Das and Achary, 2003). The estimated values of chloride in the present findings were found to be between the range of 11.52 mg l^{-1} and 22.01 mg l^{-1} with mean ± SD (15.46 ± 2.86). Thresh *et al*. (1994) in his study had made an observation on the value of Chloride of freshwater ecosystem. Again, Peres-Neto (2004) also reported that species occurrence is directly related with abiotic factor than species interaction.

It is worth mentioning that in the present investigation, a marked variation in the seasonal values of conductivity, TDS and turbidity were noticed. Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in water (EPA, 2012). The estimated value of conductivity in all the sampling sites was found between the ranges of 143 mhos cm^{-1} to 301 mhos cm^{-1} with mean ± SD (204.35 ± 46.89). The conductivity value observed was within the permissible limits as prescribed by WHO (Murhekar, 2011). TDS indicate the salinity status of riverine water. TDS content of the upper river basin was estimated in the range of 83 ppm and 162 ppm with mean ± SD (111.58 ± 26.61). Higher TDS in water system increases the chemical and biological oxygen demand and ultimately depletes the dissolved oxygen level in water (Shrinivasa and Venkateswaralu, 2000).

There are many different dissolved salts that contribute to the salinity of water. Many of these ions are also present in freshwater sources, but in smaller amounts (Wetzel, 2001). In the present study, Salinity values varied from 0.06 ppt to 0.19 ppt with mean ± SD (0.09 ± 0.04). Salinity is important in particular as it effects dissolved oxygen (Wetzel, 2001). Change in the pH value caused some of the solutes to precipitate or affect the solubility of the suspended matters (Bellingham, 2012). Similarly, the turbidity value observed with mean ± SD (17.98 ± 6.87) was found within the permissible limits as prescribed by WHO (Murhekar, 2011). It was clear from the Biplot graph that water temperature, pH, DO and chloride remains highly ideal for the physiological activities of all the aquatic organisms of the upper river basin (Boruah and Biswas, 2002). By this present investigation, it can be summarized that the variations of physical and chemical variables would be having direct impact on aquatic species richness. This might be so due to the numerous tributaries in the upper basin than the lower basin. Open river habitat was the most preferred habitat for fishes inhabited in the tropical rivers (Lobb and Orth, 1991; Aadland, 1993; Arunachalam, 2000; Sarkar *et al*., 2010). The reasons for moderate values of some physico-chemical variables in some seasons might be due to effect of municipal waste from adjoining areas and industries, high sedimentation rate, pollution and industrial boom. The study indicates that the habitat attributes of the upper river basin for now has a low anthropogenic and industrial load. Thus, regular and constant monitoring of water bodies is vital to ensure that water quality characteristics are maintained. The need of the hour is to assess the climate change and the global warming effect on these hydrological parameters with a focused approach. Any contamination or variation in the water qualities may impede the aquatic organisms in these study sites. Sudden warming of temperature disrupting seasonal events cannot be understood easily, while appropriate human interference can always thwart biodiversity. Hence, a detailed focused research approach must be carried out with respect to climate change which would be very sporadic and insignificant in comparison to the aquatic species present in the river system.

CONCLUSION AND RECOMMENDATIONS

The finding of the study reveals that the upper basin of the river Brahmaputra, from Guijan ghat, Tinsukia to Kachari ghat, Guwahati is still within the permissible limits of hydrological parameters. Although disorganized management, siltation, non-scientific harvesting and other developmental projects had gradually reduced the diversity of few aquatic species. Also, in addition to all these, there is concern as the global warming effects are making a number of aquatic species vulnerable in their natural habitat. Despite all these facts that the river Brahmaputra at its upper basin are subjected to varied pressures (both anthropogenic and natural) but the river is still very efficient for sustaining rich aquatic resources. For effective maintenance of the important hydrological variables, a comprehensive abiotic assessment programme should be planned. Hence, for the conservation purposes, varied strategies such as stopping of siltation and control of water pollution are the need of the hour. The present hydrological approaches may be applied to the entire River Brahmaputra and other river systems of the North Eastern part of India for identification of the other imperative hydrological factors which influences the ecosystem of the river basin.

It is therefore, recommended that the state government and scientific research organizations together with non-government organizations should take an active part in research and development activities for formulating effective maintenance strategies for sustaining riverine ecosystem of the region and South East Asia which have similar trend of agro-climatic conditions.

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REFERENCES

Aadland, L. P. (1993). Stream habitat types: their fish assemblages and relationship to flow. *North Am. J. Fish Manag.*, *13*, 790-806.

Adeyemo, O. K., Adedokun, O. A., Yusuf, R. K., & Adeleye, E. A. (2008). Seasonal Changes in Physico-chemical Parameters and Nutrient Load of River Sediments in Ibadan city, Nigeria. *Global NEST Journal, 10*(3), 326-336.

APHA (2017). *Standard methods for examination of water and waste water* (23rd ed.). Washington, DC: USA. American Public Health Association, American Water Works Association, Water Environment Federation.

Arunachalam, M. (2000). Assemblage structure of stream fishes in the Western Ghats (India). *Hydrobiol.*, *430*, 1-31.

Baruah, A. K., Sharma, R. N., & Borah, G. C. (1993). Impact of Sugar Mill and Distillery Effluents on Water Quality of River Gelabil, Assam. *Indian J. Environ Hlth., 35*(4), 288-293.

Barthakur, M. (1986). Weather and Climate of North East India. *North Eastern Geographer, 18*(1 &2), 20-27.

Bellingham, K. (2012). Physicochemical Parameters of Natural Waters. *Stevens Water Monitoring Systems Inc*: 205-209.

Bhatti, M. T., & Latif, M. (2011). Assessment of water quality of a river using an indexing approach during the low-flow season. *Irrigation Drainage, 60*, 103-114.

Biswas, S. P., & Boruah, S. (2000). Ecology of the River Dolphin (*Platanista gangetica*) in the Upper Brahmaputra. *Hydrobiol.*, *430*, 97-111.

Biswas, S. P., & Michael, R. G. (1992). Fishery characteristics and the present status of Fisheries of the River Brahmaputra. In: *Proceedings of Seminar on Conservation of River Dolphin in Indian Sub-continent*, 18-19 August 1986, New Delhi, India.

Biswas, S. P., Borbora, S. H., & Dutta, B. C. (1995). Present of capture fisheries in the upper stretches of the Brahmaputra. *Bull. Life Sci*., *5*, 31-40.
Boruah, S., & Biswas, S. P. (2002). Ecohydrology and fisheries of the upper Brahmputra basin. *Environmentalist, 22*, 119-131.
Chapman, D. E. (1996). *Water quality assessment: A guide to the use of Biota Sediments and water in Environmental Monitoring* (2nd ed.), London, UK: Chapman and Hall.
Chovance, A., Hoffer, R., & Schiemer, F. (2003). Fish as bioindicators; In B. A. Market, A. M. Breure & H. G. Zechmeiser (Ed.), Bioindicatos and biomonitors, 639-675.
Das, J., & Achary, B. B. (2003). Hydrology and assessment of lotic water quality in Cuttack City, India. *Water Air and Soil Pollution, 150*, 163-175.
Dawson, T. P., Berry, P. M., & Kampa, E. (2003). Climate change impacts on freshwater wetland habitat. *J. Nat. Conserv*., *11*, 25-30.
EPA (2012). 5.9. Conductivity. In: Water Monitoring and Assessment. http://water.epa.gov/type/rsl/monitoring/vms 59.cfm. Accessed 20 May 2021.
Gaikwad, S. S., & Kamble, N. A. (2013). Assessment of seasonal changes in water quality of river Panchganga. *Asian J. Biol. Life Sci*., *2*(2), 152-162.
Gangwar, R. K., Khare, P., Singh, J., & Singh, A. P. (2012). Assessment of physicochemical properties of water: River Ramganga at Bareilly. *U.P. Journal of Chemical and Pharmaceutical Research, 4*(9), 4231-4234.
Gibbs, J. P. (2000). Wetland loss and biodiversity conservation. *Conserv Biol*., *14*(1), 314-317.
Givan, O., Edelist, D., Sonin, O., & Belmaker, J. (2018). Thermal affinity as the dominant factor changing Mediterranean fish abundances. *Glob. Chang. Biol.*, *24*(1), 80-89.
Gower, J. C. (1966). Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika, 53*, 325-338.
Hugueny, B., & Léveque, C. (1994). Freshwater fish zoogeography in West Africa: faunal similarities between river basins. *Environmental Biology of Fishes, 39*, 365-380.
Jaric, I., Bellard, C., Courchamp, F., Kalinkat, G., Meinard, Y., Roberts, D. L., & Correia, R.A. (2020). Societal attention toward extinction threats: a comparison between climate change and biological invasions. *Sci. Rep.*, *10*(1), 1-9.
Kottlet, M., & Whitten, T. (1996). Fresh water biodiversity in Asia with special reference to fish. World Bank, Technical paper No. 343, Washington DC: 17-22.
Lawson, E. O. (2011). Physico-Chemical Parameters and Heavy Metal Contents of Water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research, 5*(1), 8-21.
Legendre, P., & Legendre, L. (2012). *Numerical Ecology* (3rd ed.), Amsterdam: Elsevier.
Leveque, C., Balian, E. V., & Martens, K. (2005). An assessment of animal species diversity in continental waters. *Hydrobiol*., *542*, 32-67.
Lima-Junior, S. E., Cardone, I. B., & Goitein, R. (2006). Fish assemblage structure and aquatic pollution in a Brazilian stream: some limitations of diversity indices and models for environmental impact studies. *Ecol. Freshw. Fish, 15*(3), 284-290.
Lobb, M. D., & Orth, D. J. (1991). Habitat use by an assemblage of fish in a large warm water stream. *Trans. Am. Fish Soc*., *120*, 65-78.
Mas-Marti, E., Garcia-Berthou, E., Sabater, S., Tomanova, S., & Monoz, I. (2010). Comparing fish assemblages and trophic ecology of permanent and intermittent researches in a Mediterranean stream. *Hydrobiologia*., *657*, 167-180.
Murhekar, G. H. (2011). Determination of Physico-Chemical Parameters of Surface Water Samples in and around Akot City. *Int. J. of Research in Chem. and Environ*., *1*(2), 183-187.
Nguyan, N. T. (1990). The Mekong Delta: Resources, Environment & Development (in Vietnamese). National Committee of Science programme, 60-B: 403.
Peres-Neto, P. R. (2004). Patterns in the co-occurrence of stream fish meta communities: the role of site suitability, morphology and phylogeny versus species interactions. *Oecologia, 140*, 352-360.
Ricciardi, A., & Rasmusse, J. B. (1999). Extinction rates of North American freshwater fauna. *Conserv. Biol*., *13*, 1220-1222.
Sarkar, U. K., Gupta, B. K., & Lakra, W. S. (2010). Biodiversity, ecohydrology, threat status and conservation priority of freshwater fishes of River Gomti, a tributary of River Ganga (India). *Environmentalist, 30*, 3-17.
Sepkoski, J. J., & Rex, M. A. (1974). Distribution of freshwater mussels: coastal rivers as biogeographic islands. *Syst. Zool*., *23*, 165-188.
Singh, S. P., Mehrotra, S. N., Yadava, Y. S., Choudhury, M., Biswas, B. K., & Biswas, D. K. (1988). Investigation on factors relating to decline of fishery in the River Brahmaputra and its tributaries. Annual Report, CICFRI, Barrackpore.

Shrinivasa, R. B., & Venkateswaralu, P. (2000) Physicochemical Analysis of Selected Groundwater Samples. *Indian J. Environ Prot*., *20*(3), 161.
Stickney, R. R. (2000). *Encyclopedia of Aquaculture*. New York: John Wiley and Sons.
Sujitha, P. C., Mitra, D. D., Sowmya, P. K., & Mini, P. K. (2011). Physicochemical parameters of Karamand River water in Trivandrum District, Kerala, India. *Int. J. Environ Sci*., *2*(2), 472-490.
Talling, J. F. (1957). The longitudinal succession of the water characteristics in White Nile. *Hydrobiol*., *90*, 73-89.
Thresh, J. C., Suckling, E. V., & Beale, J. F. (1994). In E.D. Taylor (Ed.), The examination of water supplies.
Venkateswarlu, J., & Jayanti, T. (1968). Hydrobiological studies of the river Sabarmati to evaluate water quality. *Hydrobiol*., *31*, 442-448.
Wang, W., Wang, A., Chen, L., Liu, Y., & Sun, R. (2002). Effects of pH on survival, Phosphorous Concentration, Adenylate Energy Charge and Na^+, K^+ ATPase Activities of Penaeus chinensis Osbeck Juveniles. *Aquatic toxicology, 60*, 75-83.
World Health Organization (1993). Guidelines for drinking water quality-I, Recommendations (2nd ed.), *1*(1), 130 pp.
Wetzel, R. G. (2001). *Limnology: Lake and River Ecosystems* (3rd ed.), San Diego, California: Academic Press.
Yadava, Y. S., & Chandra, R. (1994). Some threatened carps and catfishes of Brahmaputra river system. In P. V. Dehadrai P V, P. Das & S. R. Verma (Ed.), Threatened Fishes of India, Nature Conservators, Muzaffarnagar, 45-55.
Zeb, B. S., Malik, A. H., Waseem, A., & Mahmood, Q. (2011). Water quality assessment of Siran River. *Pakistan Int. J. Phys. Sci*., *6*, 7789-7798.

Table 1 Range, mean and standard deviation of important physico-chemical variables of study sites of Upper Brahmaputra River, Assam.

Variables	S_1		S_2		S_3		S_4		S_5	
	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD	Range	Mean ±SD
Water Temp. (^{0}C)	16.7 - 25.8	21.78 ± 3.78	17.3 - 27.4	23.1 ± 4.22	16.1 - 26.4	22.13 ± 4.37	18.3 - 27.3	23.03 ± 3.71	17.5 - 26.7	23.03 ± 3.91
pH	7.23 - 8.4	7.82 ± 0.52	7.21 - 8.71	8.08 ± 0.64	6.18 - 8.31	7.32 ± 0.88	7.26 - 7.75	7.50 ± 0.25	7.53 - 10.1	8.47 ± 1.14
FCO_2 (mg l^{-1})	3.3 - 6.6	5.23 ± 1.65	4.4 - 8.8	6.6 ± 1.80	3.3 - 6.6	5.23 ± 1.65	3.3 - 6.6	4.68 ± 1.38	2.2 - 6.6	4.40 ± 1.80
DO (mg l^{-1})	8.97 - 9.87	9.39 ± 0.41	9.32 - 12.1	10.20 ± 1.29	8.57 - 10.9	9.66 ± 1.26	8.54 - 11.7	10.33 ± 1.33	8.3 - 11.8	9.55 ± 1.55
BOD (mg l^{-1})	3.1 - 3.8	3.45 ± 0.31	2.8- 3.6	3.25 ± 0.34	2.8 - 3.7	3.23 ± 0.38	2.9 - 3.6	3.33 ± 0.31	2.6 - 3.4	3.08 ± 0.34
Total Hardness (mg l^{-1})	90 – 115	103.42 ± 12.31	59 – 110	82.75 ± 24.24	48 – 117	91.25 ± 30.20	63 - 96	74.25 ± 14.80	61 - 95	82.75 ± 15.06
Total Alkalinity (mg l^{-1})	66 – 127	95.75 ± 26.49	82 – 270	138 ± 88.50	96 – 280	192.75 ± 93.33	161 - 245	205.75 ± 40.67	215 - 270	240 ± 23.45
Chloride (mg l^{-1})	11.52 - 16.01	13.27 ± 2.02	13.01 - 18.52	15.77 ± 2.26	13.01 - 19.02	15.14 ± 2.72	12.01 - 16.01	14.02 ± 1.68	17.01 - 22.01	19.14 ± 2.18
Conductivity (mhos cm^{-1})	143 - 294	208.25 ± 68.64	186 – 256	228.5 ± 30.04	189 - 246	208 ± 25.76	153 - 219	181.50 ± 28.03	138 - 301	195.50 ± 72.42
TDS (ppm)	83 – 126	107.63 ± 20.93	107 – 150	135.25 ± 19.82	92.4 - 142	115.65 ± 24.57	78.2 - 112	93.53 ± 13.97	70.7 - 162	105.85 ± 39.83
Salinity (ppt)	0.06 - 0.07	0.065 ± 0.01	0.06 - 0.08	0.07 ± 0.01	0.06 - 0.16	0.11 ± 0.05	0.07 - 0.15	0.10 ± 0.04	0.06 - 0.19	0.10 ± 0.06
Turbidity (NTU)	9.8 - 17.32	13.94 ± 3.21	9.6 - 23.4	14.63 ± 6.04	9.4 - 21.6	16.68 ± 5.18	13.4 - 21.4	17.04 ± 3.86	22.1 - 37.3	27.64 ± 6.80

Table 2 The Pearson (n) Correlation matrix of the important physico-chemical variables of Upper Brahmaputra River, Assam.

Variables	Water Temp.	pH	FCO_2	DO	BOD	Hardness	Alkalinity	Chloride	Conductivity	TDS	Salinity	Turbidity
Water Temp.	**1**											
pH	0.445	**1**										
FCO_2	0.049	-0.001	**1**									
DO	0.706	-0.217	0.327	**1**								
BOD	-0.579	-0.501	0.221	0.016	**1**							
Total Hardness	**-0.917**	-0.090	0.125	-0.804	0.490	**1**						
Total Alkalinity	0.561	0.131	-0.625	0.162	-0.803	-0.687	**1**					
Chloride	0.548	0.742	-0.236	-0.167	-0.947	-0.358	0.676	**1**				
Conductivity	-0.148	0.191	0.899	-0.086	0.055	0.398	-0.605	-0.012	**1**			
TDS	0.080	0.220	0.903	0.089	-0.147	0.156	-0.401	0.140	0.963	**1**		
Salinity	-0.847	-0.133	-0.214	-0.692	0.686	0.851	-0.609	-0.514	-0.050	-0.316	**1**	
Turbidity	0.437	0.623	-0.640	-0.263	-0.829	-0.354	0.801	0.895	-0.428	-0.312	-0.299	**1**

Table 3 One-sample t-test and z-test with 5% Significance level and 95% Confidence interval on the mean of physico-chemical variables.

Variables	Difference	t (Observed value)	|t| (Critical value)	DF	p-value (Two-tailed)	Alpha
Water Temp.	22.610	82.096	2.776	4	< 0.0001	0.05
pH	7.839	38.250	2.776	4	< 0.0001	0.05
FCO_2	5.225	13.784	2.776	4	0.0002	0.05
DO	9.826	53.215	2.776	4	< 0.0001	0.05
BOD	3.265	53.053	2.776	4	< 0.0001	0.05
Total Hardness	86.883	17.622	2.776	4	< 0.0001	0.05
Total Alkalinity	174.450	6.808	2.776	4	0.002	0.05
Chloride	15.465	15.228	2.776	4	0.0001	0.05
Conductivity	204.350	26.248	2.776	4	< 0.0001	0.05
TDS	111.580	16.179	2.776	4	< 0.0001	0.05
Salinity	0.118	4.809	2.776	4	0.009	0.05
Turbidity	17.983	7.240	2.776	4	0.002	0.05

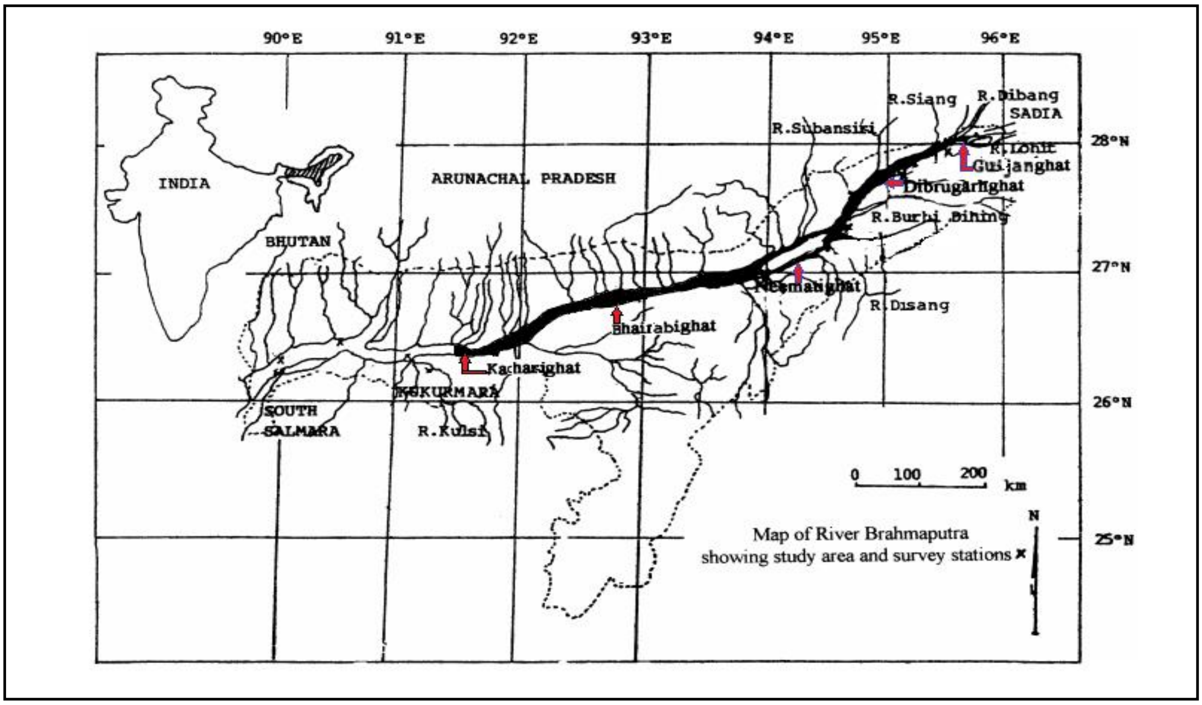
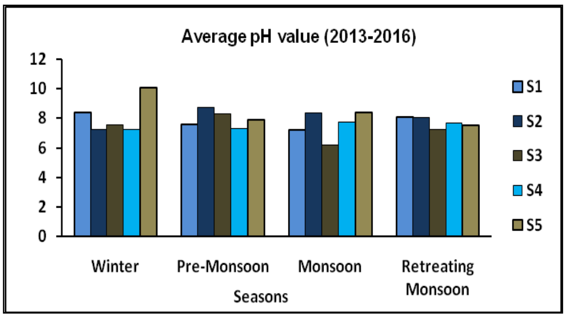
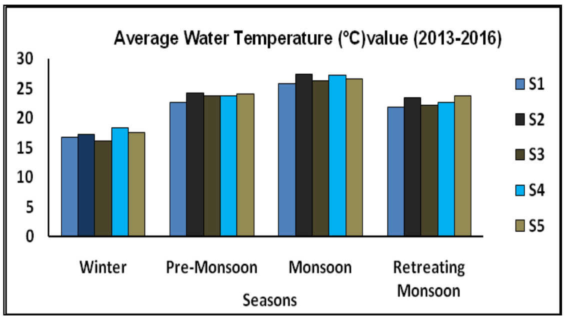
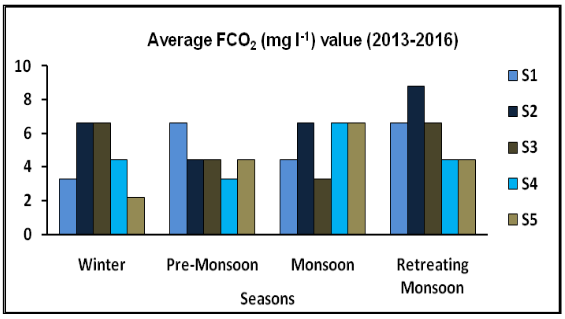
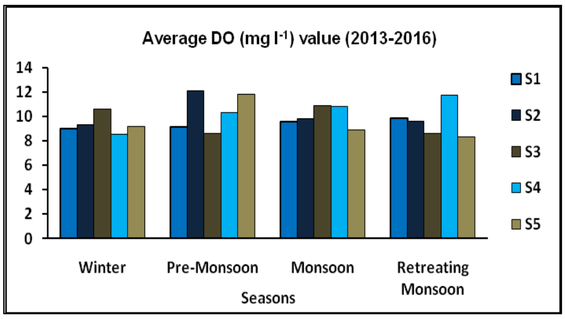


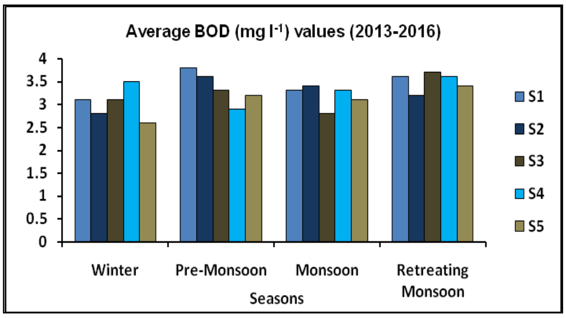
Fig. 1: Map of Brahmaputra basin showing sampling sites along upper reaches in India

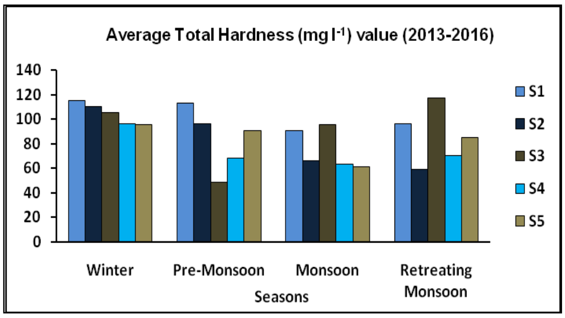

Average pH value (2013-2016)
12
10
8
6
4
2
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5

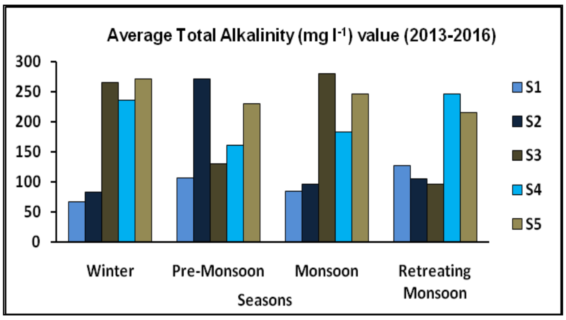

Average Water Temperature (°C)value (2013-2016)
30
25
20
15
10
5
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5

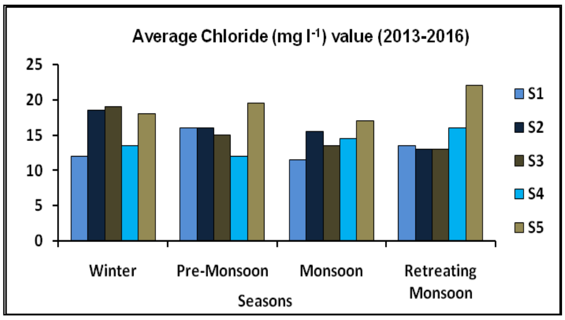

Average FCO_2 (mg l^{-1}) value (2013-2016)
10
8
6
4
2
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5


Average DO (mg l^{-1}) value (2013-2016)
14
12
10
8
6
4
2
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5


Average BOD (mg l^{-1}) values (2013-2016)
4
3.5
3
2.5
2
1.5
1
0.5
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5


Average Total Hardness (mg l^{-1}) value (2013-2016)
140
120
100
80
60
40
20
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5


Average Total Alkalinity (mg l^{-1}) value (2013-2016)
300
250
200
150
100
50
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5


Average Chloride (mg l^{-1}) value (2013-2016)
25
20
15
10
5
0
Winter
Pre-Monsoon
Monsoon
Retreating Monsoon
Seasons
S1
S2
S3
S4
S5

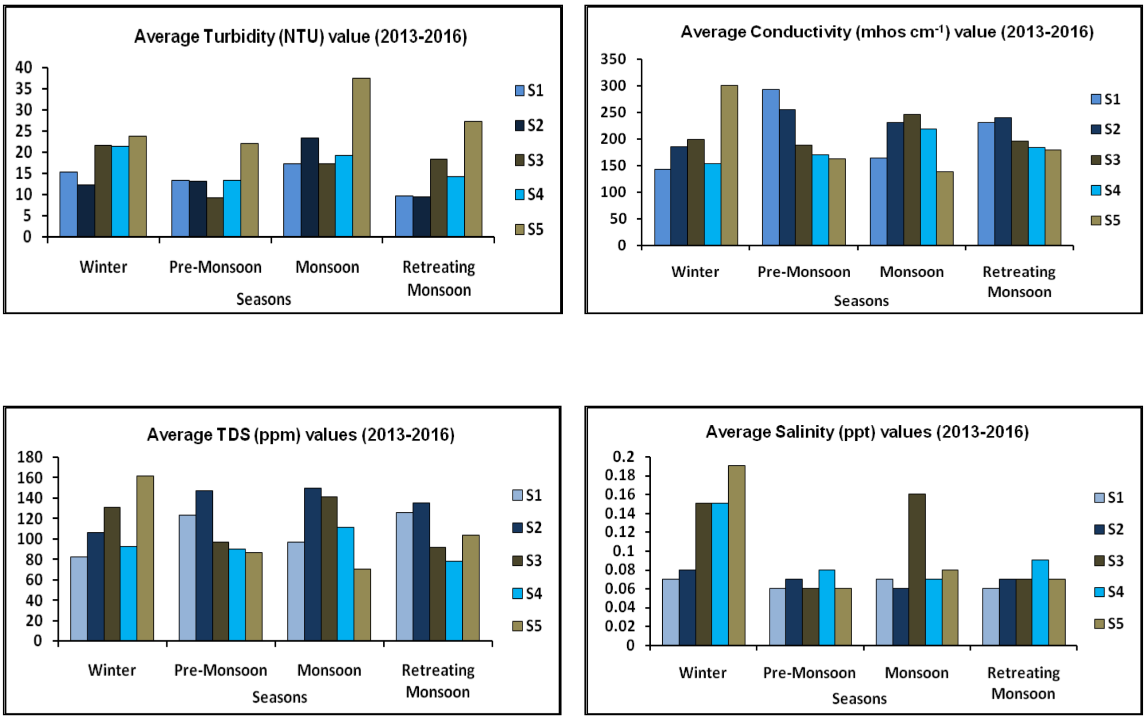


Fig. 2 Season-wise average value of important physico-chemical parameters of Upper Brahmaputra River

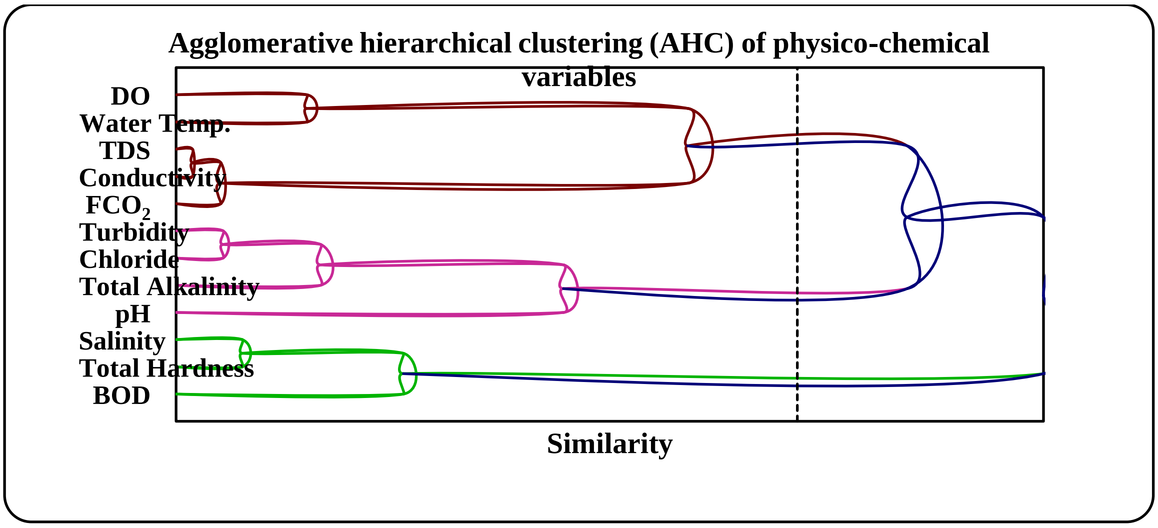


Fig. 3 Agglomerative hierarchical clustering (AHC) of important physico-chemical parameters of Upper Brahmaputra River

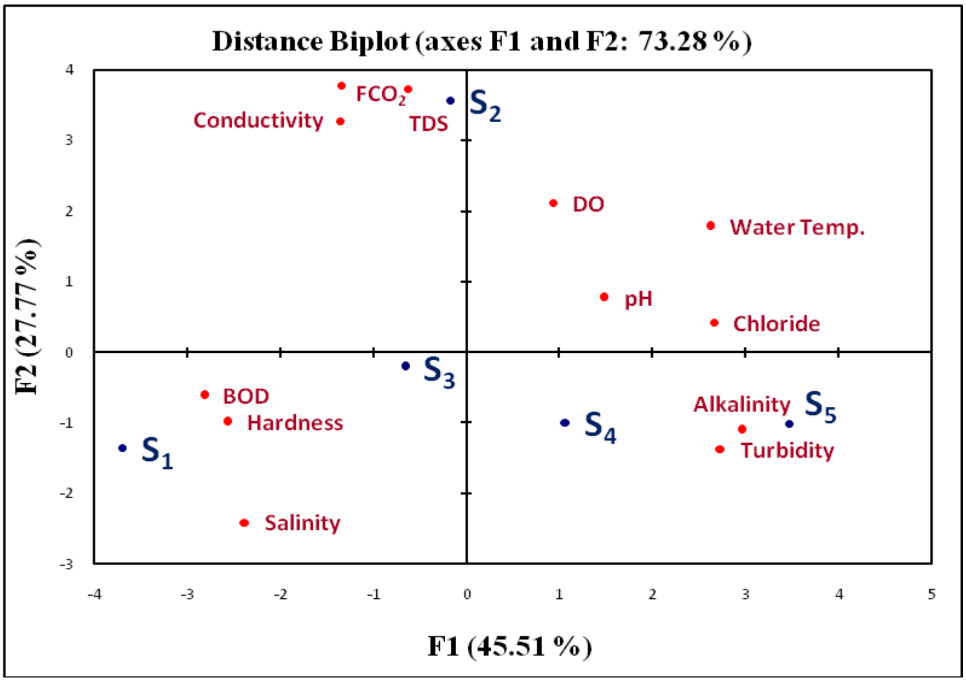


Fig. 4 PCA ordination showing the relationship among the physico-chemical variables of the Upper Brahmaputra River, Assam

CLIMATE RISK ASSESSMENT OF MANAS RIVER: A BIODIVERSITY HOTSPOT IN WESTERN ASSAM

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ABSTRACT

Climate related risks were identified for Manas National Parkand Manas River. Mann-Kendall test have been used to analyse the changing trend for precipitation and temperature. Significant increasing trend have been observed in Monsoon rainfall. Also, significant increasing trend has been observed in post-monsoon temperature and winter temperature. Changing rainfall and precipitation pattern might have impact on the grassland ecosystem. To assess the key and emergent risks, stakeholder's consultation and experts survey were carried out. The stakeholders observed changes both in temperature and precipitation and also mentioned about decrease in grazing area. To analyse the change in the river, land cover classification was done. From the satellite images, for the year 1995 and 2020, change in the area of the river have also been observed. Floods and cloudbursts might cause such change and it might increase the vulnerability of the region. Increase in the rainfall might result in the water level in the river and carry huge amount of siltation and damage the land area. Melting of glaciers in the Himalayas has the possibilities of increase the risk at the foothills. If the mitigation and adaptation strategies are not implemented, then the climate related risk might get severe.

Keywords: Climate risk, vulnerability, Manas National Park, Mann-Kendall test and trend

INTRODUCTION

Climate induced environmental disasters have been increasing and it results in loss of lives and destruction of infrastructures. Some of the key drivers of climate change are greenhouse gases emissions, land use and land cover change and anthropogenic activities (Krishnan *et al*., 2020). The change in climate might aggravate climate extremes, which includes heatwaves, floods and droughts. The well-being of an ecosystem is important for survivability of various species. An ecosystem consists of various species and are dependent on each other directly or indirectly. The sectors other than human health that are also severely affected due to change in climate are agriculture, forest and water. The level of vulnerability differs in each case depending on the type of hazard, exposure and sensitivity level. Geographical locations also play a vital role in determining the risks associated with it. Most of the forests in the north east are moderately vulnerable (Ravindranath *et al.*, 2011). Climate also plays a crucial role in proper functioning of the ecosystem. Climatic factors, such as precipitation and temperature help in regulating the ambience of these ecosystems. The water resource for the major river system in India is formed from the Himalayas. The changes in the ecosystem of the upper region of the Himalayas in terms of climate might also disrupt the ecosystem at the lower region. Brahmaputra is one of the major river basins of Himalaya and the melting of its glaciers will impact the water of the Brahmaputra and also become susceptible to reduction of flow (The Hindu, 2016). Both increasing and decreasing trend have been observed in the subdivisions of Brahmaputra basin. Using the global models for India, a maximum increase in rainfall was projected for northeast and west coast (Kumar *et al*., 2011). Existence of large uncertainties in the projection of future rainfall. Brahmaputra and Barak basin received maximum rainfall in the pre-monsoon season (Jain *et al*., 2016). Climate extremes like heavy or untimely rainfall and increase in temperature may have direct or indirect impact on the species at sub-Himalayan foothills. The forest fires might contribute to the increase in temperature, which might lead to increase in the formation of cloudburst and result in flash flood. It would also lead to the release of carbon into the atmosphere and might also disrupt hydrological activities. All these factors might increase the risk of the grassland ecosystem and make it more vulnerable. So, a risk assessment is necessary to identify the key risk factors and emergent risk factors. The sensitivity, vulnerability and adaptive capacity of the species would indicate the level of risk they might fall due to climate extremes. The objective of the study is to (i) assess the climate trends and variability in climate and (ii) identify key climate risks in the region.

MATERIALS AND METHODS

Study Area

Manas National Park is located in Assam, at the foothill of the Himalaya (DebRoy, 1991). The region falls in Chirang-Baksa district of Assam. It is considered as a World Heritage site by UNESCO due to rich biodiversity (Goswami *et al*., 2011). The Indian monsoon influences the climate of the area, with maximum temperatures of 37°C in the summer and minimum temperatures of 5°C in the winter (Das *et al*., 2019). It is the habitat for various animals and insects. The Manas River, which is one of the major tributaries of the Brahmaputra River passes through the park, acts as the source of hydrological activities for the park. Flood and change in river courses might disrupt the successional phases represented by Terai grasslands. On the other hand, there has been decline in water source along with significant shift towards a drier and woodland type of vegetation (Sarma *et al*., 2008). Heavy rainfall also results in the enormous deposition of silt and rock (Conservation Outlook Assessment, 2020).

LITERATURE REVIEW

Climate trend in Assam

Observed rainfall and temperature trend have been studied for western Assam region, since Manas National Park falls in the western part of Assam. Therefore, the rainfall and temperature trend of the entire western Assam was focused. It was found that Kokrajhar received highest rainfall over other districts during June, July and August and Chirang received rainfall during September. Kokrajhar received maximum rainfall for SW monsoon annually and it received 73% of annual rainfall in SW monsoon season. Dhubri is experiencing decreasing rainfall trend. Whereas Chirang is experiencing increase in rainfall trend. Baksa is experiencing minimum rainy days. Whereas it was observed that both Chirang and Baksa is experiencing maximum number of heavy rainfalls throughout the rainy season along with maximum dry days have been observed for both the districts. It was also observed that Baksa is experiencing a significant decrease in rainy days. The combination of maximum heavy rainfall and minimum rainy days might be contributing factor for increase in the intensity of floods and landslides. This might be an indicator of change in climate.

Manas River

The Manas River is an important part of the Manas National Park and both are under the threat of various environmental challenges. The area has experienced floods multiple times. Some of the major flash floods that took place in Manas were during the period 2001-2009. These were the outcome of cloudbursts and rainstorms which took place in the upper catchment area of the Manas River (Bora, 2018). On the other hand, increase in temperature would also lead to melting of glaciers and increase the formation of glacial lakes. This would cause more flash floods in the Manas National Park, thereby making its ecosystem more vulnerable. The disastrous event that took place in 2004 due to the excess water release from the Kurichu dam had a severe impact on the Manas National Park. It washed away a significant amount of landmass along with forest cover. It even changed the course of the Manas River and led to complete change in some parts of the area. The impact of climate change or increase in climate extremes might increase the risk level and the species of such ecosystem might be more sensitive. There are linkages between the increase in anthropogenic activities, climate change and increase in disasters. Change in climate might increase the intensity of the rainfall, which might increase the flood level. According to Sanchez-Rodriguez *et al*., 2018, the response of ecosystems to extreme weather events is highly dependent on temperature, with higher temperatures having a stronger detrimental impact than lower temperatures. Increase in events like floods might alter the soil quality. This might impact the soil productivity and cause restrictions in the growth of grasses. There is also possibility that flood events have the potential of being source of GHGs due to large potential release of CH_4 and N_2O (Sanchez-Rodriguez *et al*., 2018).

Climate Data

Precipitation and temperature data have been obtained from NASA POWER (Data Access Viewer) for 30 years period i.e., from 1990 to 2020. Mann-Kendall test have been used to analyze the climate data. The hypothesis included in the test are, Ho: There is no trend in the data and H_A: There is trend in the data.

Risk Assessment

The increase or decrease of risk depends on the level of exposure to hazard and the extent to which the system is vulnerable. For assessing the risk in the study area, key climate variables need to be identified. The identification of impact thresholds for risk can be analyzed by stakeholder consultation. It will help in gaining different perspective from various stakeholders from various sectors. Risk is then analyzed and evaluated and then feedbacks are identified. Risk assessment is essential to identify future possible risks and reduce existing risk affecting both ecosystem and human health. In some cases, risk is directly exposed to system and sometimes its hidden.

Change in climate and increase in climate extremes might raise the level of risk. Such risks, developing from climate change or climate extremes can cause extreme disasters and might reach a threshold level, returning from which might be very difficult. These disasters might lead to loss of life, infrastructure and natural resources. The impact of risk on a system or an individual depends on its adaptive capacity, sensitivity and the extent to which it is exposed. Identifying risk at the earlier stage would be helpful in developing adaptation strategies, solutions for mitigation and framing an effective policy.

Land cover classification

To observe the change in land cover in Manas National Park, land cover classification was carried out. Satellite images for the years 1995 and 2020 were taken under study for the month of November. The data for land cover classification have been obtained from USGS. Both Landsat-7 and Landsat-8 satellite imagery have been used. Classification was carried out in QGIS to observe whether there has been increase or decrease in the woodland and grassland and change in the course of the river. This would reflect the impact of climate change, disasters and the level of risk of the study area. Increase or decrease in the green cover would indicate the vulnerability level of the area and sensitivity of the ecosystem.

RESULTS

Stakeholder assessment and Expert's perception

In the current study, the stakeholders that were consulted were the officials from the Forest Department and the community residing there. The questionnaire was framed in their local language and then translated to English for analysis. Their perspectives based on sub-Himalayan grasslands, variation in temperature and rainfall, various native species and invasive species were taken into account. The information obtained from the questionnaire were helpful in understanding the risks and vulnerabilities of grassland ecosystem and different climatic factors that would increase the risk of such ecosystem. Vulnerability assessment was also carried out. The stakeholders were asked about the change in temperature and rainfall within 10 to 20 years in the study region and it was found that 56% of the stakeholders have observed change in the temperature and 60% of the stakeholders have observed change in the rainfall. It was observed that flood, drought and temperature extremes are the key climatic hazards which impacts the wildlife and their habitat.

Another survey was carried out, which included the inputs from the experts. The experts were from academic (professors, scientists, research scholars and post graduate students) and developmental organizations (project officers, landscape coordinator and project associates). The consultation was carried out by distributing online survey similar to the survey distributed to the stakeholders. Consulting with the experts was helpful in knowing the possible threats and risks that sub-Himalayan grasslands and its ecosystem would be exposed due to change in climate. It was found that 66.2% of the experts agreed that flood is likely to impact the sub-Himalayan grasslands, followed by heatwave, which accounts for 54.4% of the experts. 91.2% agree that climate extremes will have impact on the grassland ecosystem. Variation and intensity of rainfall patterns might be the possible reason for such impact. Change in climate might affect the temperature and precipitation period or intensity. This would also impact the rivers and their tributaries which might cause severe floods. It was also observed that climate change would impact the hydrological cycle and 59% of the experts say that it has very high possibilities.

Rainfall and temperature trend

The precipitation data have been divided into winter rainfall, pre-monsoon rainfall, monsoon rainfall, and post-monsoon rainfall. Also, for temperature, it has been divided into winter temperature, pre-monsoon temperature, monsoon temperature, and post-monsoon temperature. Similarly, maximum and minimum temperatures have been divided. Significant increasing trends have been observed in Monsoon rainfall (p-value = 0.035). No significant trend has been observed in case of winter rainfall, pre-monsoon rainfall, and post monsoon rainfall. Although, slight decreasing trend has been observed in winter rainfall and pre-monsoon rainfall. Significant increasing trend has been observed in post-monsoon temperature and winter temperature. No significant trend has been observed for pre-monsoon and monsoon temperatures. In case of maximum temperature, significant increasing trend have been observed during post monsoon but no significant trend has been observed for winter, pre-monsoon and monsoon. In case of minimum temperature, significant increasing trend have been observed for winter, pre-monsoon, monsoon and post-monsoon.

Land cover classification

On the basis of the availability of data, two study period (1995 and 2020) have been selected. Land cover classification was carried out and Figure 1 and Figure 2 were obtained. Comparing both the figures, where dark green signifies woodland and light green signifies grassland, it can be observed that woodland have increased over the years and grassland have decreased gradually. On the other hand, changes were also observed in the Manas River. Increase in the area of the river have been observed and braided river pattern have been observed. Since ground truthing was not carried out, satellite images were used to observe the changes in the area of the river. LANDSAT 7 data was used to obtain the image for the year 1995 and LANDSAT 8 data was used to obtain the image for the year 2020. From the satellite imageries differences in the river area can be observed (Figure 3 & Figure 4).

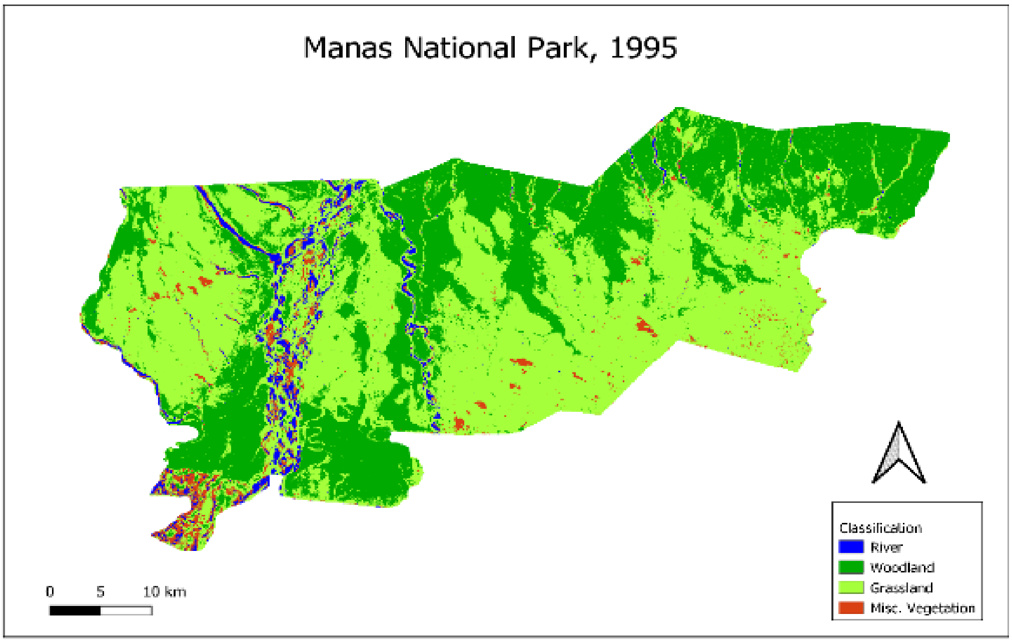

Figure 1 Classification of Manas National Park for the year 1995

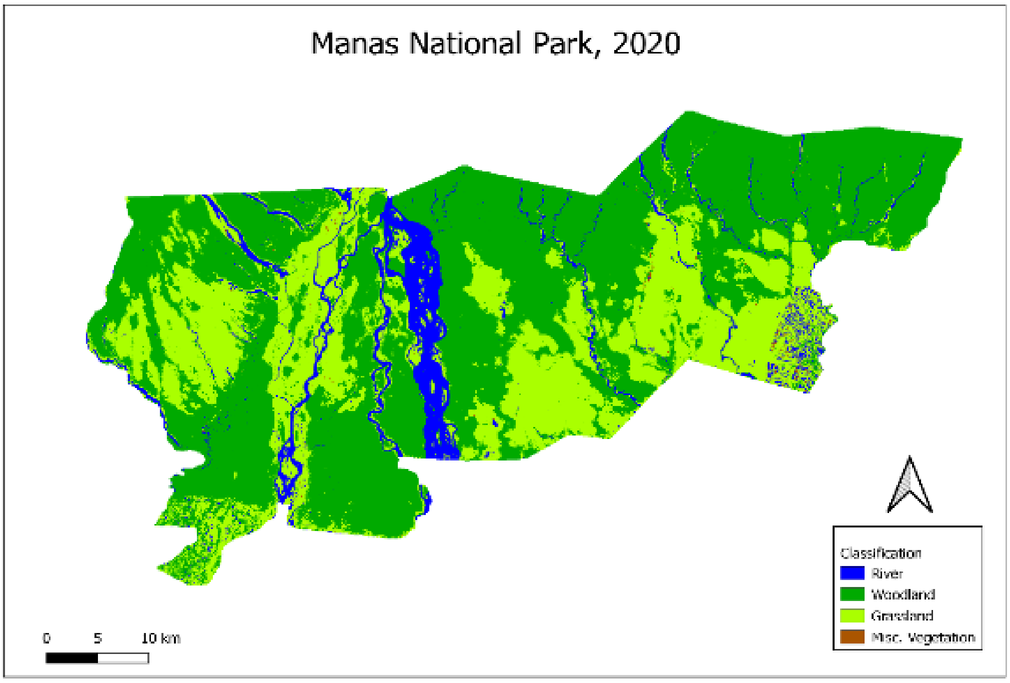

Figure 2 Classification of Manas National Park for the year 2020

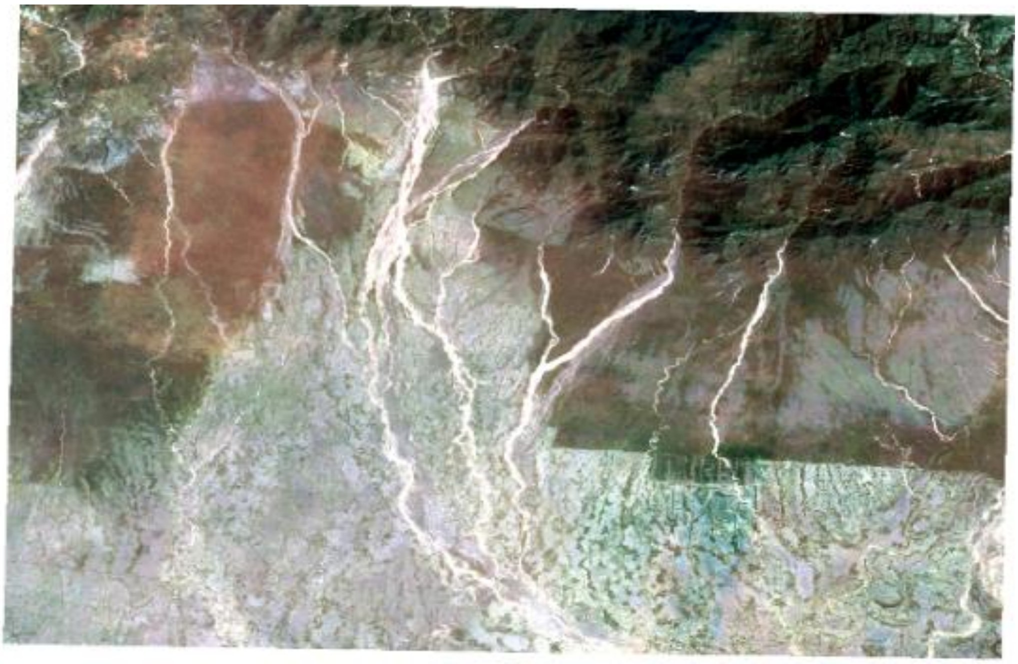

Figure 3 Satellite imagery for the year 1995

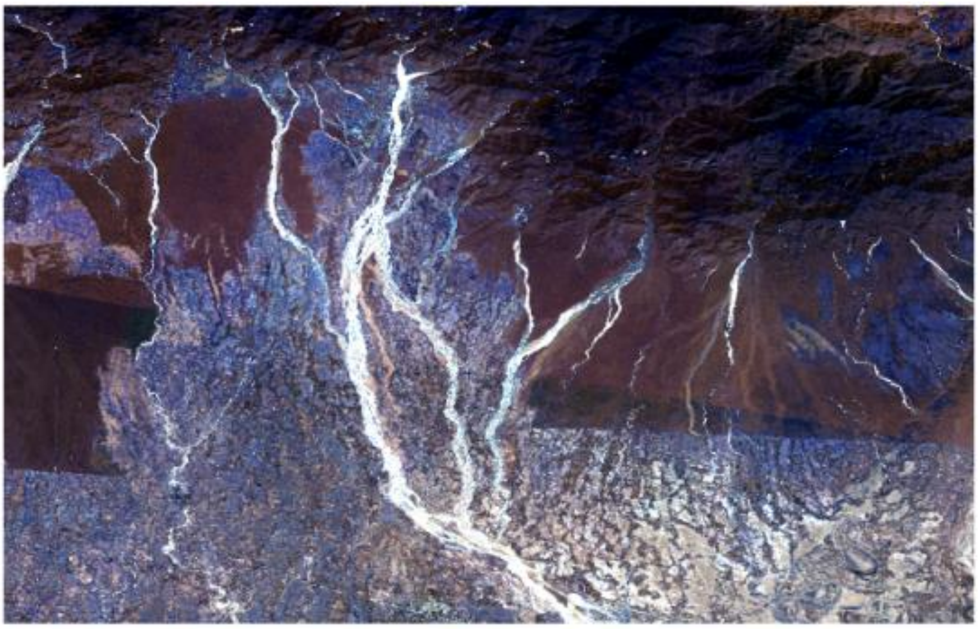

Figure 4 Satellite imagery for the year 2020

The analysis was done using the semi-automatic classification plugin with maximum likelihood estimation for the year 1995 and 2020 respectively. The area of river was found to be increased from 2.8326 % (1995) to 7.0365 % (2020).

DISCUSSION

The observed trend on rainfall and temperature obtained from the Indian Meteorological Department (IMD) indicates that for Western Assam, most of the districts are experiencing both maximum dry days and maximum heavy rainfall days. The Chirang and Baksa districts falls in both the categories. So, the Manas National Park, which falls in the Chirang-Baksa region have been experiencing both extreme weather events. Also, from the calculated rainfall values, significant monsoon rainfall trend was observed. Both the observed and calculated data showed similarities. This might indicate that the study area has high possibility of experiencing frequent extreme weather events. This might increase the flood events and increase the risk of the region. The stakeholder's consultation was contributing factor in understanding the risk factors that might increase the vulnerability of the river. Comparing the inputs from the expert's survey with the stakeholder's, it was found that both have agreed on the likelihood of the sub-Himalayan grassland being affected by flood. Changes have also been observed in the Manas River in case of its area. Cloudbursts and flash floods might cause such changes in the river. Also, the Kurichu hydro-electric project in Bhutan had major impact on the river. Due to excess release of water from the dam, the forest and the landmass of the Manas National Park were washed away (Bora, 2018). It also changed the course of the Manas River. This might contribute to the change in the river which can be observed from the satellite image. The braiding pattern in the river might increase the sediments.

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REFERENCES

Bora, J. 2018. Climate change and its effect on hydrology and threat to biodiversity: A study on Manas River (Upper part) and the Manas National Park, Assam, India BT-Urban Ecology, Water Quality and Climate Change.

Conservation Outlook Assessment, 2020.

Das, D. *et al*. 2019. Predicting the distribution and abundance of invasive plant species in a sub-tropical woodland-grassland ecosystem in northeastern India.

DebRoy, S. 1991. Manas- A Monograph.

Goswami, R. *et al*. 2011. Conservation amidst political unrest: the case of Manas National Park, Misuse of scientometry for individual assessment.

Guhathakurta, P. *et al*. 2020. Observed Rainfall Variability and Changes Over Assam State. Indian Meteorological Department (IMD), Pune.

Jain, S.K. *et al*. 2016. Trend analysis of rainfall and temperature data for India.

Krishnan, R. et al. 2020. Assessment of Climate Change over the Indian Region.

Kumar, V. *et al*. 2011. Trends in rainfall amount and number of rainy days in river basins of India (1951–2004).

Ravindranath, N. H., *et al*. 2011. Climate change vulnerability profiles for North East India.

Sanchez-Rodriguez, A.R. *et al*. 2018. Extreme flood events at higher temperatures exacerbate the loss of soil functionality and trace gas emissions in grassland, Soil Biology and Biochemistry.

Sarma, P. K. *et al*. 2008. Land-use and land-cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data. Current Science, 95(2), pp. 223–227.

The Hindu. 2016. https://www.thehindu.com/sci-tech/energy-and-environment/Melting-Himalayan-glaciers-to-have-varying-impact-on-river-basins/article16245342.ece

IMPACT OF AMD OF OPEN CAST COALMINES ON FISHES OF SIMSANG RIVER, GARO HILLS; MEGHALAYA USING GENOTOXICITY BIOMARKERS IN CHANNA PUNCTATA (BLOCH)

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ABSTRACT

The present investigation deals with the studies on genotoxic and mutagenic potential of Acid Mine Drainage (AMD) of open caste coal mines on *Channa punctata* (Bloch) of Simsang River, Meghalaya, India. *Channa punctata* (Bloch) were collected from three different sites of the river in various seasons and blood samples were processed for micronuclei test and comet assay as genotoxic biomarkers. A significant ($p < 0.05$) high micronuclei induction, nuclear abnormalities and percent of tail DNA was recorded in the specimen collected from affected site.

Keywords: Acid mine drainage, *Channa punctata*, Simsang, Meghalaya.

INTRODUCTION

The coal deposits in Meghalaya, India along the southern fringe of Shillong plateau are distributed in Khasi, Garo and Jaintia hills (Singh, 1988). East Garo Hill region is a major producer of coal, and coal excavation is commonly done by primitive mining method known as 'rat-hole' mining (Singh, 1988). Coal mining activities in East Garo Hills is posing serious threats to the fish and fisheries of Simsang River, the longest River of Garo Hills, Meghalaya, India (Sarma *et al*., 2009). The large number of coal mine quarries in Garo Hills, Meghalaya drains Acid Mine Drainage (AMD) directly into the Simsang River as well as dumping of coal for auction on its bank are posing threat to the biota of the river. Excessive accumulation of AMD due to open cast coal mines of the region since 1980's has altered some area of the Simsang River making it devoid of aquatic organism seasonally (Talukdar *et al*., 2015). AMD streams generally contain low pH, a more diverse blend of toxic metals (e.g., Al, Fe, Mn, Zn, Cu, Ar, Pb) higher conductivity and higher sulphate concentrations (Grippo and Dunson, 1996).High metal concentration in the coal mining areas may lead to its bioaccumulation in fish tissue which leads to fish mortality (Canil and Alay, 1998).

River water near the coalmining area receives huge amounts of AMD waste derived directly or indirectly from the atmospheric deposition of airborne emissions and hence be contaminated with complex, ill-defined mixtures of chemicals. Trucks which are used to transport coal may affect air and water quality of the some of the sites of river. Most freshwater organisms will be exposed, to varying degrees, to this contamination and little is known about whether or not species are adversely affected by the chemicals present in their environment (Sumpter, 2009).

Fishes are genetic models for the evaluation of pollution in aquatic ecosystems (Mitchell and enned, 1992; Park *et al*., 1993). Micronucleus assays have emerged as one of the preferred methods for assessing chromosome (Fenech, 2008). Moreover, erythrocyte micronucleus test has been used to monitor aquatic pollutants displaying mutagenic features which give quick results with little suffering on the part of the organisms used in bio monitoring (De *et al*., 1993; Minissi *et al*., 1996). The formation of nuclear abnormalities (NA), apart from micronuclei formation, in fish cells exposed to genotoxic substances have also been reported by Cavas and Ergene-Gozukara, 2005. These abnormalities are considered to be indicators of genotoxic damage, and therefore they may complement micronucleus scoring in routine genotoxicity surveys (Toni *et al*., 2009). The comet assay or single cell gel electrophoresis has also found wide application as a simple and sensitive method for evaluating DNA damage in fish exposed to various xenobiotics in the aquatic environment (Dhawan *et al*., 2009; Frenzillli *et al*., 2009).

In the present investigation an effort has been made to verify the potential of AMD of coal mine as a genotoxic agent which drains into the Simsang River by comet assay, calculating micronucleus frequency and other nuclear abnormalities in *Channa punctata*.

MATERIALS AND METHODS

Study area, sampling and fish species

The River Simsang of Garo Hills Meghalaya, India receives a huge amount of AMD from coal mining operated in the area since 1980. The location of sampling stations is shown in Fig. 1. Water sample were collected from river during winter; Nov. 2014, pre-monsoon; Feb. 2015 and monsoon; April 2015 at three locations, i.e., near Rombagre; S_1 (longitude $90^{0}34^{/}21^{//}$E & latitude $25^{0}32^{/}41^{//}$N) free from coal mining activities and was used as the reference site. The two other sites were Near Siju; S_2 (longitude $90^{0}45^{/}22^{//}$E & latitude $25^{0}23^{/}46^{//}$N) where maximum coal mining activities are practiced (Figure 2) in the hills of the vicinity and Baghmara; S_3, (longitude $90^{0}37^{/}9^{//}$E & latitude $25^{0}12^{/}1^{//}$N) where coal dumping activities are found at the bank of the river in the downstream. The specimens of test species *Channa punctata* (Bloch) were collected from the affected sites and processed for comet assay and micronuclei test.

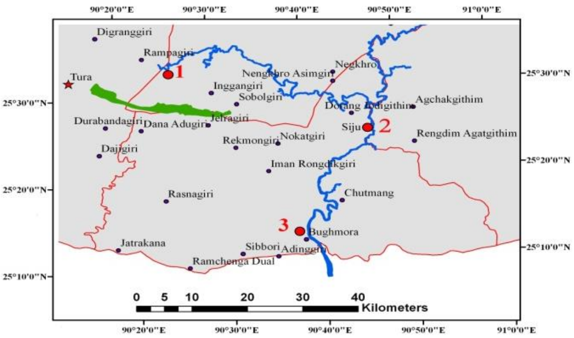

Fig 1 Geographical location of the three sampling areas in Simsang River

For control, *Channa punctata* (Bloch) 17.47±2.21 g (mean± SD) was obtained from a local fish farm from Kamrup rural district, Assam. The procured fish specimens were subjected to prophylactic treatment at the laboratory by immersing them in 0.05% $KMnO_4$ solution for 1 min to avoid any dermal infections. Prior to experiments, the fishes were acclimatised for about 1 month in 300 L tanks with non-chlorinated water at room temperature. During acclimatisation, the fishes were fed with commercial food every 2 days interval. For each sampling duration and control, the experiment was replicated twice.

Physico-chemical characteristics of water sample

Immediately after collection, water samples were analysed to determine pH, salinity, dissolved oxygen (DO), free carbon-di-oxide (FCO2) and sulphate followed after APHA 2005. For heavy metal estimation water samples were collected in clean bottles from the three sampling sites and acidified with 1% of concentrated nitric acid (HNO_3) analyzed according to the standards of APHA. Analysis of heavy metal concentrations (lead, chromium, copper, nickel, iron and zinc) were quantified using Atomic Absorption Spectrophotometer (Varian SpectrAA-220 AAS). Respective WHO 2008 values were taken as reference to compare.

Experimental procedure

On each of the sampling day, about 5 ml of peripheral blood was collected from caudal vein of each test specimens (n=5) using heparinised 1 ml disposable syringes and transferred to 1 ml eppendorf tube containing EDTA for study of micronucleus and other nuclear abnormalities, and for single cell gel electrophoresis assay (comet assay) kidney tissues were placed in 450 µl of chilled Ca and Mg free phosphate buffer saline (PBS).

Micronucleus test- Prepared blood smeared was fixed with methanol for 10 min and stained with 8 % Giemsa in phosphate buffer. Micronuclei and other anomalies in erythrocytes were detected by analyzing slides in 1000X magnification in Leica make bright field microscope (DM3000). In each fish, 1000 erythrocytes have scrutinised. Micronuclei were considered as small inclusions of nuclear material inside erythrocytic cytoplasm characterised by round or oval shaped with a flat and well-defined outline, coloration similar to that of the main nucleus and a size from 1/3 to 1/20 of the main nucleus (Al-Sabti and Metcalfe, 1995). For a detailed description on nuclear abnormalities Ayllon and Garcia-Vazquez, 2000; Cavas and Ergene-Gozukara, 2003 and Cavas and Ergene-Gozukara, 2005 were followed.

Comet assay

To detect single strand breaks and alkali labile sites, Alkaline Comet assay was performed following Singh et al., 1988 with certain modifications. Microscopic slides were prepared with a thin layer of 1% (w/v) normal melting point agarose. For each slide, suspension of cells were mixed with low melting point agarose (1:10 v/v) spread on the base, covered with cover slip and allowed to solidify by placing it in refrigerator for about 10 min. When the gel gets solidified, a second layer of low melting point agarose (0.05%) was placed over it and allowed to solidify. After placing slides in lysis solution at 4 °C for 1 h in dark, subjected to electrophorese at 25 V, 300 mA for 15 min. Then the slide was neutralized, fixed in methanol and stained with ethidium bromide (20g m/L); examined under Leica Microscope (DM 3000) at 400x magnification.

The extent of DNA damage was quantified by the length of DNA migration in 100 randomly selected and non-overlapping cells. The DNA damage quantified by visual classification of cells into five categories 'comets' corresponding to the tail length: undamaged, Type 0; low-level damage, Type 1; medium-level damage, Type 2; high-level damage, Type 3 and complete damage, Type 4, as demonstrated in Figure 3 following Anderson 1994. The extent of DNA damage has been expressed as the mean percentage of cells with medium, high and complete damaged DNA, which has calculated as the sum of cells with damage Types II, III and IV (Palus et al., 1999). From the arbitrary values assigned to the different categories (from Type 0 = 0 to Type IV = 4), a genetic damage index (GDI) was calculated for each subject (Pitarque, 1999).

Data analysis

One-way analysis of variance (ANOVA) was used to compare the micronuclei frequency and GDI between the three sites. All analysis was carried out using Statistical Package of the Social Sciences (SPSS) VERSION 18.0. The p value < 0.05 were considered statistically significant.

RESULTS

Physico-chemical characteristics of water samples

The physico-chemical parameters of water from the three sampling sites found to be highly fluctuated (Table 1). The low pH, DO and, relatively high level of sulphates and few heavy metals were observed in site 2. The heavy metals Fe, Pb, Ni, Mn and Zn were detected above the permissible limit in site 2 and high concentration was detected in monsoon season. The site 1 and 3 showed lower concentrations of heavy metals than the permissible levels established by WHO guidelines.

Table 1. Physico-chemical characteristics of river water samples collected from different sites of Simsang River.

Sampling period	Sampling site	Temp	pH	DO	FCO2	Sulphate	Fe	Ni	Pb	Mn	Cd	Zn	Cr
Winter	S1	21	7.8	8.6	2.6	45	0.05	0.005	0.004	0.017	0.001	0.009	0.009
	S2	23	5.2	4.6	10.5	190	3.6	0.08	0.003	0.39	0.025	2.88	0.056
	S3	24.5	7.2	6.5	3.4	87	0.39	0.007	0.006	0.092	0.002	0.197	0.004
Premonsoon	S1	24	7.9	9.2	3	33	0.06	0.003	0.007	0.034	ND	0.022	0.004
	S2	25	5.6	5.3	10	139	2.3	0.02	0.065	0.267	0.009	1.933	0.029
	S3	27.9	7.2	7.8	4.2	30	0.07	0.006	0.009	0.011	0.001	0.931	0.018
Monsoon	S1	23.7	7.2	8.2	4	23	0.11	0.002	0.021	0.02	0.001	0.052	0.001
	S2	25.6	4.6	4.8	24	270	7.17	0.09	0.234	0.875	0.081	5.14	0.068
	S3	28	6.8	6.7	4	97	0.13	0.005	0.029	0.119	0.009	0.069	0.013

DO, FCO_2 and sulphates are expressed in mg /L, temperature as (°C), Fe, Ni, Pb, Mn, Cd, Zn and Cr as µg /L. (ND-not detected)

Micronuclei induction

Micronuclei and nuclear abnormalities such as binuclei, lobbed nuclei, notched nuclei and blebbed nuclei have been observed in the erythrocytes of the specimen collected from the AMD discharge site (Fig 2). In effluent discharge site, the micronuclei frequency was significantly higher in monsoon compared to other seasons. The micronuclei frequency in specimens from site 2 was significantly different from that of the other two sites (Table 2). The micronuclei frequency in the specimens from site 1 and laboratory acclimatized specimens was almost identical. A similar trend was observed in the frequency of nuclear abnormalities which was higher in monsoon at AMD discharge site compared to other two seasons. Amongst the abnormalities observed, lobbed nuclei were the most frequent.

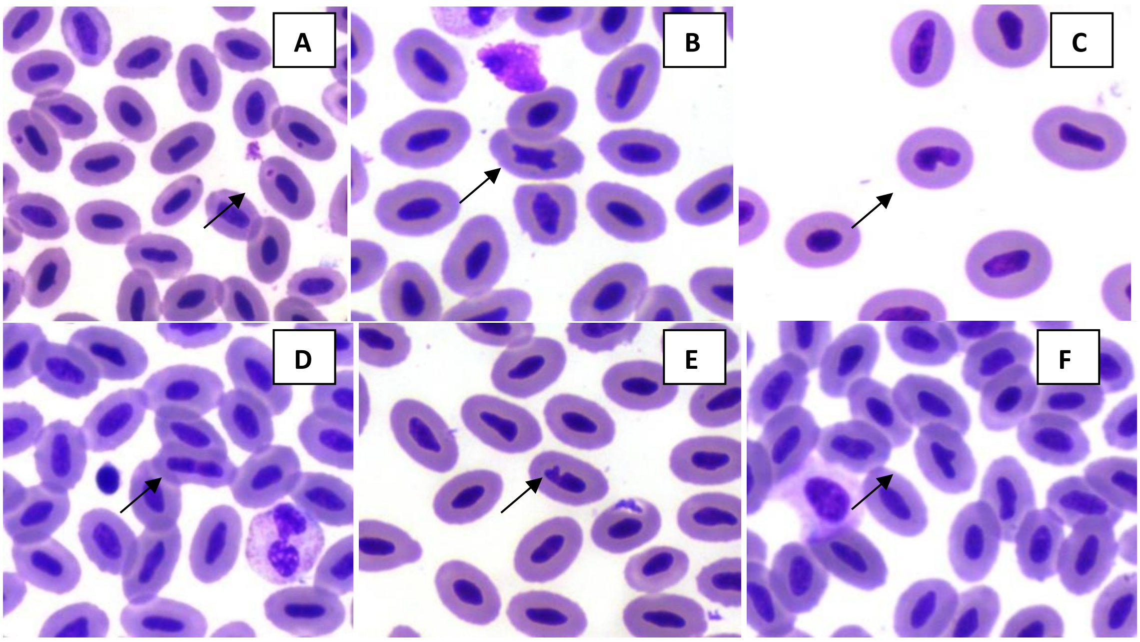

Fig 2- Photomicrograph of erythrocyte of *Channa punctata* with micronuclei **(A)** and with other nuclear abnormalities: lobed nuclei **(B)**; notched nuclei **(C)**; binuclei nuclei **(D)**;blebbed nuclei; **(E)**; **(F)**

Table2. Average Frequency of micronuclei and nuclear abnormalities in peripheral blood erythrocytes of *Channa punctata* collected from different sites of Simsang River. (MN-micronuclei, NA-other nuclear abnormalities)

Sampling period	**Sites**	**MN (1000 cells)**		**NA (1000 cells)**	
Winter	Control	0.1±0.28		7.4±2.28	
	Site 1	0.1±1.18		11.3±0.76	
	Site 2	5.2±.83*		48±1.18*	
	Site 3	1.1±1.48		21±3.22	
Premonsoon	Control	0.1±0.86		4.4±1.24	
	Site 1	.2±.45		8.3±0.76	
	Site 2	3.1±.46*		38±3.12*	
	Site 3	1.2±.47		31±3.58*	
Monsoon	Control	0.2±0.26		8.3±1.94	
	Site 1	0.3±1.22		18±2.80	
	Site 2	6.2±0.83*		68±2.36*	
	Site 3	1.6±.54		37.5±4.22*	

Superscripts (*) show statistical significant ($P < 0.05$)

DNA damage. The extent of DNA damage of the specimens of site 2 was higher as compared to site 1 and 3 (Table 3). During monsoon season, higher DNA damage was recorded compared to the other two seasons (Fig 3). The specimens collected from AMD discharge site (site 2) exhibit significantly (p <0.05) higher DNA damage compared to control.

Table 3. Damage index estimated by the comet assay (mean ± standard deviation) in kidney tissues of *Channa punctata* collected from different sites of Simsang River in different

Sampling Periods	**Sites**	**Comet assay (100 cells analysed for each fish)**					**% of damaged cells (II+III+IV)**	**GDI**
		Comet class						
		Type 0	**Type I**	**Type II**	**Type III**	**Type IV**		
Winter	Control	95	4	1	0	0	1± 0.59	0.06± 0.06
	Site 1	88	9	2	0	1	3 ± 0.09	0.17 ± 0.02
	Site 2	69	10	9	7	5	21 ± 1.70*	0.69 ± 0.04*
	Site 3	81	14	2	1	2	5 ± 0.09	0.29 ± 0.02
Premonsoon	Control	93	3	4	0	0	4± 0.89	0.11± 0.09
	Site 1	94	4	1	0	1	2 ± 0.09	0.1 ± 0.05

Sampling Periods	Sites	Comet assay (100 cells analysed for each fish)					% of damaged cells (II+III+IV)	GDI
		Comet class						
		Type 0	Type I	Type II	Type III	Type IV		
	Site 2	65	19	6	3	7	16 ± 2.21*	0.68 ± 0.01*
	Site 3	77	10	11	1	1	13 ± 1.19	0.39 ± 0.03
Moonson	Control	91	5	4	0	0	4± 0.22	0.13± 0.16
	Site 1	86	9	3	1	1	5 ± 0.09	0.22 ± 0.02
	Site 2	10	39	31	14	6	51 ± 2.75*	1.67 ± 0.04*
	Site 3	53	23	17	5	2	24 ± 1.82	0.8 ± 0.22

Superscripts (*) show statistical significant ($P < 0.05$)

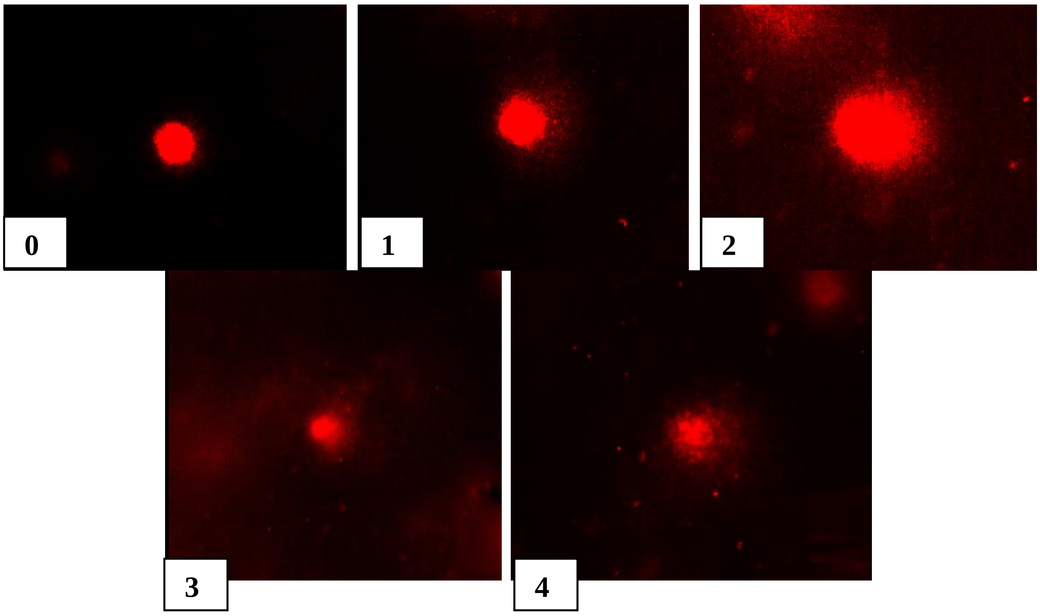

Fig 3. Classification of the comet formations in kidney tissues of fish *Channa punctata*. Type 0; no damage, Type 1; low-level damage, Type 2; medium-level damage, Type 3; high-level damage, and Type 4; complete damage.

DISCUSSION

Among other organisms, fishes accumulate pollutants either directly from polluted water or indirectly by intake of contaminated aquatic organisms during the process of food chain and consequently threatened the entire ecosystem (Olaifa *et al.*, 2004;.Farkas *et al.*, 2002) In this present investigation we analysed some of the heavy metal present in the water body along with the genotoxic and mutagenic effects of AMD mixed water in the fresh water fish *C. punctata* inhabiting the water body.

Erythrocyte micronucleus is a powerful monitoring tool for detecting genotoxic agents in coastal environment and micronuclei frequencies proved to be very reliable for testing genotoxicity studies in situ and in vitro but nuclear abnormalities are not good indicators for genotoxicity evaluation in field studies compared to laboratory condition (Toni *et al.*, 2009). Micronucleus assay in fish genome is a sensitive monitor for aquatic pollution (Ali and El-Shehawi, 1991). It is worth mentioning that the mechanisms of formation of these nuclear abnormalities are not yet fully understood (Çavas and Ergene-Gözükara, 2003). The results of studies with micronuclei frequency and nuclear abnormalities demonstrate their effectiveness as genotoxicity markers mainly in fresh water fishes in field condition as well as in the laboratory under controlled conditions which is supported by many author (Çavas and Ergene-Gözükara, 2005; Ayllon and Garcia, 2000).

A significant higher micronuclei frequencies and nuclear abnormalities observed in water contaminated with the AMD indicate genotoxic effects of some of the heavy metals present in the coal mine effluents released into the river. Other nuclear abnormalities observed in the erythrocytes of specimens from the AMD released site reveal the extent of heavy metal pollution in the site which is concurrent to earlier studies (Pacheco and Santos, 19977; Metcalfe, C.D. 1988).

Similarly, comet assay showed a higher DNA damage in the specimens collected from AMD discharge site. This results clearly indicates that presence of certain of the heavy metals in that habitat, mainly accumulated from the AMD, induced DNA damage similar to the other genotoxic observation (Frenzillli *et al*., 2009). Moreover, seasonal variation in the induction of micronuclei and DNA damage was observed i.e., higher in monsoon compared to winter and pre-monsoon with similar investigations by earlier researchers (Andrade *et al*., 2004 Scalon *et al*., 2013).

The present investigation has demonstrated that the river Simsang is polluted by the AMD from nearby coal fields of Garo Hills. Significant results with regard to micronuclei and comet tail length observed in *Channa punctata* have shown that AMD of coal mines has a genotoxic effect on the fish population.

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REFERENCES

Ali, F., El-Shehawi, A. M., & Seehy, M. A. (2008). Micronucleus test in fish genome: A sensitive monitor for aquatic pollution. *African journal of biotechnology*, *7*(5).

Ali, F.A. & El-Shehawi, A.M. (1991). Estimation of Water Pollution by Genetic Biomarkers. In: Al-Sabti, K Handbook of Genotoxic Effects and Fish Chromosomes. Jozef Stefan Institute, Jamova.

Al-Sabti, K., & Metcalfe, C. D. (1995). Fish micronuclei for assessing genotoxicity in water. *Mutation Research/Genetic Toxicology*, *343*(2-3), 121-135.

Anderson, D. Y. T. W., Yu, T. W., Phillips, B. J., & Schmezer, P. (1994). The effect of various antioxidants and other modifying agents on oxygen-radical-generated DNA damage in human lymphocytes in the COMET assay. *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*, *307*(1), 261-271.

APHA, W. (2005). Standard Method for the Examination of Water and Wastewater 21st Edition. *Methods for the Examinations of Waters and Associated Materials General Principles of Sampling and Accuracy of Results*.

Ayllon, F., & Garcia-Vazquez, E. (2000). Induction of micronuclei and other nuclear abnormalities in European minnow Phoxinus and mollie Poecilia latipinna: an assessment of the fish micronucleus test. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *467*(2), 177-186.

Canli, M. A. Y. O., Ay, Ö., & Kalay, M. (1998). Levels of Heavy Metals (Cd, Pb, Cu, Cr and Ni) in Tissue of Cyprinus carpio, Barbus capitoand Chondrostoma regiumfrom the Seyhan River, Turkey. *Turkish journal of zoology*, *22*(2), 149-158.

Çavaş, T., & Ergene-Gözükara, S. (2003). Micronuclei, nuclear lesions and interphase silver-stained nucleolar organizer regions (AgNORs) as cyto-genotoxicity indicators in Oreochromis niloticus exposed to textile mill effluent. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *538*(1-2), 81-91.

Çavaş, T., & Ergene-Gözükara, S. (2005). Induction of micronuclei and nuclear abnormalities in Oreochromis niloticus following exposure to petroleum refinery and chromium processing plant effluents. *Aquatic Toxicology*, *74*(3), 264-271.

De Flora, S., Vigano, L., D'agostini, F., Camoirano, A., Bagnasco, M., Bennicelli, C., ... & Arillo, A. (1993). Multiple genotoxicity biomarkers in fish exposed in situ to polluted river water. *Mutation Research/Genetic Toxicology*, *319*(3), 167-177.

Dhawan, A., Bajpayee, M., & Parmar, D. (2009). Comet assay: a reliable tool for the assessment of DNA damage in different models. *Cell biology and toxicology*, *25*(1), 5-32.

Farkas, A., Salanki, J., & Specziar, A. (2002). Relation between growth and the heavy metal concentration in organs of bream Abramis brama L. populating Lake Balaton. *Archives of environmental contamination and toxicology*, *43*(2), 236-243.

Fenech, M. (2008). The micronucleus assay determination of chromosomal level DNA damage. In *Environmental genomics* (pp. 185-216). Humana Press.

Frenzilli, G. I. A. D. A., Nigro, M. A. R. C. O., & Lyons, B. P. (2009). The Comet assay for the evaluation of genotoxic impact in aquatic environments. Mutation research/reviews in mutation research, 681(1), 80-92.

Galindo, T. P., & Moreira, L. M. (2009). Evaluation of genotoxicity using the micronucleus assay and nuclear abnormalities in the tropical sea fish Bathygobius soporator (Valenciennes, 1837)(Teleostei, Gobiidae). *Genetics and molecular biology*, *32*, 394-398.

Grippo, R. S., & Dunson, W. A. (1996). The body ion loss biomarker. 1. Interactions between trace metals and low pH in reconstituted coal mine-polluted water. *Environmental Toxicology and Chemistry: An International Journal*, *15*(11), 1955-1963.

Metcalfe, C. D. (1988). Induction of micronuclei and nuclear abnormalities in the erythrocytes of mudminnows (Umbra limi) and brown bullheads (Ictalurus nebulosus). *Bull. Environ. Contam. Toxicol.;(United States)*, *40*(4).

Minissi, S., Ciccotti, E., & Rizzoni, M. (1996). Micronucleus test in erythrocytes of Barbus plebejus (Teleostei, Pisces) from two natural environments: a bioassay for the in situ detection of mutagens in freshwater. *Mutation Research/Genetic Toxicology*, *367*(4), 245-251.

Mitchell, S. H., & Kennedy, S. (1992). Tissue concentrations of organochlorine compounds in common seals from the coast of Northern Ireland. *Science of the Total Environment*, *115*(1-2), 163-177.

Olaifa, F. E., Olaifa, A. K., & Onwude, T. E. (2004). Lethal and sub-lethal effects of copper to the African catfish (Clarias gariepinus) juveniles. *African Journal of Biomedical Research*, *7*(2).

Pacheco, M., & Santos, M. A. (1999). Biochemical and genotoxic responses of adult eel (Anguilla anguillaL.) to resin acids and pulp mill effluent: laboratory and field experiments. *Ecotoxicology and Environmental Safety*, *42*(1), 81-93.

Palus, J., Dziubałtowska, E., & Rydzyński, K. (1999). DNA damage detected by the comet assay in the white blood cells of workers in a wooden furniture plant. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *444*(1), 61-74.

Park, E. H., Lee, J. S., Yi, A. K., & Etoh, H. (1989). Fish cell line (ULF-23HU) derived from the fin of the central mudminnow (Umbra limi): suitable characteristics for clastogenicity assay. *In vitro cellular & developmental biology*, *25*(11), 987-994.

Pitarque, M., Creus, A., Marcos, R., Hughes, J. A., & Anderson, D. (1999). Examination of various biomarkers measuring genotoxic endpoints from Barcelona airport personnel. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *440*(2), 195-204.

Sarma, D., Mahanta, P. C., Sarma, D., & Dutta, A. (2009). Coalmines degraded Ichthyofaunal Diversity of Simsang River, Meghalaya. A report on climate change. *Bulletin no-15. Published by Directorate of Coldwater Fisheries Research (Indian Council of Agricultural Research). Bhimtal, Nainital*..

Scalon, M., Rechenmacher, C., Siebel, A. M., Kayser, M. L., Rodrigues, M. T., Maluf, S. W., ... & Basso da Silva, L. (2013). Genotoxic potential and physicochemical parameters of Sinos River, southern Brazil. *The Scientific World Journal*, *2013*.

Singh, G. (1988). Impact of coal mining on mine water quality. *International journal of mine water*, 7(3) 49-59.

Singh, N. P., McCoy, M. T., Tice, R. R., & Schneider, E. L. (1988). A simple technique for quantitation of low levels of DNA damage in individual cells. *Experimental cell research*, *175*(1), 184-191.

Sumpter, J. P. (2009). Protecting aquatic organisms from chemicals: the harsh realities. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *367*(1904), 3877-3894.

Talukdar, B., Basumatary, S., Kalita, H. K., Baishya, R. A., Dutta, A., Srivastava, S. K., & Sarma, D. (2015). Histopathological alternations in liver and kidney of Tor (Ham) inhabited in coal mining affected areas of Simsang River, Garohills; Meghalaya. *National Academy Science Letters*, *38*(4), 321-324.

World Health Organization, WHO., & World Health Organisation Staff. (2004). *Guidelines for drinking-water quality* (Vol. 1). World Health Organization.

SESSION 3: OPPORTUNITY AND TOOLS FOR LIVELIHOODS AND SUSTAINABLE MANAGEMENT

POTENTIAL OF FROG FARMING IN NORTH EAST INDIA FOR SUSTAINABLE DEVELOPMENT vis-à-vis BIODIVERSITY CONSERVATION

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ABSTRACT

Spread over two biodiversity hotspots, the North Eastern Region of India is home to diverse ethnic communities which depend upon wild harvests to sustain a part of their nutritional and medicinal requirements. These communities are reported to harvest at least 17 species of frog species from the wild. This includes two endemic and one vulnerable species; and only three species are accorded some sort of legal protections. As such, there exists an opportunity for potential frog farming in the Region which, if undertaken under the legal frameworks, can address the dietary requirements of the local tribes, which will in turn reduce the pressure on wild population. The frog farming if undertaken in concerted manner can also address a number of targets highlighted in the NBT, ABT and UN's SDGs. The pertinent requirements for such frog farming would include inventorisation of the species consumed for selecting potential species, knowledge on their breeding and feeding behaviours and framework for certification of produce.

Keywords Northeast India, biodiversity hotspot, indigenous communities, frog culture, sustainable development goals

INTRODUCTION

The North Eastern Region of India has a rich biodiversity as well as ethnic communities, possibly the former contributing to the diverseness of the later; as it is widely accepted that that environment including biodiversity is known to influence the amplification of genetic diversity leading to speciation (Dillon, 1970; Gilbert, 2005). These ethnic communities live very proximally with the nature beginning from their birth till death. Biodiversity components are ingrained in their various activities like rituals, culture, food, fodder, shelter, medicine and similar others. A large part of their dietary intake is met from the wild including wild vegetables and game. While hunting and consumption of wild animals, especially higher vertebrates is legally prohibited, through both national and international regulations; however, there are no such restrictions on or very marginal protection for amphibians, particularly frogs. There is ample evidence that the indigenous communities of North Eastern India consume different species of frogs as a source of protein as well as for medicinal purposes (Borah *et al*., 2002; Narzary & Bordoloi, 2014; Talukdar & Sengupta, 2020; Talukdar *et al*., 2020; Hussain & Tynsong, 2021). One can also witness the selling of frogs, both fresh and dried, in different markets in the hill areas of the Region: indicating the demand and supply of the item, a pre-requisite for a successful business opportunity.

Amphibians are cold-blooded animals; most of the species spent at least a part of their life in water. The North Eastern Region including the NERAQ project areas has one of the highest diversities of about 163 species of amphibians in the country (*see* Frost, 2021) which is next only to highest diversity of 252 species known from the Western Ghats (Dahanukar & Molur, 2021) another biodiversity hotspot in the country. Because of the high diversity and its abundance in the region, the local communities might have found an easy source of delicacy and protein in the amphibians. Even though there is relatively less legal protection for amphibians, the present traditional and unregulated continuous and unsustainable extraction of frogs from the wild is neither wise nor justified. Because every species has an ecological role and still some species are of aesthetic and conservation importance. For instance, the Indian Gliding Frog, *Pterorana khare* is consumed in Nagaland (Kiyasetuo & Khare, 1986) but it is a vulnerable species under criteria B1ab(iii) of IUCN (Dutta *et al*, 2004). So, this is an issue of concern and needs to be addressed immediately.

Herein, we argue that a regulated and scientific frog farming, *in-situ* and/or *ex-situ* depending on the species and habitat are practically feasible in North East India. This will be in tune with a number of India's National Biodiversity Targets and Aichi Biodiversity Targets under the CBD and realization of the 2030 agenda for Sustainable Development Goals (SDG) of striking a balance between human well-being and development priorities and addressing global societal challenges. A preliminary model of the prospective frog farming in North East

India is proposed for critical deliberation by all stakeholders.

MATERIAL AND METHODS

The present analysis has been carried out based on literature review. A preliminary review of existing information on the consumption of frogs for different purposes like food, medicine, rituals etc.by the different ethnic communities of the northeastern region particularly the four NERAQ project states namely Assam, Manipur, Meghalaya and Nagaland were carried out. Validity of the reported species was ascertained based on present taxonomic knowledge of the taxon. Both National as well as International legal protection status of the species was worked out as per the provisions of Wildlife Protection Act (1972) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Conservation status is based on IUCN assessment.

RESULTS AND DISCUSSION

A preliminary scrutiny of the literature available in the public domain revealed that as many as 17 species of frogs are consumed by the ethnic tribes of the four states of northeast India namely Assam, Manipur, Meghalaya and Nagaland mainly for as food and medicine (Table 1). Out of the 17 species, 15 species are solely used as food while *Hoplobatrachus tigerinus* is used as food as well as for medicine; while *Duttaphrynus melanostictus* is used only for medicinal purposes by the Bodo tribe of Assam (Narzary & Bordoloi, 2014). Maximum consumption of 14 species was observed in the state of Nagaland.

Of 17 species, two species, namely *Euphlyctis hexadactylus* & *Hoplobatrachus tigerinus* enjoy both national/international legal protection under the WPA and CITES respectively while another species, *Hoplobatrachus crassus* has national legal protection under the WPA (Saikia & Sinha, 2022). This somehow gives us the impression that commercial frog farming can be undertaken in a sustainable manner for some species provided these are not rare, endangered, threatened and endemic from the conservation point of view. As per the latest IUCN conservation status, nine out of 17 species are least concerned. Of the 17 species, conservation data of two are deficient while conservation statuses of three species are yet to be evaluated. Only one species, ***Pterorana khare*** is vulnerable, so its consumption is not desirable. Further, among these frogs, two species, namely, *Euphlyctis ghoshi* and *Xenophrys flavipunctata* are endemic to Northeast India (*see* Frost, 2021). Any unabated consumption of endemic species like these may lead to severe decline of the already limited populations which may lead to eventual extinction. Taking cognizant of the endemicity and vulnerability, any commercial *ex-situ* frog farming should only focus on those species which are abundantly available in the wild.

With the current delineation of *Euphlyctis cyanophlyctis* range from South India to eastern coast of India by Dinesh *et al*. (2021), the previous reports of *E. cyanophlyctis* from Northeast India (Ahmed et al., 2009; Mathew & Sen, 2010; Frost, 2021) is referable to *E. kalasgramensis.* Similarly, the report of *E. hexadactylus* from Assam and *E. ghoshi* from Nagaland are probably erroneous, as both the species are not known to occur from these range (*see* Frost, 2021).

Table 1 List of frogs consumed in North East India. (LC-Least Concern, DD-Data deficient, NE-Not evaluated, VU-Vulnerable). * Probable misidentification

SN	Species	Uses	States	CITES	WPA	IUCN (Version 2021-3)
1	*Duttaphrynus melanostictus*	Medicine	Assam			LC
2	*Euphlyctis cyanophlyctis**	Food	Assam, Nagaland			LC
3	*Euphlyctis ghoshi**	Food	Nagaland			DD
4	*E. hexadactylus**	Food	Assam	Appendix II	Sch IV	LC
5	*Minervarya teraiensis*	Food	Nagaland			LC
6	*Hoplobatrachus crassus*	Food	Nagaland		Sch IV	LC
7	*H. tigerinus*	Food/ Medicine	NERAQ states	Appendix II	Sch IV	LC
8	*H. litoralis*	Food	Nagaland			NE
10	*Xenophrys major*	Food	Nagaland			LC
11	*X. flavipunctata*	Food	Nagaland			NE
12	*Odorrana mawphlangensis*	Food	Meghalaya			DD
13	*Amolops* spp.	Food	NERAQ states			_
14	*Pterorana khare*	Food	Nagaland			VU

SN	Species	Uses	States	CITES	WPA	IUCN (Version 2021-3)
15	*Polypedates teraiensis*	Food	Nagaland			NE
16	*Rhacophorus bipunctatus*	Food	Nagaland, Meghalaya			LC
17	*Zhangixalus smaragdinus*	Food	Nagaland			LC

Based on our findings, it is safe to assume that there exists a pressure on the natural populations of frogs, including legally protected species, from unsustainable wild harvest. As such, controlled frog farming in Northeast India has a potential of not just providing dietary requirements for the local tribes but to reduce the pressure on the wild populations of frogs from unsustainable wild harvest. Further, this will also help in preventing the local communities from landing into any legal complications for consumptions of wild species.

India is a signatory of the Convention on Biological Diversity (CBD), and to comply with the provisions of the global treaty, India has setup a few ambitious but achievable National Biodiversity Targets (NBTs). The proposed frog farming, if undertaken in a concerted manner, will contribute to achieving a few of the NBTs goals (No. 1, 7, 8 & 11). This will also address a number of Aichi Biodiversity Targets (No. 1, 4, 6, 13, 14 &18) and realization of a couple of the Sustainable Development Goals (SDGs) of the United Nations particularly, no poverty (SDG 1), no hunger (SDG 2) and good health and well-being (SDG 3) of vulnerable and marginalized sections of the society while fulfilling the criteria of responsible consumption and production (SDG 12).

Any ideal model for frog farming will require acquaintance with the current legal provisions, conservation and distribution statuses accorded to the targeted species. For that, a detailed taxonomic identity of the frog species consumed in the region needs to be studied. Such study will lead to the inventorisation of the dataset on edible frogs of the region, which will aid in selecting the potential species for farming. Another study imperative to frog farming will be the knowledge on their breeding and feeding behaviours, which will help in R&D for developing induced breeding techniques/protocols. Lastly, to comply with the legal frameworks, a licensing and certification of the farming produce will be needed to differentiate it from wild harvested frogs in the market.

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REFERENCES

Ahmed, M. F., Das, A., and Dutta, S. K. (2009). Amphibians and Reptiles of Northeast India. A Photographic Guide. Guwahati, India: *Aaranyak*. Pp 168.

Borah, M. M., Bordoloi, S. & Borkotoky, A. (2002). Ethnozoological findings of Amphibian fauna of Arunachal Pradesh, India. *Frogleg*, 1(2), 1-2.

Dahanukar, N., & Molur, S. (2020). JoTT Checklist of amphibians of the Western Ghats (v1.0), 01 January 2020. https://threatenedtaxa.org/index.php/JoTT/checklists/amphibians/westernghats.

Dillon, L. S. (1970). Speciation and changing environment. *Am. Zoologist*, 10, 27-39.

Dinesh, K. P., Channakeshavamurthy, B. H., Deepak, P, Ghosh, A. K., & Deuti, K. (2021). Morphological groupings within *Euphlyctis* (Anura: Dicroglossidae) and description of a new species from the surroundings of Thattekad Bird Sanctuary, Kerala, India. *Zootaxa*, 4990, 329–353 (https://doi.org/10.11646/zootaxa.4990.2.7).

Dutta, S., Sengupta, S. &Bordoloi, S. (2004). *Pterorana khare*. *The IUCN Red List of Threatened Species* 2004: e.T58488A11776771. https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T58488A11776771.en. Acces sed on 28 January 2022.

Gilbert, S. F. (2005). Mechanisms for the environmental regulation of gene expression: Ecological aspects of animal development. *J. Biosci*., 30, 65–74.

Frost, D. R. (2021). Amphibian Species of the World: an Online Reference. Version 6.1 (*27.09.2021*). Electronic Database accessible at https://amphibiansoftheworld.amnh.org/index.php. American Museum of Natural History, New York, USA. doi.org/10.5531/db.vz.0001

Hussain, J. F. & Tynsong, H. (2021). Ethno-zoological study of animals-based medicine used by traditional healers of North-east India. *Asian J. Ethnobiol*., 4(1), 1-21.
Kiyasetuo & Khare, M. M. (1986). A new genus of frog (Anura: Ranidae) from Nagaland at the northeastern hills of India. *Asian J. Exp. Sci*., 1, 12-17.
Mathew, R., & Sen, N. (2010). Pictorial guide to the amphibians of North East India. (Published by the Director*, Zoological Survey of India,* Kolkata: 1–144.
Narzary, J. & Bordoloi, S. (2014). Ethnozoological practices on frogs of Bodo tribe from Kokrajhar district, Assam, India. *Am. J. Ethnomed*., 1 (6), 368-370.
Saikia, B., & Sinha, B. (2022). Amphibians need legal protection, *Current Science*, 122 (1), 9-10.
Talukdar, S. & Sengupta, S. (2020). Edible frog species of Nagaland. *J. Environ. Biol*., 41, 927-930.
Talukdar, S, Sengupta, S., Konyak K., Shunyei & Rizwan, M. (2020). Cooking methods and medicinal uses of frog species among the Naga tribes in Dimapur. *World News of Natural Sciences*, 30(2), 144-149.

STUDIES ON COMPARATIVE GROWTH OF TUBIFEX WORMS GROWN IN DIFFERENT CULTURE MEDIA AND OBSERVING THE CHANGE IN THE GROWTH OF ANABAS TESTUDINEUS FED ON TUBIFEX

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ABSTRACT

Tubifex sp. is one of the best and cheapest live feed for fish, prawns and frogs. It has been an important live feed in rearing the larvae of hatchery produced catfishes, prawns, ornamental fishes etc. They are considered as one of the nutritious foods for fish as they contain high food value. The purpose of this study was to find out a suitable nutrient media containing simple culture ingredients in which maximum growth of *Tubifex* worms was observed. These worms grown in different culture mediums were further tested on the larval stage of *Anabas testudineus* so as to observe the change in growth and colour of the fish. Results of this study suggested that biomass of *Tubifex* was maximum when grown on culture media having 2% Fish Meal, 2% Soymeal, 42% Mud, 42% Cow dung, 8% Rice bran, and 4% Mustard oil cake(Culture medium III). ANOVA test results indicated that there was significant difference in mean total calculated productions among the three different media. Statistical analysis showed that the standing biomass of *Tubifex* worms was significantly higher ($P<0.05$) in Culture medium-III than those of I and II throughout the experiment. Feeding the worms grown in Culture medium III on larval offsprings of *Anabas* showed contrasting results in colour too.

Keywords Fishmeal, Mustard oil cake, Rice bran, Soymeal, *Tubifex*

INTRODUCTION

The field of aquaculture is expanding tremendously. With this expansion farmers are in need of an alternative source of feed that is low in cost and cheap to produce. The use of tubificid worms as a live food for juveniles has been long practised in farmers' fields (Mandal *et al.* 2018). *Tubifex* worm is an important food item to freshwater intensive aquaculture throughout the world because of its high calorific value (Mandal *et al.* 2018). Tubifex or tubificid worms are aquatic invertebrates that reside mostly in old canals, sewage and drains in towns where there is a steady and continuous flow of water and where large amounts of organic detritus are present. They are very small reddish worms having a length of 3-4 cm (Mellanby, 1953; Jordan and Verma, 1978). It has been reported to be an important live feed in rearing the larvae of hatchery producing catfishes, prawns, ornamental fishes etc. (Hossain *et al.* 2011). The demand of these worms is considerably high for people who rear fish in aquariums. Some hatcheries also use these worms to certain extent for larvae nursing purposes. They are considered as one of the nutritious foods for fish as they contain high food value of 5,575 Cal/g dry weight (Giere and Pfannkuche, 1982).

There have been few reports of attempts taken to develop a technique for tubificid worm culture. Therefore, finding a suitable culture media with the least optimal cost as well as having rich nutritional composition for culturing these worms was felt important.

MATERIALS AND METHODS

Collection of worms and culture system setup

Parent tubificid worms (*Tubifex tubifex*) were collected and the experiments were carried out in Aquaculture and Biodiversity Centre, SAP, DIST under Zoology Dept. Gauhati University, Guwahati, Assam. Continuous flow of water was used to clean the worms after collection. The experiments were conducted from February 2019 to June 2020. The worms were cultured in a small cement raceway culture system ($100 \times 30 \times 10$ cm^3) properly covered with a roof above so as to protect them from sunlight and rain (Fig 1).

Preparation of culture media

The experimental variable was water for five culture durations (30, 45, 60, 70 and 90 days) (Table 1). The substrate was filled up with mud in all the experimental treatments. Cow dung was mixed with mud for Culture medium III. This substrate was wetted with continuous flow of water for a period of 6-7 days. The media ingredients were mixed thoroughly by hand and spread over the raceways. Water flows from the tap were adjusted accordingly before inoculation of worms into the raceway.

Spreading of worms

Worms were spread homogeneously in each raceway at a density of 250 mg/cm^2 (i.e., 25 g/raceway).

Homogenous spreading of culture media

After inoculation of worms culture media were spread evenly throughout each raceway at a density of 500 mg/cm^2. The flow of water was stopped while spreading of culture media. This activity of spreading culture media was carried out every day for a period of 10 days initially and after that at a week interval time. Media supply was done during the morning hours between 9-10 a.m.

Water parameter check

Continuous water was supplied with the help of taps already fitted above the raceways. Water parameters were measured every 15 days by collecting water from the outlet the help of YSI Pro DSS Multiparameter water quality meter.

Sampling

Samples were collected on 30, 45, 60, 70, and 90th day of inoculation of worms. The worms were collected by a sampler (5×5 cm^2) from two particular places within each raceway (which were specially marked with small sticks at a square length of 5 cm). The worms were then cleaned under flowing water. The worms were then dried with blotting paper and weighed in High Precision Balance (SCALE-TEC Model: SAB-203).

Estimation of cost of media production

The cost of media ingredients used in production of 1 kg worms was determined in Indian RUPEES. The price of 1 kg Fishmeal, Soymeal, Ricebran, Mustard oil cake and Cow dung were 110, 90, 30, 29 and 5 Rs respectively. No cost was associated with mud. Total media requirements per culture medium up to 90 day was determined as follows; Initial media supply + periodic media supply (mg/cm^2)×area (cm^2)× frequency of media supply.

Use of statistical analysis

Data were analysed by using ANOVA in Microsoft Excel sheet software. Data were presented as Mean±SD and analysed by using the same statistical sheet software with the level of significance at $p<0.05$.

Test fish species

To check the acceptance rate of *T. tubifex* worms by aquarium fishes and to observe any physiological changes, these worms grown in different culture mediums were fed on the larval offspring of *Anabas testudineus*. *T. tubifex* worms were fed twice a day and regular body weight of the fish was taken at the interval of 10 days.

RESULTS

The standing biomass of *T. tubifex* worms during the 90 days experimental period in three different culture media are presented in Table 2 and Graph I. The average standing biomass of tubificid worms on the 70th experimental day were 504±1.26, 456±0.98, 856±1.48 mg/cm^2 in Culture media-I, II and III respectively. The standing biomass in the three Culture media under study on the 90th day of culture is shown in Figure 2. One-way-ANOVA test results indicate that there is significant difference in mean total calculated productions among the three different Culture media (Table III). Statistical analysis showed that the standing biomass of tubificid worms is significantly higher ($P<0.05$) in Culture media-III than those of I and II throughout the experiment.

The effect of *T. tubifex* worm grown in three different culture media and noticeable changes in growth have been shown in Table V and Graph II. The data shows that during the 120 days period of feeding on *T. tubifex* worms, fishes body mass increases with increasing time intervals quite in a similar manner in all of the three culture media, the difference was found to be almost nil. But greater colour variation wad observed in fishes fed on worms grown in Culture media-III. Colour was found to be prominent and long lasting in case of *Anabas* fed on *T. tubifex* worms grown in Culture medium-III (Fig 3). Although fish fed on worms grown in the other two culture media developed colour but that did not last till broodstock period. During the experiment, temperature, dissolved oxygen and pH of water of the raceways were suitable ranging from 24.7 - 27.8°C, 7.0 - 7.5 ppm and 6.5 - 7.5 respectively.

DISCUSSION

Marian and Pandian (1984) and Ahamed and Mollah (1992) reported the highest yield of 200mg/cm^2 and 419.4 mg/cm^2 at 70th day culture. In the current study, the highest standing biomass 856±1.48 mg/cm^2 was found in Culture media-III on the 70th experimental day where the presence of nutrient medium was highest along with cow dung as a mineral rich component compared to the other media. This is significantly higher than those reported above may be due to the suitability of the nutrient supply for better growth and proliferation of the worms. The lower yield reported in the previous study by Ahamed and Mollah (1992) in a medium of 35% WB, 25% CD, 20% MOC and 20% sand could be due to the absence of required protein medium such as fishmeal (FM) as well as soymeal (SM) rendering it as a less suitable culture medium. Use of 60% nutrient medium (FM plus SM in the present study along with the use of cow dung) could have provided the required level of nutrients for growth and propagation. According to Hossain, Mollah and Hassan (2011) the highest yield (678.62±11.50mg/cm^2) of worms was found by using 30% SM treatment. In the current study yield of 456±0.98 mg/cm^2 was obtained by using 7% SM only. In all of the treatments a gradual increase in standing biomass of tubificid worms was found up to the 70th experimental day followed by a decrease in biomass up to the end of the experimental periods (90th day). Statistical analysis by one way-ANOVA showed that there is no significant difference (P<0.05) in production between Culture media-I and II. Ahamed and Mollah (1992) stated that 2.85 kg raw materials were required for 1 kg worm production against 18 kg and 25 kg cow-dung reported by Marian and Pandian (1984) and Marian *et al.* (1989) respectively. The present study showed that the lowest media ingredients for producing 1 kg worms were in Treatment-I and II which required only 2 kg raw materials valued 67.34 Rs only (Table 3). The lowest cost incurred for producing 1 kg worms was that in Culture medium III, producing maximum biomass which proved the superiority of media for the production of tubificid worms compared to the previous ones (Table 3).

The highest worm yield was found on 70th day of culture (Graph I). From this it can be inferred that up to this period the maximum utilization of nutrients from these media ingredients took place for proper growth. Culturing the worms for less than 70 days is not optimal and commercially not viable because low period harvest will result in a smaller yield, while a longer culture period will increase the culture cost. According to Mariom and Mollah (2012), culture duration of 70 days is optimum for the production of tubificid worms. The decline in production after 70 days could be due to the decreased carrying capacity of the culture medium.

CONCLUSION

Findings of the above study indicate that the nutrient medium comprising of all of the essential media (Fishmeal + Soymeal + Cow dung) proved to be the most beneficial medium for harvesting tubificid worms on a larger scale in terms of biomass. Further biochemical analysis of the *T. tubifex* worms cultured in Culture medium-III too revealed that it contains significantly high nutrient composition compared to that grown in the other two treatments. Comparison of harvesting *T. tubifex* worms using the two separate nutrient mediums (FM and SM) produced little significant difference in biomass as well as biochemical properties of the worms. But taking the two treatments together along with cow dung (as taken in Culture medium–III) as a nutrient media, the results were significantly promising than the two treatments undergone separately.

ACKNOWLEDGEMENTS

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REFERENCES

Ahamed, M.T., & Mollah, M.F.A. (1992). Effects of various levels of wheat bran and mustard oil cake in the culture media on TUBIFICID production. *Aquaculture 107*:107-113.

Giere, O., & Pfannkuche, O. (1982). Biology and ecology of marine Oligochaete, a review. In: *Oceanography and Marine Biology (ed. M. Barnes)*. pp.173-308. Aberdeen University Press.

Hossain, A., Hasan, M., & Mollah, M.F.A. (2011). Effects of soyabean meal and mustard oil cake on the production of fish live food tubificid worms in Bangladesh. *World Journal of Fish and Marine Sciences 3*:183-189.

Jordan, E.L., & Verna, R.S. (1978). Invertebrate Zoology. S. Chand and Company Ltd., Ram Hagar, New Delhi. 1018pp.

Marian, M.P., & Pandian, T.J. (1984). Culture and harvesting techniques of Tubifex tubifex. *Aquaculture 42*:303-315.

Marian, M.P., Chandran, S., & Pandian, T.J. (1989). A rack culture system for Tubifex tubifex. *Aquaculture Engineering 8*:329-337.

Mellanby, H. (1953). Animal life in freshwater. Methuen and Company Ltd. London.296pp.

Mandal, R.N., Kar, S., Chakrabarti, P.P., Chattopadhyay, D.N., Paul, B.N., Adhikari, S., Maity, J., & Pillai, B.R. (2018). Production of tubifex - a new dimension of aquaculture in feeding juvenile fish. *Aquaculture 22:*3.

Mariom, M., & Mollah, M.F.A. (2012). Development of a Suitable Culture Medium for the Production of Tubificid Worms. *Asian Fisheries Science 25*:40-51.

Mollah, M.F.A., & Ahamed, M.T. (1989). A note on preliminary study of culture of tubificid worms. *Bangladesh Journal of Fisheries 12*:91-95.

Table 1 Composition of media ingredients used in the experimental diets

Media ingredients	% in Culture medium-I	% in Culture medium-II	% in Culture medium-III
Kholihoi (mustard oil cake)	0.5 kg(7%)	0.5 kg(7%)	0.5 kg (4%)
Rice bran	1 kg(14%)	1 kg(14%)	1 kg (8%)
Cow dung	-	-	5 kg(42%)
Mud	5 kg(72%)	5 kg(72%)	5 kg(42%)
Fish meal	0.5 kg(7%)	-	0.25 kg (2%)
Soymeal	-	0.5 kg(7%)	0.25 kg (2%)

Table 2 Standing biomass (mg/cm^2) of *T.tubifex* worms in three different treatments during 90 days experimental period (mean±SD)

TREATMENTS	EXPERIMENTAL PERIODS IN DAYS				
	30	45	60	70	90
I	316±0.65	476±0.83	488±1.67	504±1.26	492±0.86
II	268±1.30	420±1.67	428±0.66	456±0.98	432±0.98
III	406.8±1.63	788±0.93	812±0.59	856±1.48	840±1.79

Table 3 Total media ingredients, price, yield and production cost per treatment at 90th day of culture

INGREDIENTS	**LEVEL OF MEDIA INGREDIENTS IN %**		
	Treatment 1	Treatment 2	Treatment 3
Fish meal(kg)	0.5 kg	-	0.25 kg
Soya meal (kg)	-	0.5 kg	0.25 kg
Rice bran	1 kg	1 kg	1 kg
Mustard oil cake	0.5 kg	0.5 kg	0.5 kg
Cowdung	-	-	5 kg
Total price of medium	99 Rs	89 Rs	144 Rs
Total yield	1.47 kg	1.29 kg	2.52 kg
Cost of producing per kg worms (Rs)	67.34 Rs	68.99 Rs	57.14 Rs
Cost of producing per kg worms ($)*	0.89 $	0.91 $	0.75 $

**currency conversion was done dated June 2021*

Table 4 Comparison of three groups of fish of same species (*Anabas testudineus*) fed on *T. tubifex* worms for a period of 120 days

Time interval (days)	initial	15	30	45	60	75	90	105	120
wt. of fish fed on *T. tubifex* (Culture medium-I & II) (gm)	0.7	1.16	1.22	1.36	1.55	1.85	2.07	2.89	3.21
Wt. Of fish fed on *T. tubifex* (Culture medium-III) (gm)	1.2	1.5	1.67	1.78	1.81	1.89	2.33	2.99	3.40

Fig 1. Setup for culture of *T.tubifex* worms

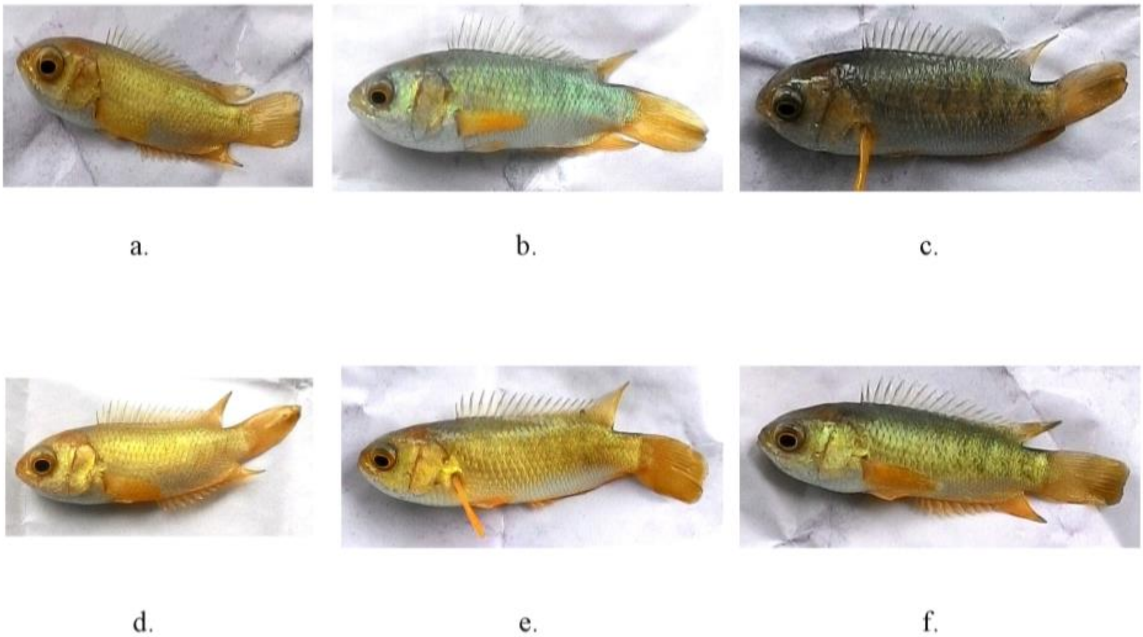
Fig 2. a *T. tubifex* worms on the 90th day of culture using Culture medium-I; **b.** *T.tubifex* worms on the 90th day of culture using Culture medium-II; **c.** *T.tubifex* worms on the 90th day of culture using Culture medium-III

a.

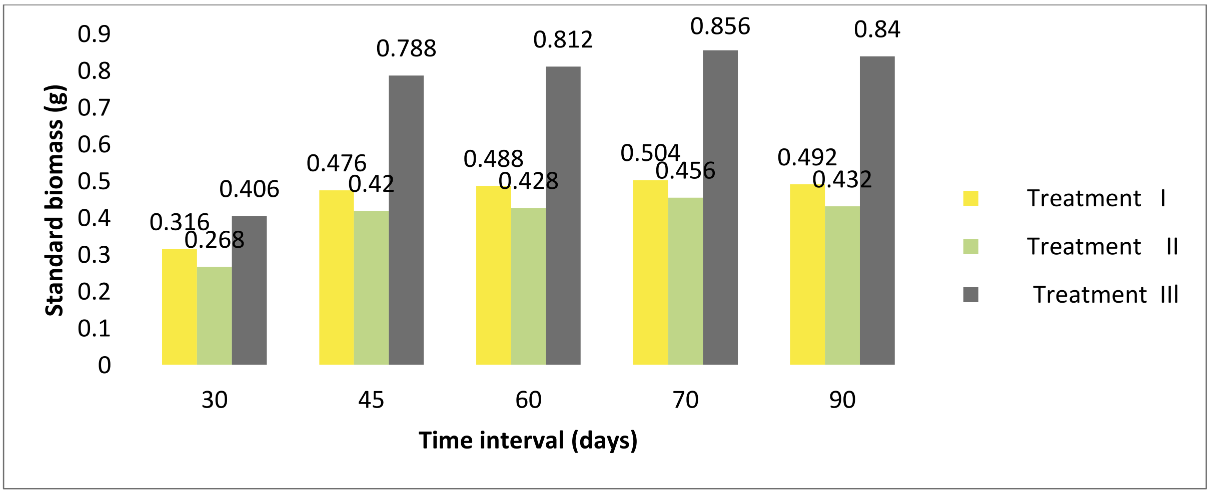
b.

c.

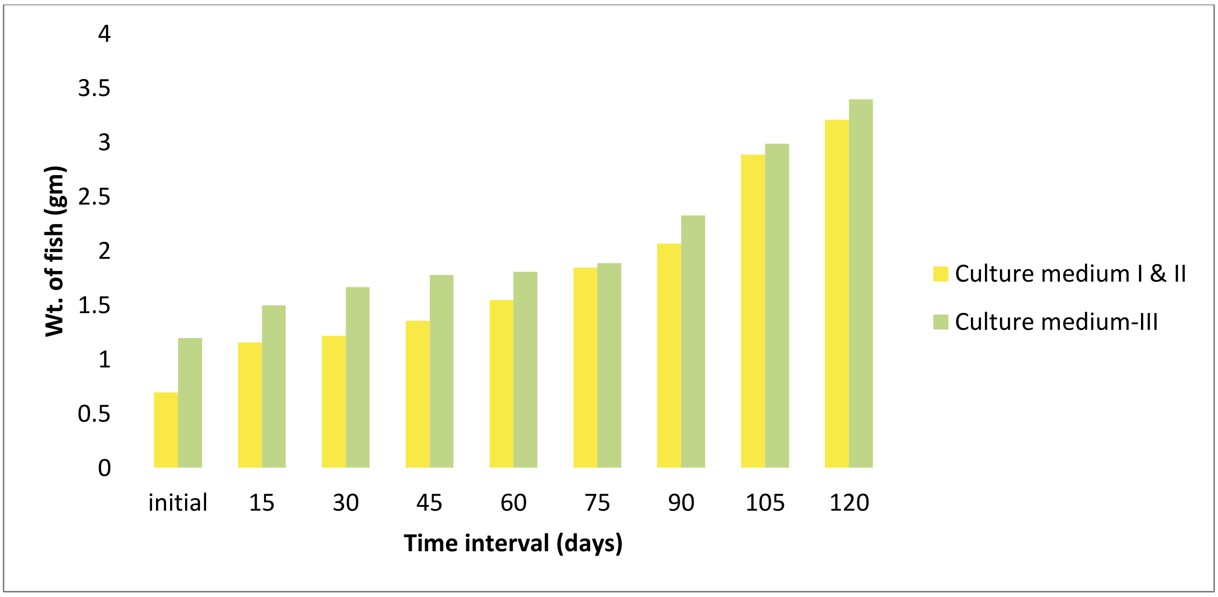
Fig 3. Fish fed on *T.tubifex* for a period of 120 days; **a,b,c-** Culture medium-I and II; **d,e,f** - Culture medium-III



Graph I Statistical graphs showing the comparative analysis of standing biomass of the three Culture media under study during a period of 90 days.



Graph II Statistical graphs showing the comparative analysis of growth of *Anabas testudineus* fed on *T. tubifex* for a period of 120 days.



4
3.5
3
2.5
2
1.5
1
0.5
0
Wt. of fish (gm)
initial
15
30
45
60
75
90
105
120
Time interval (days)
Culture medium I & II
Culture medium-III

MALACOPHAGY IN NORTH-EAST INDIA - AN INVENTORY OF THE EDIBLE FRESHWATER MOLLUSCA OF THE REGION

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ABSTRACT

The term "Malacophagy" is, perhaps, used for the first time in connection with consumption of mollusca as food by humans. In the present study, the term is used after comprehending the extensive use of mollusca, as food by the people inhabiting the North - eastern region of India. It is a known fact that many species of mollusca are relished as food by people in different parts of the world. But there is scant information on the taxonomy of the species used as food in India, particularly in the context of North-East (NE) India. Though both terrestrial and freshwater species of mollusca are consumed as food by the indigenous people of this region, the preference is more for the freshwater mollusca species, even though the diversity is comparatively lesser compared to the land molluscs. A variety of freshwater snails are consumed by the people living here. During the present investigation, it was found that a total of 49 species under 2 class, 3 orders, 5 families and 17 genera represent the edible mollusca of the NE India. Of these 49 species, 21 species under nine genera comes under Gastropoda, whereas the remaining 28 species under eight genera are edible mussels of the region. Regular freshwater mollusca markets can be found in parts of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Nagaland where these freshwater mollusca are sold as a delicacy that is relished by the local populace. There are even cultural and zoo-therapeutic practices associated with malacophagy.

Keywords: Bioresources, traditional knowledge, zoo-therapeutics, poultry feed, heliciculture

INTRODUCTION

Since time immemorial, molluscs have been used as a source of food especially by the economically weaker sections of society. Review of literature indicates that malacophagy existed since the Pleistocene and Holocene eras (Fernandez-López de Pablo *et al*., 2014) and the practice is widespread in almost all continents of the world. In India, the consumption of snails as food is found chiefly among the tribal communities living along the coastal parts of the country, those in central India and in North-Eastern region of India (Hornell, 1917; Ramakrishna & Dey, 2007, Jadhav *et al*., 2020).

North-East India consists of eight Indian States - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. The local populace comprises of more than a hundred tribal communities, each with its own traditional knowledge practises when it comes to utilising the bioresources around them for their sustenance and livelihood. As part of their traditional knowledge system, the local tribes use both terrestrial and aquatic bioresources for food. The most common aquatic bioresources utilized as food are the varieties of fishes and prawns available in the fresh waterbodies in the region. Additionally, a variety of aquatic insects, amphibians and molluscs are also sourced from these waterbodies for consumption.

The numerous wetlands or beels in the plain belts of the region coupled with the permanent ponds, lakes, rivers, streams and paddy fields provide a good natural habitat to the molluscs. The freshwater molluscs are sourced from the wild for domestic consumption and also for selling in the local markets and roadside stalls. Jadhav *et al.* (2020) documented the use of 12 species of edible mollusca by people from North-East India. Besides their work there are scant records on edible mollusc from India, in general, and NE India, in particular. Keeping in mind the economic value of molluscs as an unconventional source of easily available and cheap protein, an attempt has been made to bring out a close to complete list on the edible freshwater mollusc of North-East India to, not only highlight the rich food diversity of the people of this region, but also to bring out a document that could serve as a base for any future economic prospects utilizing these bioresources, their sustainable use and conservation.

MATERIAL AND METHODS

The present study is the outcome of various surveys conducted under different projects of the Zoological Survey of India undertaken by the Arunachal Pradesh Regional Centre, Itanagar and Northeastern Regional Centre, Shillong. Based on the collection during extensive field surveys taken up by the authors and *review of* published literatures (Theobald, W. 1875 and 1876; Preston, 1915; Subba Rao, 1989; Ramakrishna & Dey, 2007; Jadhav *et al*., 2020), an inclusive list of edible freshwaters mollusca reported from the region is presented here. The nomenclature used in this study is based on the most recent taxonomic classification as suggested by Vaught (1989), Bouchet & Rocroi (2005) and **Mollusca Base eds. (2021).** Conservation status of the species were worked out following *IUCN Red List of Threatened Species version 2021-1.*

RESULTS

During the present investigation, it was found that a total of 49 species under two classes, three orders, five families and 17 genera represent the edible mollusca of the North –East India. Of these 49 species, 21 species are Gastropods of the orders Architaenioglossa and Caenogastropoda https://www.molluscabase.org/aphia.php?p=taxdetails&id=489327, whereas the remaining 28 species are edible mussels (Bivalvia) of the order Unionida. The details of the species, along with classification, categorization in the *IUCN Red List of Threatened Species. Version 2021-1 is detailed below.*

Class : Gastropoda
Family : Ampullariidae

1. ***Genus: Pila*** Röding, 1798

Local name: *Hamuk* in Assamese, *Tharoiachuaba* in Manipuri, *Chengkawl* in Mizo, *Yafu* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Species under this genus are known by the common name Apple snail. A total of five species [*Pila olea* Reeve, 1856 , *Pila mizoramensis* Maitreya *et al*., 2021, *Pila olea* Reeve, 1856, *Pila globosa* (Swainson, 1822), *Pila theobaldi* (Hanley, 1875) and *Pila virens* (Lamarck, 1822)under the genera which were reported from Assam, Mizoram, Manipur, Meghalaya and Tripura are consumed by the people of this region, including one recently described species from Mizoram, *Pila mizoramensis*.

IUCN status: Data Deficient (DD): *Pila olea* Reeve, 1856; Least Concern (LC): *Pila globosa* (Swainson, 1822), *Pila theobaldi* (Hanley, 1875) and *Pila virens* (Lamarck, 1822);
Not Evaluated: *Pila mizoramensis* Maitreya *et al*. 2021.
Remarks: Species of this genus are consumed almost all over NE India.
Family : Pachychilidae

Genus: Brotia H. Adams, 1866

Local name: *Hamuk* in Assamese, *Laitharoi* in Manipuri, *Chengkawl* in Mizo, *Yafu* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

A single species, *Brotia costula* (Rafinesque, 1833) is reported from the entire North-East region. Since the species shows polymorphism, various forms of the species are reported throughout the region. *Brotia costula* is widely available throughout the region and is the most widely consumed species in NE India.

IUCN status: LC

Remarks: Among the Meitei communities of Manipur, there is customary practice of consuming this particular species one day ahead of Meitei New Year (lunar) which falls in March/April every year and this tradition is followed till date.

Genus: *Paracrostoma* Cossmann, 1900

Local name: *Hamuk* in Assamese, *Laitharoi* in Manipuri, *Chengkawl* in Mizo, *Yafu* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Till date a single species, *Paracrostoma huegelii* (Philippi, 1843), under this genus is reported from NE India and is earlier known by the name *Sulcospira huegeli* and *Melania huegelii*.

IUCN status: LC

Remarks: Rabha *et al*. (2014) have mentioned that this species is non-edible, but we have seen them being sold in the markets along with other edible mollusca species like *Brotia*, *Filopaludina* and *Pila* species.

Family : Paludomidae

2. **Genus: *Paludomus*** Swainson, 1840

Local name: *Hamuk* in Assamese, *Nungtharoi* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

A total of seven species under this genera of is reported from NE India, of which *Paludomus conica* (Gray, 1833); *P. blandfordiana (*Nevill, 1877); *P. ornate (*Benson, 1856); *P. regulate (*Benson, 1856); *P. crassa* (von dem Busch, 1842) and *P. pustulosa (*Annandale, 1921) are consumed as food even though the size range of these species are small

.

IUCN status: DD: *Paludomus pustulosa;* LC: *Paludomus regulata* and *Paludomus blanfordiana*; Not Evaluated: *Paludomus ornata* are *Paludomus crassa.*

Remarks: *Paludomus stephanus* (Benson, 1836) is not found to be sold in the market as they are not as commonly available as the other species, though there are indications that the species is consumed in Meghalaya.

Family : Viviparidae

3. **Genus: *Angulyagra*** Rao, 1931

Local name: *Hamuk* in Assamese, *Nungtharoi* in Manipuri, *Chengkawl*in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Two species of the genus *Angulyagra* have reported from this region. Both the species are savored specially by Meiteis and Nagas of Manipur and Nagaland, respectively.

IUCN status: LC

Remarks: *Angulyagra* species is also known for its medicinal value in Manipur, where it has been used for treating smallpox among Meitei community. The empty shell of this species is used in *Eraikhongdaibi puja* by the Meiteis. The species is also used as poultry feed in olden times but due to its decreasing availability, the species has been substituted by *Filopaludina and Cipangopaludina* species*.*

4. **Genus: *Cipangopaludina*** Hannibal, 1912

Local name: *Hamuk* in Assamese, *Laubuk tharoi* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

A single species*, Cipangopaludina lecythis* (Benson, 1836), is reported from NE India. The species is abundantly available in the paddy fields of Manipur and neighbouring States.
IUCN status: LC
Remarks: The species are used as poultry feed to increase egg production.

5. Genus: *Filopaludina* Habe, 1964

Local name: *Hamuk* in Assamese, *Tharoi* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Filopaludina species are the most common gastropods available in NE India, and the most widely consumed in the region because of their easy availability in stagnant waterbodies. Three species

[*Filopaludina crassispiralis* (Annandale, 1921), *F. miron* (Annandale, 1921) and *F. bengalensis* (Lamarck, 1822)] have been reported from the region.
IUCN status: DD: *F. crassispiralis* and *F. micron*; LC: *F. bengalensis*.
Remarks: Most widely consumed edible mollusk.

6. **Genus: *Idiopoma*** Pilsbry, 1901

Local name: *Hamuk* in Assamese, *Tharoi* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi, *Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

The genus is represented by a single species, *Idiopoma dissimilis* (Müller, 1774) of edible mollusk.
IUCN status: LC
Remarks: Sold in the markets alongside other species of the family Viviparidae.

7. **Genus: *Mekongia*** Crosse & P. Fisher, 1876

Local name: *Hamuk* in Assamese, *Tharoi* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi, *Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

The genus, like the genus *Idiopoma*, was separated from genus *Bellamya* and a single species is reported from the region, i.e., *Mekongia crassa* (Benson, 1836).
IUCN status: LC
Remarks: The species is found in the stagnant water bodies of the region along with *Filopaludina* , *Mekongia, Idiopoma and Angulyagra* and consumed by the local people along with its counterparts.

Class : Bivalvia
Order : Unionida
Family : Uniondale

8. **Genus: *Balwantia*** Prashad, 1919

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi, *Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Balwantia soleniformis (Benson, 1836) is the lone bivalve species under this genus that is reported from the region.
IUCN status: LC
Remarks: The species is consumed by the Mizos and other communities of the region and is found sold with other freshwater mussels.

Genus: *Indonaia* Prashad, 1918

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi, *Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

About nine species of *the* genus *Indonaia* have been reported from NE India viz., *Indonaia nuttalliana* (Lea, 1856), *I. andersoniana* (Nevil, 1877), *I. caerulea* (Lea, 1831), *I. involuta* (Hanley, 1856), *I. lima* (Simpson, 1900), *I. occata* (Lea, 1860), *I. olivaria* (Lea, 1831), *I. pachysoma* (Benson, 1862) and *I. theobaldi* (Preston, 1912).

IUCN status: DD: *I. nuttalliana*; LC: *I. andersoniana, I. caerulea, I. involuta*, *I. lima*, *I. occata*, *I. olivaria*, *I. pachysoma* and *I. theobaldi.*

Remarks: It is difficult to determine which of these species are more widely consumed as food by the indigenous communities of the region as a mixture of these mussels are sold in the local markets.

Genus: *Lamellidens* Simpson, 1900

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Altogether five species of the genus *Lamellidens* reported from NE India are consumed as food. They are *Lamellidens corrianus* (I. Lea, 1834), *L. generosus* (A. Gould, 1847), *L. jenkinsianus* (Benson, 1862), *L. marginalis* (Lamarck, 1819) and *L. phenchooganjensis* Preston, 1912.

IUCN status: LC
Remarks: Along with *Indonaia* species*,* these species are sold in the local market, particularly during the winter season.

9. **Genus: *Leoparreysia*** Vikhrev, Bolotov & Aksenova, 2017

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

In NE India, this genus is represented by the edible species *Leoparreysia burmana* (Blandford, 1869).
IUCN status: LC
Remarks: This species is also sold and consumed along with its counterparts in the local markets of the region.

10. **Genus: *Parreysia*** Conrad, 1853

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

Bivalves of the genus *Parreysia* are the most commonly available members of the family Unionidae, and the most widely consumed mussel sold in the local markets. Altogether, nine species of the genus represent the edible mussels of the region viz., *Parreysia annandalei* Preston, 1912, *P. corbis* (Hanley, 1856), *P. corrugate* (O.F.Müller, 1774), *P. favidens* (Benson, 1862), *P. gowhattensis* (Theobald, 1873), *P. rajahensis* (Lea, 1841), *P. sikkimensis* (Lea, 1859), *P. smaragdites* (Benson, 1862) and *P. triembola* (Benson, 1862).
IUCN status: DD: P. annandalei and P. corbis; LC: *P. corrugata*, *P. favidens*, *P. gowhattensis*, *P. rajahensis*, *P. sikkimensis*, *P. smaragdites* and *P. triembola*.
Remarks: Most widely consumed edible mussels in the region.

11. Genus: *Radiatula* C. T. Simpson, 1900

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

A single species under this genus is consumed by the local people i.e., *Radiatula bonneaudii* (Eydoux, 1838).
IUCN status: LC
Remarks: This species too is sold side by side with other bivalves.

12. Genus *Scabies* F. Haas, 1911

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

A single species under this genus, *Scabies crispata* (Gould, 1843), is sometimes found along with the common bivalves species being sold in the market.
IUCN status: LC
Remarks: Though the species is small in size, it is also consumed along with other edible mussels.

13. **Genus: *Trapezidens*** Bolotov, Vikhrev & Konopleva, 2017

Local name: *Hamuk* in Assamese, *Kongreng* in Manipuri, *Chengkawl* in Mizo, *Etcheluk* in Garo, *Mattah* in Khasi*, Jemna* in Ao, *Nula* in Angami, *Chokibo* in Sumi, *Nuna* in Chakesang and *Hamok* in Nagamese, Lotha dialects.

The single species found in the region, *Trapizidens exolescens* (Gould, 1843), is consumed in Mizoram, but is rarely seen being sold with other edible mussels in the markets.
IUCN status: LC
Remarks: Largely consumed in Mizoram.

DISCUSSION

Our current report of 49 species of edible freshwater mollusca is the first comprehensive of its kind from NE India. Though the edible mussels with 28 species are the more speciose, yet the gastropods with 21 edible species show more diversity in terms of families (with three families) and genera (nine genera). During the study it is also revealed that people preferred gastropoda species than mussels, which is reflected in the cost and abundance in the local markets. Regular freshwater mollusca markets can be found in Assam, Manipur, Meghalaya, Mizoram and Nagaland, and even some parts of Arunachal Pradesh, where they are a delicacy that are consumed with relish by the local populace. Almost all the large-sized freshwater snails are consumed by the people of NE India. *Paludomus* spp., although comparatively smaller in size, are savored with equal relish by the people of Meghalaya and Manipur. In terms of naming the edible freshwater Mollusca, Manipuri people has the most refined dialect giving name to each genera whereas other communities give a common name for all the edible freshwater mollusca.

Freshwater mollusca are commonly consumed by the tribal communities like Bodo, Mishing and Kachari of Assam, Meitei of Manipur, Garo and Khasi - Jaiñtia of Meghalaya, Mizos of Mizoram, various tribes of Nagaland, the tribal people of Tripura and few tribes of Arunachal Pradesh. The animals are harvested from the wild for consumption and sale. In the markets, the mollusks are sold mostly in measures of a mug or a can or visual estimates or lumps; rarely are they sold in weighted measures. Different communities have their own traditional recipe or method of cooking snails. Some communities remove the flesh from the shells first, and then steam the meat or make spicy curries for eating. But the most common practice is to partially remove the top whorl of the shells by breaking them and then boiling the animal. This not only facilitates penetration of the salt and condiments to enhance the taste, but also makes it easier for eating as the meat and be sucked out from the broken part of the shells.

Besides being a source of cheap protein, calcium, phosphorus, iron and zinc, the edible mollusks are also believed to have medicinal properties. However, the zoo-therapeutic use of these mollusks is out of the scope of this paper and not dealt here in detail. However, it is worthwhile to mention that traditional knowledge practices accept that the edible mollusks are beneficial for treating health problems like asthma, arthritis, joint swelling, rheumatism, tuberculosis, stomach ailments, eye irritation, diabetes, fertility enhancement, healing of wounds, etc. (Kakati & Doulo, 2002; Solank & Chutia, 2009; Hanse & Teron, 2012; Chinlampianga *et al*., 2013; Ngaomei & Singh, 2016).

Freshwater snails are harvested in bulk from the wild and so far, mollusca farming has not started in the region though there is high market demand. Though no studies on the market demand and supply of edible freshwater Mollusca have been done but steady increase in the price of the species and popularity among the local people corroborated the findings. Unfortunately, there is no control or monitoring of the mollusca population in the wild (Budha *et al*., 2010; Jadhav *et al*., 2020) putting them at risk of depletion from over-harvesting. We have noticed a decline in the populations of the edible mollusks in their natural habitat over the years. Factors like pollution of the natural water bodies, changing land use patterns leading to siltation of rivers and streams, land reclamation or encroachment through filling up of *beels* and wetlands for urbanization or housing purposes, have contributed to destruction of their natural habitats. Additionally, the impact of climate change such as prolong periods of drought, erratic rainfall patterns, etc. have led to early or prolonged drying up of *beels* and ponds resulting in interrupted development and production of natural populations of mollusks in the wild. Overharvesting could also be another contributing factor to the declining wild population. While demand for these bioresources is on the rise, their wild population is on the decline. Considering their economic importance as food, source of medicine, livestock feeds, etc., it is imperative that the supply of these bioresources be augmented through heliciculture or snail farming as a component of aquaculture. There is scope for establishing such snail farms in NE India to meet the increasing demand of the growing population of the regions and exporting the surplus to other parts of the country or abroad.

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REFERENCES

Bouchet, P. and Roroi, J. P. 2005. Classification and nomenclator of gastropod families. *Malacologia*, **47**(1-2): 1-397.

Budha, P.B., Aravind, N.A. and Daniel, B.A. 2010. The status and distribution of freshwater molluscs of the eastern Himalaya. In: *The Status and Distribution of Freshwater Biodiversity of the Eastern Himalaya* (Allen, D.J., Molur, S. and Daniel, B.A., compilers), p. 42- 53. IUCN, Cambridge, UK and Gland, Switzerland; Zoo Outreach Organisation, Coimbatore, India.

Chinlampianga, M., Singh, R. K. and Shukla, A. C. 2013. Ethnozoological diversity of Northeast India: Empirical learning with traditional knowledge holders of Mizoram and Arunachal Pradesh. *Indian Journal of Traditional Knowledge*, **12** (1): 18-30.

Fernandez-López de Pablo, J., Badal, E., Ferrer Garcia, C., Martinez-Orti, A. and Sanchis Serra, A. 2014. Land snails as a diet diversification proxy during the early upper Palaeolithic in Europe. *PLoSONE*, **9**(8): e104898.

Hanse, R. and Teron, R. 2012. Ethnozoological practices among The Karbi Tribe in Karbi Anglong District of Assam (India). In: *The EcoScan, Special Issue, Proceedings of International Conference on Anthropogenic Impact on Environment and Conservation Strategy*. ISSN: 0974 – 0376, **1**: 117-120.

Hornell, J. 1917. The edible molluscs of the Madras Presidency. *Madras Fisheries Department Bulletin*, **11**: 1-51.

Jadhav, A., Das, N. K. and Aravind, N. A. 2020. Edible freshwater mollusks from Northeast India. *Tentacle*, **28**: 3-4.

Kakati, L. N. and Doulo, V. 2002. Indigenous knowledge system of zootherapeutic use by Chakhesang tribe of Nagaland, India. *J. Hum. Ecol*., **13**(6): 419-423. DOI: 10.1080/09709274.2002.11905579.

MolluscaBase eds. 2021. MolluscaBase. Accessed at http://www.molluscabase.org

Ngaomei. G. and Singh, E. J. 2016. Traditional knowledge of therapeutic use of animals by Rongmei Tribe, Manipur, India. *Int. J. Sci. Eng. Res*., **7** (8): 1982-1991.

Preston, H.B. 1915. *The Fauna of British India, Mollusca (Freshwater gastropoda and Pelecypoda)* Taylor and Francis, London: i-xi + 1-244, text-figs. 1-29.

Rabha, H. P., Mazumdar, M. and Baruah, U. K. 2014. Habitat diversity of freshwater snail in Goalpara district, India. *Scholars Journal of Agriculture and Veterinary Sciences*, **1**(3):107-114

Ramakrishna and Day, A. 2007. *Handbook on Indian Freshwater Molluscs.* Zoological Survey of India, Kolkata. Xxiii+399 pp.

Solanki, G. S. and Chutia, P. 2009. Studies on Ethno-Medicinal Aspects and Zoo-Therapy in Tribal Communities in Arunachal Pradesh, India. Int. *J. Ecol. Environ. Sci*.,**35** (1): 67-76.

Subba Rao, N. V. 1989. *Handbook on Freshwater Molluscs of India and adjacent countries.* pp. 1-282, figs. 1-600.

Theobald, W. 1875. Descriptions of some 'new land and freshwater shells from India and Burmah. *Journal of the Asiatic Society of Bengal*, **5**: 184-189.

Theobald, W. 1876. *Catalogue of the land and freshwater shells of British India.* pp. 1-65.

Vaught, K. 1989. *A classification of the living Mollusca*, ed. R.T. Abbott and K.J. Boss. *American Malacologist, U.S.A*., pp. 1-189.

ORNAMENTAL FISH RESOURCES, THREATS AND CONSERVATION STATUS OF THE CHINDWIN AND BARAK RIVER BASINS OF MANIPUR

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ABSTRACT

The ichthyofaunal diversity of Manipur, northeast India is very high. The present study revealed the occurrence of 206 species of Ornamental fishes under 30 families and 81 genera in the Chindwin and the Barak River basins of Manipur. The family Cyprinidae has the maximum number of species followed by Nemacheilidae and Sisoridae, respectively. The paper also discussed the possible threats and conservation status of these fishes.

Keywords Diversity, Ornamental fishes, Manipur, northeast India

INTRODUCTION

Ornamental fishes are categorized based on vivid colour pattern (colourful), morphologically uniqueness (special), behaviorally charismatic (semi aggressive, community and non-community), and compatibility for domestication. Since ornamental fishes are usually kept in glass aquarium they are popularly known as "Aquarium .fishes". Ornamental fish trade is growing worldwide. India's ornamental fish trade industry saw 20% rise per annum with annual income of US$ 1.2 million (Marine Products Export Development Authority, MPEDA). Manipur, which lies in the Northeastern corner of India, comes under the Eastern Himalaya Freshwater Biodiversity hotspot has rich ichthyofaunal diversity owing to the presence of two major drainages viz., the Chindwin and the Barak River basins. The torrential hill streams of Manipur forms an ideal habitat for ornamental fishes. About 85% of all exports of ornamental fishes from India are from Northeast India including Manipur (Mahapatra *et al.* 2005). The rich Ornamental fish diversity of the Chindwin and the Barak River basins of Manipur have been studied in the present paper.

MATERIAL AND METHODS

Fishes were collected from different water bodies of the Chindwin and the Barak River basins of Manipur using electrofishing machine, nets, traps and local fishing techniques. Collections were done from May 2019 to September 2021. Fishes were preserved in 10% formalin. Before preservation, photograph of freshly collected specimens were taken whenever possible to record the colour of the specimens. Counts and measurements followed Hubbs & Lagler (1946) and Kottelat (1990) with slight modifications. The specimens are deposited in the Manipur University Museum of Fishes (MUMF). Specimens in MUMF were also examined. Conservation status was determined using IUCN Red List (2022). Published information used: Vishwanath (2021).

RESULTS

The study revealed the occurrence of 206 valid species of Ornamental fishes under 30 families and 81 genera in the Chindwin and the Barak River basins of Manipur (Table I). Maximum diversity of the species is found in the family Cyprinidae with 84 species, followed by Nemacheilidae and Sisoridae with 25 and 20 species respectively. Out of 206 species, nine species belong to the endangered category, 31 species to vulnerable category, and 14 species falls under the Near Threatened category (IUCN Red List 2022).

Table 1. Ornamental Fishes of Manipur, northeast India, their distribution and IUCN status (NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered)

Family	Species	Distribution	IUCN status	
		Barak	Chindwin	
Notopteridae	1. *Notopterus notopterus* (Pallas)	+	+	LC
Anguillidae	2. *Anguilla bengalensis* (Gray)	+	+	VU
Clupeidae	3. *Gudusia chapra* (Hamilton)	+	-	LC
	4. *Amblypharyngodon mola* (Hamilton)	+	+	LC

Family	Species	Distribution	IUCN status	
		Barak	Chindwin	
Cyprinidae	5. *Bangana dero* (Hamilton)	+	-	LC
	6. *Bangana devdevi* (Hora)	-	+	LC
	7. *Barilius barnoides* (Vinciguerra)	-	+	VU
	8. *Barilius bendelisis* (Hamilton)	+		LC
	9. *Barilius dogarsinghi* Hora	-	+	VU
	10. *Barilius lairokensis* Arunkumar & Tombi Singh	-	+	VU
	11. *Cabdio ukhrulensis* (Selim & Vishwanath)	-	+	DD
	12. *Chagunius nicholsi* (Myers)	-	+	LC
	13. *Cirrhinus cirrhosis* (Bloch)	+	+	VU
	14. *Cirrhinus reba* (Hamilton)	+	+	NE
	15. *Ctenopharyngodon idella* (Valenciennes)	+	+	NE
	16. *Cyprinus carpio* Linnaeus	+	+	NE
	17. *Danio quagga* Kullander, Liao & Fang	-	+	VU
	18. *Devario acuticephala* (Hora)	-	+	VU
	19. *Devario aequipinnatus* (McClelland)	+	-	LC
	20. *Devario deruptotalea* Ramananda & Vishwanath	-	+	LC
	21. *Devario devario* (Hamilton)			LC
	22. *Devario manipurensis* (Barman)	-	+	DD
	23. *Devario naganensis* (Chaudhuri)	-	+	VU
	24. *Devario yuensis* (Arunkumar & Tombi Singh)	-	+	VU
	25. *Esomus danrica* (Hamilton)	+	+	LC
	26. *Garra abhoyai* Hora	-	+	NE
	27. *Garra chakpiensis* Nebeshwar & Vishwanath	-	+	NE
	28. *Garra chindwinensis* Premananda *et al.*	-	+	NE
	29. *Garra chivaensis* Moyon & Arunkumar	-	+	NE
	30. *Garra compressa* Kosygin & Vishwanath	-	+	VU
	31. *Garra cornigera* Shangningam & Vishwanath	-	+	NE
	32. *Garra elongata* Vishwanath & Kosygin	-	+	DD
	33. *Garra lissorhynchus* (McClelland)	+	-	LC
	34. *Garra litanensis* Vishwanath	-	+	VU
	35. *Garra manipurensis* Vishwanath & Sarojnalini	+	-	VU
	36. *Garra naganensis* Hora	+	-	LC
	37. *Garra nambulica* Viswhwanath & Joyshree	-	+	VU
	38. *Garra namyaensis* Shangningam & Vishwanath	-	+	NE
	39. *Garra paralissorhynchus* Vishwanath & Shanta Devi	-	+	VU
	40. *Garra paratrilobata* Roni *et al.*	+	-	NE
	41. *Garra substrictorostris* Roni & Vishwanath	+	-	NE
	42. *Garra trilobata* Shangningam & Vishwanath	-	+	NE
	43. *Garra ukhrulensis* Nebeshwar & Vishwanath	-	+	NE
	44. *Gibelion catla* (Hamilton)	+	+	LC
	45. *Hypophthalmichthys molitrix* (Valenciennes)	+	+	NT

Family	Species	Distribution		IUCN status
		Barak	Chindwin	
	46. *Hypophthalmichthys nobilis* (Richardson)	+	+	DD
	47. *Hysibarbus myitkyinae* (Prasad & Mukerji)	-	+	VU
	48. *Labeo bata* (Hamilton)	+	+	LC
	49. *Labeo calbasu* (Hamilton)	+	+	LC
	50. *Labeo gonius* (Hamilton)	+	+	LC
	51. *Labeo pangusia* (Hamilton)	+	+	NT
	52. *Labeo rohita* (Hamilton)	+	+	LC
	53. *Laubuka khujairokensis* (Arunkumar)	-	+	VU
	54. *Neolissochilus hexagonolepis* (McClelland)	+	-	NT
	55. *Neolissochilus hexasticus* (McClelland)	+	-	NT
	56. *Neolissochilus paucisquamatus* (Smith)	-	+	NE
	57. *Neolissochilus stracheyi* (Day)	-	+	LC
	58. *Osteobrama belangeri* (Valenciennes)	-	+	NT
	59. *Osteobrama cotio* (Hamilton)	+	-	LC
	60. *Osteobrama cunma* (Day)	-	+	LC
	61. *Osteobrama feae* Vinciguerra	-	+	DD
	62. *Pethia ater* Linthoingambi & Vishwanath	-	+	VU
	63. *Pethia khugae* Linthoingambi & Vishwanath	-	+	VU
	64. *Pethia manipurensis* Menon *et al.*	-	+	EN
	65. *Pethia meingangbii* (Arunkumar & Tombi Singh)	-	+	NE
	66. *Pethia ornata* (Vishwanath & Laisram)	-	+	VU
	67. *Pethia stoliczkana* (Day)	-	+	LC
	68. *Pethia ticto* (Hamilton)	+	-	LC
	69. *Pethia yuensis* (Arunkumar & Tombi Singh)	-	+	VU
	70. *Poropuntius burtoni* (Mukerji)	-	+	LC
	71. *Poropuntius clavatus* (McClelland)	+	-	NT
	72. *Poropuntius shanensis* (Hora & Mukerji)	-	+	DD
	73. *Puntius chola* (Hamilton)	+	+	LC
	74. *Puntius sophore* (Hamilton)	+	+	LC
	75. *Puntius terio* (Hamilton)	+	-	LC
	76. *Raiamas guttatus* (Day)	-	+	LC
	77. *Rasbora daniconius* (Hamilton)	+	+	LC
	78. *Rasbora ornata* Vishwanath & Laisram	-	+	VU
	79. *Rasbora rasbora* (Hamilton)	+	+	LC
	80. *Salmostoma bacaila* (Hamilton)	+	-	LC
	81. *Salmostoma sladoni* (Day)	-	+	LC
	82. *Schizothorax chivae* Arunkumar & Moyon	-	+	NE
	83. *Semiplotus cirrhosis* Chaudhuri	-	+	DD
	84. *Tariqilabeo burmanicus* (Hora)	-	+	NE
	85. *Tor mosal* (Hamilton)	+	-	DD
	86. *Tor putitora* (Hamilton)	+	-	EN
	87. *Tor tor* (Hamilton)	+	-	NT
	88. *Psilorhynchus balitora* (Hamilton)	+	-	LC
	89. *Psilorhynchus chakpiensis* Shangningam & Vishwanath	-	+	NE

Family	Species	Distribution		IUCN status
		Barak	Chindwin	
Psilorhynchidae	90. *Psilorhynchus homaloptera* (Hora & Mukerji)	+	-	LC
	91. *Psilorhynchus konemi* Shangningam & Vishwanath	-	+	NE
	92. *Psilorhynchus maculatus* Shangningam & Vishwanath	-	+	NE
	93. *Psilorhynchus microphthalmus* Vishwanath & Manojkumar	-	+	EN
	94. *Psilorhynchus ngathanu* Shangningam & Vishwanath	-	+	NE
	95. *Psilorhynchus nudithoracicus* Tilak & Husain	+	-	NE
	96. *Psilorhynchus rowleyi* (Hora & Misra)	-	+	NE
Botiidae	97. *Botia dario* (Hamilton)	+	-	LC
	98. *Botia histrionica* Blyth	-	+	LC
	99. *Syncrossus berdmorei* (Blyth)	-	+	NT
Cobitidae	100. *Acantopsis spectabilis* (Blyth)	-	+	NT
	101. *Canthophrys gongota* (Hamilton)	+	-	LC
	102. *Lepidocephalichthys alkaia* Havird & Page	-	+	NE
	103. *Lepidocephalichthys annandalei* Chaudhuri	+	-	LC
	104. *Lepidocephalichthys berdmorei* (Blyth)	-	+	LC
	105. *Lepidocephalichthys guntea* (Hamilton)	+	-	LC
	106. *Lepidocephalichthys irrorata* Hora	-	+	LC
	107. *Lepidocephalichthys micropogon* (Blyth)	-	+	LC
	108. *Pangio pangia* (Hamilton)	+	+	LC
Balitoridae	109. *Balitora brucei* Gray	+	-	NT
	110. *Balitora burmanica* Hora	-	+	LC
	111. *Homalopteroides rupicola* (Prashad & Mukerji)	-	+	LC
Nemacheilidae	112. *Mustura chindwinensis* Lokeshwor & Vishwanath	-	+	NE
	113. *Mustura prashadi* (Hora)	-	+	VU
	114. *Mustura taretensis* Chinglemba *et al.*	-	+	NE
	115. *Mustura tigrina* Lokeshwor & Vishwanath	-	+	NE
	116. *Mustura tuivaiensis* Lokeshwor *et al.*	+	-	NE
	117. *Neonoemacheilus assamensis* (Menon)	+	-	NT
	118. *Neonoemacheilus morehensis* Arunkumar	-	+	DD
	119. *Neonoemacheilus peguensis* (Hora)	-	+	DD
	120. *Paracanthocobitis botia* (Hamilton)	+	-	LC
	121. *Paracanthocobitis marmorata* Singer *et al.*	-	+	NE
	122. *Paracanthocobitis linypha* Singer & Page	-	+	NE
	123. *Rhyacoschistura ferruginea* Lokeshwor & Vishwanath	+	-	NE
	124. *Rhyacoschistura manipurensis* (Chaudhuri)	-	+	NT
	125. *Schistura chindwinica* (Tilak & Hussain)	+	-	VU

Family	Species	Distribution		IUCN status
		Barak	Chindwin	
	126. *Schistura fasciata* Lokeshwor & Vishwanath	+	-	NE
	127. *Schistura kangjupkhulensis* (Hora)	-	+	EN
	128. *Schistura khugae* Vishwanath & Shanta	-	+	VU
	129. *Schistura liyaiensis* Lokeshwor & Vishwanath	+	-	NE
	130. *Schistura minuta* Vishwanath & Shanta Kumar	+	-	EN
	131. *Schistura nagaensis* (Menon)	-	+	VU
	132. *Schistura phamhringi* Shangningam *et al.*	-	+	NE
	133. *Schistura reticulata* Vishwanath & Nebeshwar	-	+	EN
	134. *Schistura rubrimaculata* Bohlen & Šlechtová	-	+	NE
	135. *Schistura sikmaiensis* (Hora)	-	+	LC
	136. *Schistura tigrina* Vishwanath & Nebeshwar	+	-	EN
Amblycipitidae	137. *Amblyceps mangois* (Hamilton)	+	-	LC
	138. *Amblyceps torrentis* Linthoingambi & Vishwanath	-	+	DD
	139. *Amblyceps tuberculatum* Linthoingambi & Vishwanath	-	+	DD
Akysidae	140. *Akysis manipurensis* (Arunkumar)	-	+	DD
	141. *Akysis prashadi* Hora	-	+	LC
Sisoridae	142. *Erethistes hara* (Hamilton)	+	-	LC
	143. *Erethistes pussilus* Muller & Troschel	+	-	LC
	144. *Exostoma barakensis* Vishwanath & Joyshree	+	-	DD
	145. *Exostoma dujanggensis* Shangningam & Kosygin	-	+	DD
	146. *Gagata cenia* (Hamilton)	+	-	LC
	147. *Gagata dolichonema* He	-	+	LC
	148. *Glyptothorax burmanicus* Prasad & Mukerji	-	+	LC
	149. *Glyptothorax cavia* (Hamilton)	+	-	LC
	150. *Glyptothorax clavatus* Rameshori & Vishwanath	+	-	NE
	151. *Glyptothorax giudikyensis* Kosygin *et al.*	+	-	NE
	152. *Glyptothorax granulus* Vishwanath & Linthoingambi	-	+	LC
	153. *Glyptothorax igniculus* Ng & Kullander	-	+	DD
	154. *Glyptothorax maceriatus* Ng & Lalramliana	+	-	NE
	155. *Glyptothorax manipurensis* Menon	+	-	VU
	156. *Glyptothorax ngapang* Vishwanath & Linthoingambi	-	+	LC
	157. *Glyptothorax senapatiensis* Premananda *et al.*	-	+	NE
	158. *Glyptothorax ventrolineatus* Vishwanath & Linthoingambi	-	+	LC
	159. *Myersglanis jayarami* Vishwanath & Kosygin	-	+	VU
	160. *Pseudecheneis ukhrulensis* Vishwanath & Darshan	-	+	VU
	161. *Sisor barakensis* Vishwanath & Darshan	+	-	VU
Siluridae	162. *Ompok bimaculatus* (Bloch)	+	+	NT

Family	Species	Distribution		IUCN status
		Barak	Chindwin	
	163. *Pterocryptis barakensis* Vishwanath & Nebeshwar	+	-	NE
	164. *Pterocryptis berdmorei* (Blyth)	-	+	LC
	165. *Wallago attu* (Schneider)	+	+	NT
Chacidae	166. *Chaca chaca* (Hamilton)	+	-	VU
Clariidae	167. *Clarius gariepinus* (Burchell)	+	+	LC
	168. *Clarius magur* (Hamilton)	+	+	EN
	169. *Heteropneustes fossilis* (Bloch)	+	+	LC
Bagridae	170. *Batasio affinis* Blyth	-	+	DD
	171. *Hemibagrus microphthalmus* (Day)	-	+	LC
	172. *Hemibagrus peguensis* (Boulenger)	-	+	LC
	173. *Mystus cineraceus* Ng & Kottelat	-	+	DD
	174. *Mystus falcarius* Chakrabarty & Ng	-	+	LC
	175. *Mystus ngasep* Darshan *et al.*	-	+	LC
	176. *Mystus pulcher* (Chaudhuri)	-	+	LC
	177. *Mystus rufescens* (Vinciguerra)	-	+	LC
	178. *Mystus tengara* (Hamilton)	+	-	LC
	179. *Sperata acicularis* Ferraris & Runge	-	+	LC
	180. *Sperata aor* (Hamilton)	+	-	LC
Mugilidae	181. *Sicamugil cascasia* (Hamilton)	+	-	LC
Belonidae	182. *Xenentodon cancila* (Hamilton)	+	+	LC
Aplocheilidae	183. *Aplocheilus panchax* (Hamilton)	+	+	LC
Synbranchidae	184. *Monopterus javanensis* Lacepede	-	+	LC
Mastacembelidae	185. *Macrognathus aral* (Bloch & Schneider)	+	+	LC
	186. *Macrognathus morehensis* Arunkumar & Tombi Singh	-	+	LC
	187. *Macrognathus pancalus* Hamilton	+	-	LC
	188. *Mastacembelus armatus* (Lacepede)	+	+	LC
Ambassidae	189. *Chanda nama* Hamilton	+	-	LC
	190. *Parambassis waikhomi* Geetakumari & Vishwanath	-	+	DD
Nandidae	191. *Nandus nandus* (Hamilton)	+	-	LC
Badidae	192. *Badis ferrarisi* Kullander & Britz	-	+	LC
	193. *Badis kanabos* Kullander & Britz	+	-	DD
	194. *Badis tuivaiei* Vishwanath & Shanta	+	-	EN
Ciclidae	195. *Oreochromis mossambicus* (Peters)	+	+	VU
Gobiidae	196. *Glossogobius giuris* (Hamilton)	+	+	LC
Anabantidae	197. *Anabas testudineus* (Bloch)	+	+	DD
Osphronemidae	198. *Trichogaster fasciata* Bloch & Schneider	+	+	LC
	199. *Trichogaster labiosa* Day	-	+	LC
	200. *Trichogaster sota* (Hamilton)	+	-	NE
Channidae	201. *Channa aurolineata* (Day)	-	+	NE
	202. *Channa gachua* (Hamilton)	+	+	LC
	203. *Channa marulius* (Hamilton)	+	+	LC
	204. *Channa punctata* (Bloch)	+	+	LC
	205. *Channa striata* (Bloch)	+	+	LC
Tetraodontidae	206. *Leiodon cutcutia* (Hamilton)	+	+	LC

DISCUSSION

The present study found that the Chindwin and the Barak River basins of Manipur have high diversity of Ornamental fishes. Most of these fishes are endemic to the particular basin, yet some species have wide range of distribution and found in both the River basins. The list of Ornamental fishes in Table I also include fishes which are treated as food fishes as these fishes are treated as Ornamental fishes when they are small. Many of these "living jewels" are threatened and face extinction in the future. One of the major threats faced by these fishes is illegal Ornamental fish trade. Other threats include habitat destruction, construction of dams and barrages, water pollution, overexploitation, and introduction of invasive species. Till date many interior parts of Manipur remain inaccessible due to poor connectivity of road. Thus, many species are awaiting discovery. In the light of the above observation, further exploration is needed to know the exact species composition of the two River basins of Manipur. If the rate of pace of discovery is slow, some species may go extinct even before discovery.

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REFERENCES

Hubbs, C.L., & Lagler, C, F (1946). Fishes of the Great Lakes Region. Cranbrook Instt. *Science*, 26: 1–186.

IUCN (2022). The IUCN Red List of Threatened Species. Version 2021-3.
http:// www.iucnredlist.org/apps/redlist/search

Kottelat, M. (1990). *Indochinese nemacheilines: A revision of nemacheiline loaches (Pisces: Cypriniformes) of Thailand, Burma, Laos, Cambodia and southern Vietnam.* Verlag, Dr. Friedrich Pfiel, Munchen, 262 pp.

Mahapatra, B. K., Vinod, K., & Mandal, B. K (2005). Export potentiality of native ornamental fish from north eastern hill states of India with a note for development of such fisheries. *Environment and Ecology,* 23, 780–786.

Vishwanath, W. (2021). *Freshwater Fishes of the Eastern Himalayas*. Academic Press publications, 1-401.

CONSERVATION & MANAGEMENT OF DOYANG RESERVOIR WETLAND, NATIONAL PLAN FOR CONSERVATION OF AQUATIC ECOSYSTEM (NPCA):2019-2020

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OVERVIEW

The Doyang Reservoir Wetland project under the National Plan for Conservation of Aquatic Ecosystem (NPCA) is the first of its kind for the state. Altogether twenty (20) villages have been taken up for Implementation of Conservation and Management of Doyang Wetland Reservoir. Out of 20 villages, eight (8) villages fall under Baghty Range, two (2) other villages under Doyang Beat, Wokha Forest Division while the remaining ten (10) villages comes under Doyang Afforestation Range, Doyang Plantation Division.

OBJECTIVES

i. To maintain and enhance, where appropriate, the ecological character of the wetland and surrounding habitats.

ii. To monitor and manage the hydro-geomorphologic system of the area, including its immediate zone of influence and the link with the catchment areas and the river/streams that supplies water to it, in a way that offers long-term optimum yield for fisheries and optimum habitat for aqua tic birds.

iii. To optimize the conservation of biological diversity (species, habitats) in the long-term.

iv. To investigate, monitor and manage the natural habitats in order to maintain and develop maxi mum biodiversity of the area and beyond.

v. To develop tourist-related activities and related infrastructure in a way compatible with the wet land and biodiversity conservation requirements and to provide the local villages in the immediate zone of influence with long-term sustainable forms of activities and income to assure their survival without harming the ecosystem.

vi. To provide support to human activities and sustainable use of natural resources where compatible with biodiversity conservation.

vii. To increase public awareness of the values of the Wetland.

EXPECTED OUTCOMES

i. Successful conservation of the Wetland and its biodiversity.

ii. Reduction in siltation though large-scale plantation and soil and moisture conservation works viz-a-viz check dams, gully plugs, trenches etc. and at the same time, leading to enhancement of water holding capacity in the catchment area.

iii. Increased public awareness of the values of the Wetland and ushering the people towards conservation and better management of the wetland area.

iv. Livelihood improvement of the people through alternative livelihood interventions leading to wise-use of the wetland areas.

v. A balance where the sanctity of the wetland is maintained and the livelihood of the stakeholders are met.

ACTIVITY WISE WORK PROGRESS

Works under the project includes various activities and interventions that is targeted towards improving the overall health of Doyang Reservoir Wetland, while also addressing the needs and requirements of local community in terms of livelihood generation. The various works undertaken so far are:

1. Brushwood Check dam

12 streams were selected on which 20 nos. each of low-cost brushwood check dams were constructed in order to check siltation in the reservoir by controlling erosion brought in by streams through runoff. The check dams have been completed in all the streams viz. Tzuza, Ngalang, Shumrow, Tontongchu, Yaksokyu, Ralantchu, Chayii, Lumki, Tchupum, Tchupvu, Rampung and Sangphya.

2. Gully Plugging

For this activity as well, 12 streams were selected on which four boulder-based gully plugs each were constructed in order to check siltation in the reservoir by controlling erosion brought in by streams through runoff. The check dams have been completed in all the streams viz. Tzuza, Ngalang, Shumrow, Tontongchu, Yaksokyu, Ralantchu, Chayii (26o1'41.5" N, 94o19'58.4" E), Lumki, Tchupum, Tchupvu, Rampung and Sangphya (26o11'06.2" N, 094o16'53.0" E).

3. *Assisted Natural Regeneration*

In all villages, 50 Ha of degraded forest area was taken up for plantation. Activities undertaken included survey and demarcation, cut back operations (CBO) cleaning including cutting of weeds and plantation. Species such as Hollock (Terminalia myrocarpa), Khokon (Duabanga grandiflora), Bogi-poma (Chukrasia tabularis), Teeta chap, Cadam (Neolamarckia cadamba), Badam, Aojar (Lagerstromia speciosa), Seesam (Dalbergio sissoo), Lali poma (Dysoxylum excelsum), Pine (Pinus spp.), Semul (Bombax ceiba), Teak (Tectona grandis), Jamun (Syzygium cumini), Hilika (Terminalia chebula), Uriam (Bischofia javanica), Ghora Neem (Melia azedarach) etc. were planted. Plantation was carried out as per the work program and 200 seedlings per Ha were planted.

4. Artificial Regeneration

For artificial regeneration plantation, 6 villages were selected- Pangti, Lakhuti, Akuk, Littami New, Seluku and Nungying. In total, 100 Ha of area was covered under artificial regeneration. Activities undertaken included survey and demarcation, cut back operations (CBO) cleaning including cutting of weeds and plantation. Species such as Hollock (Terminalia myrocarpa), Khokon (Duabanga grandiflora), Bogi-poma (Chukrasia tabularis), Teeta chap, Cadam (Neolamarckia cadamba), Badam, Aojar (Lagerstromia speciosa), Seesam (Dalbergio sissoo), Lali poma (Dysoxylum excelsum), Pine (Pinus spp.), Semul (Bombax ceiba), Teak (Tectona grandis), Jamun (Syzygium cumini), Hilika (Terminalia chebula), Uriam (Bischofia javanica), Ghora Neem (Melia azedarach) etc. were planted. Plantation was carried out as per the work program and 1100 seedlings per Ha were planted.

5. Grassland and Fodder Plantation

For fodder and grassland plantation, 6 villages were selected- Okotso, Ripyim Old, Riphyim New, N. Longidang, Changsu Old and Changsu New. In total, 100 Ha of area was covered under fodder and grassland plantation. Works included survey and demarcation, cut back operations (CBO), cleaning including cutting of weeds, and plantation. Species such as Banana (Musa spp.), Bamboo (Bambusa spp. and Dendrocalamus spp.), Elephant Grass (Pennisetum pupureum), Cadam (Neolamarckia cadamba), Semul (Bombax ceiba), Jamun (Syzygium cumini), Hilika (Terminalia chebula), Uriam (Bischofia javanica), Ghora Neem (Melia azedarach), Neem (Azadirachta indica), Aonla (Phyllantus indica) etc. were planted.

6. Habitat Improvement

Habitat improvement plantation for in-situ conservation of soft-shelled turtle was carried out in Mekokla village. Species such as Hollock (Terminalia myrocarpa), Khokon (Duabanga grandiflora), Bogi-poma (Chukrasia tabularis), Teeta chap, Cadam (Neolamarckia cadamba), Badam, Aojar (Lagerstromia speciosa), Seesam (Dalbergio sissoo), Lali poma (Dysoxylum excelsum), Pine (Pinus spp.), Semul (Bombax ceiba), Jamun (Syzygium cumini), Hilika (Terminalia chebula), Uriam (Bischofia javanica), Ghora Neem (Melia azedarach) etc. were planted.

7. Horticulture

Horticulture crops such as Litchi, Coffee, Cardamom, Orange, Jackfruit, Jamun, Banana, Ginger etc were provided to all the villages.

8. Horticulture Food Processing Unit

2 horticulture-based food processing units were set up, one each at Doyang and Tsungiki village respectively. Machineries such solar water heaters, solar street lights, ginger peeler, dryer, containers and packaging units were provided to the two units.

9. Watch tower

10 villages were selected for construction of watch towers under the NPCA. The villages are N. Longidang, Tsungiki, Seluku, Nungying, Riphyim Old, Changsu Old, Okotso, Aree Old, Yonchucho and Akuk

10. Water hole cum water harvesting structure

In all the villages, one water hole cum water harvesting structure was constructed. All twenty structures have been completed in Pangti, Okotso, Aree Old, Aree New, Sunglup, Yonchucho, Lakhuti, Akuk, Riphyim Old, Riphyim New, Changsu Old, Changsu New, Nungying, Tsungiki, Mungya, Seluku, Littami Old, Littami New and N. Longidang.

11. Trenches

In each village, 24 numbers of trenches were made, amounting to 48.6 cu. m. of earth work per village. Altogether, for the 20 villages, a total of 480 trenches were made amounting to 972 cu. m. of earth work. Bamboos are abundantly available in the area, and hence it was used to make bamboo bunds along the trench. The local people also themselves contributed to this at no extra cost of the project. The added advantage for this form of trenching is that the local people can plant crops on the bunds as well.

12. Pig Breeding Centre
Two villages were selected to establish Pig Breeding Centres, one at Nunying and the other at New Riphyim village. 10 piglets each were provided to the breeding centres along with feeds.

13. Poultry Distribution
Poultry chicks were distributed to all the 20 villages. Chicks were provided to the villages along with the poultry feeds.

14. Nursery creation
Two nurseries were established- one each at Wokha Forest Division and Doyang Plantation Division.

15. Awareness Program
Observation of World Wetlands Day on 2nd February 2020 at Vivekananda Kendra Vidyalaya, NEEPCO, Doyang. World Wetlands Day is observed annually across the world on February 2, marking the date of the adoption of the Convention on Wetlands on February 2, 1971.

16. Training on Mushroom Cultivation
A training program on "Method Demonstration on Oyster Mushroom Cultivation" was organised through convergence program between Wokha Forest Division, Doyang Plantation Division and Nagaland State Rural Livelihoods Mission, Wokha. Altogether 20 villages from Wokha and Zunheboto districts participated in the training, represented by Self Help Groups (SHG) and Eco-development Committees (EDC) of the respective villages. Over 300 kg of oyster mushroom spawns and various kits required for its cultivation were also distributed to all the villages.

17. Formation of Eco-Development Committees
Eco-development committees were formed for all 20 villages.

REPRODUCTIVE BIOLOGY AND OPTIMISATION OF HORMONE DOSAGE FOR BREEDING OF BANGANA DEVDEVI (HORA, 1936) FOR EX-SITU CONSERVATION AND MASS SEED PRODUCTION

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ABSTRACT

Bangana devdevi (Hora) is an indigenous medium-sized and bentho-pelagic minor carp, widely distributed in the Chindwin headwaters of Manipur, Northeast India. A study on reproductive biology of *B. devdevi* collected from different rivers of Manipur was carried out. The minimum size at which fish attains maturity was determined based on the examination of the maturity stages. Samples were collected monthly for detailed investigation on reproductive biology for two years and the data were pooled to one year. For studying maturity and spawning season, maturity stages were classified based on colour, shape, size of ovary and the space it occupied in the body cavity. The maximum value of GSI (1.17) was observed during August for males whereas for females the highest was observed during the month of July (2.24). Induced breeding of *Bangana devdevi* was done using Gonopro-FH in different doses @ 0.4mL, 0.5mL & 0.6mLKg^{-1} body weight in a set of three experimental groups T1, T2 and T3 respectively. All the males were given half the doses of females. Spawning commenced 6–10 hrs after injection and was completed within 4–5 hours. Fertilized eggs were hatched out after 11–16 hours of fertilization at temperatures of 26.4–27.5°C. Statistical analysis was carried out to determine the relation between the hormone dosage with egg output, fertilisation rate and hatching rate. The highest number of fertilisation (94.25%) and hatching rate (89.03%) were found in fish with Gonopro-FH @ 0.5ml/kg body weight female and significantly higher (P<0.05) than T1 and T3. The present study may be beneficial for species conservation and management strategies in rivers and tributaries as well as mass seed production of *B. devdevi.*

Keywords GSI, Gonopro-FH, induced reproduction, sexual maturity, spawning

INTRODUCTION

Bangana devdevi, Hora, 1936 (formerly *Labeo devdevi*) was described based on the Burmese and Siamese specimens of Mukherji's collection while discussing the identity of *Labeo dyocheilus* (M'Clelland, 1839) and *Labeo dero* (Hamilton, 1822). Kottelat (1989, 1998, 2013) placed *L. devdevi* under the genus *Bangana*. According to the IUCN red list of threaten species (Vishwanath, et.al. 2010) it is assessed as Least Concern (LC). *Bangana devdevi* is an indigenous medium-sized and bentho-pelagic minor carp, widely distributed in the Chindwin headwaters of Manipur, Northeast India (Vishwanath *et al.,* 2007). The species is known popularly as 'Khabak' for advanced stages while 'Ngaton' for fingerling stages. The study of fish biology plays a vital role in better understanding of life history of fishes including migration, distribution, fishery management and conservation (Bal and Rao, 1990). Studies on reproduction, including the assessment of size at maturity, fecundity, duration of reproductive season, daily spawning behaviour and spawning fraction, permit quantification of the reproductive capacity of individual fish (Murua *et al*., 2003). *B. devdevi* is an economically important as there is high demand of the fish in the local market of Manipur. It reaches almost triple the prices of that of Indian Major Carps (IMC). This fish usually breeds in rivers and lakes but the population of this fish has been decreased for the past decades due to unplanned development projects of flood control and irrigation, dam construction, embankments, modification of river courses and other human activities and categorized as a vulnerable fish (Mahanta et al., 1994). A little study has been done about the reproductive biology and there is no study on breeding of *B. devdevi* till today*.* Since no proper breeding protocol has been established for this species, there is a need of developing induced breeding protocol to produce seeds to increase the population and to meet its increasing demand in the market as this fish does not breed naturally in captivity.

The present research aims at proper understanding of reproductive biology of *B. devdevi* and standardizing the optimum effective dosage of a synthetic hormone, Gonopro-FH for induced breeding of *B. devdevi* to find out the effectiveness of spawning, fertilization and hatchability of the fish in captivity.

MATERIALS AND METHODS

Collection of fish for studying biology

A total of 220 individuals of *Bangana devdevi* were collected every month by using cast net, gill net, drag net and giant tubular bamboo traps (local name: tekhao-loo) for two years from different rivers of Manipur i.e., Thoubal river, Iril river and Imphal river and 2 years data were pooled to one year data.

Reproductive biology

Samples were collected monthly for detailed investigation on reproductive biology for two years and the data were pooled to one year. To study fecundity and ova diameter, ovaries were preserved in 5% formaldehyde and for separation of ova, Gilson's fluid was used.

Length at first maturity

The minimum size at which fish attains maturity was determined based on the examination of the maturity stages. Female specimens in stage III (The size of ova increases to maximum size of 1.5mm with a mode at 1.45mm) and above based on Qasim (1973) were considered as mature in this study. Data collected for 2 years and cumulative frequency was plotted against the length groups. The size at which 50% of fish population was matured was taken as the length at first maturity.

Spawning season

For studying maturity and spawning season, maturity stages were classified based on colour, shape, size of ovary and the space it occupied in the body cavity. In addition, ova diameter and deposition of yolk in the ova were taken into consideration for recognizing the different maturity stages for female. Different maturity stages of ovary were determined by following Tamhane and Somvanshi (1998) as immature, maturing, mature, ripe and spent. The percentage of occurrence of various stages of maturity in different months was studied for 2 years. The spawning period was ascertained from the occurrence of ripe specimens in the collected samples.

Spawning periodicity

Ova diameter measurements of intra ovarian eggs were recorded from preserved ovaries as described by Clark (1934) and Prabhu (1956). For ova diameter studies, 10 mature ovaries were taken from each fish. The ova from anterior, middle and posterior region were examined to know differential pattern of egg distribution. At least 1000 eggs were examined from each ovary in order to eliminate the possible errors in representation of different stages of maturity. Leica DFC 425 camera fitted on Leica S8APO stereo zoom microscope was used to measure ova diameter. The measured ova diameters were grouped into 0.01 millimeters division class intervals and their frequency polygons were drawn.

Gonado-somatic Index (GSI)

To study GSI weight of each specimen was taken to the nearest gram and after dissection the weight of gonad was also recorded every month. The ratio was calculated month-wise and sex-wise using the following equation (Vladykov, 1956).

GSI = weight of gonad × 100 / total body weight

Fecundity

The gravimetric method was used for studying fecundity following Hunters and Goldberg (1980). Ten mature ovaries (preserved in 5% formaldehyde) were taken for the estimates of fecundity. Gilson's fluid was used for separation of ova. Fecundity was estimated by counting the number of mature ova from a known weight of mature ovary i.e., 0.1g of subsamples was taken from three segments (anterior, middle and posterior) of each ovary. The sub samples were spread evenly on a counting slide with a few drops of water and the number of mature ova was counted and average number of three subsamples was used to determined fecundity by the following formula:
Fecundity = (No. of ova in the sub sample × Total ovary weight / weight of sample)

Relative fecundity i.e., number of eggs/1g of body weight (unit body weight or ovary weight) was obtained by dividing absolute fecundity with total weight of fish. To establish the relation of fecundity "F" with total length "TL" and body weight "TW" the following formula (Bagenal, 1978) was used:

$F = aL^b$

$F = aW^b$

Where, a and b are constants.

L is total length in mm.

W is body weight in g.

The least square method was used to determine the correlation coefficient between fecundity and total length and also between fecundity and body weight.

Sex ratio. Sex ratio is expected to be 1:1 in nature, variations from this are often observed in fish because of differential behavior of sexes, environmental conditions, fishing methods employed and also due to bias in sampling.

To study the distribution of sexes according to season and size the males and females were recorded for two years and data was pooled, and the ratio of males to females were worked out month wise and length wise. To know the homogeneity of the distribution of sex, Chi-square test was applied (Snedecor and Cochran, 1967) and the formula used was:

$X^2 = (O - E)^2/E$
Where, "O" is observed frequencies and "E" is expected frequencies.

Collection of brood fish for induced breeding
100 numbers of fish were collected from Iril river, Thoubal river and Imphal river. The fish were acclimatized in the Central farm pond, Central Agricultural University, Imphal located at Lamphelpat, Imphal West where the experiment was conducted. The fish were collected during October-November 2017 and transported in well aerated Hundi. The fish were reared in brooder pond and were fed with a mixture of rice bran and mustard oil cake at the ratio 1:1 @ 3% body weight per day. 40 males with average length of 17cm and 20 females of average length 18cm were kept for around 1 month in separate tanks before the induced breeding start. Sexual dimorphism of *Bangana devdevi* is distinct during breeding season, the pectoral fin of male will be rough when touch whereas for female will be smooth. When the fish is over 2 years, they will be matured enough for breeding however males mature earlier than females.

Experiment designs
The breeding experiment was conducted during the month of June 2018. The brooders were collected from the earthen brooder pond by netting and transferred into FRP tanks for acclimatization for 5–6 hours before giving injection with hormone Gonopro-FH marketed by APC NUTRIENTS PVT. LTD. Each mL of Gonopro-FH contains synthetic gonadotropin releasing hormone analogue (SALMO-Gn-RhA – 20mcg). Five different experimental group viz. T1, T2, T3 and Control were given four different doses of hormone Gonopro-FH, i.e., 0.4 mL, 0.5 mL, 0.6 mL & 0 $mLKg^{-1}$ body weight respectively for females and males were given half the doses of females. Another group was injected with CPE (Carp Pituitary Extract) with initial dose of 2 $mgKg^{-1}$ body weight of fish and after 6hrs final dose was injected with 4 $mgKg^{-1}$ body weight of fish as a positive control. The males were given a single dose of 4 $mgKg^{-1}$ body weight at the time of final injection

Selection of brood fish
12 fish (4 females and 8 males) were put in each experimental group in the ratio of 1:2 (female: male) and each group have 4 replicates. Milt oozing males and fully matured female having 65±2g were used for this experiment. The matured females were distended abdomen and readily oozed eggs when pressed.

Hormone injection
The males and females in each group were injected according to their required doses of hormone using 1ml graduated syringe intramuscularly at an angle of 45° between dorsal fin and lateral line. The fish were divided into five treatment groups. Three groups were injected with 0.4, 0.5, 0.6ml Gonopro-FH per Kg body weight of fish. Another group was injected with CPE (Carp Pituitary Extract) collected from silver carp. The acetone dried pituitary gland (PGs) of locally available silver carp were placed on blotting paper to take out excess acetone followed by weighing to pool the desired amount of PGs. The PGs were ground using a tissue homogeniser and diluted with desired amount of distilled water. The females were injected with an initial dose of $2mgKg^{-1}$ body weight of fish and after 6hrs final dose was injected with $4mgKg^{-1}$ body weight of fish as a positive control. The male was given a single dose of $4mgKg^{-1}$ body weight at the time of final injection. The control group was not given any injection. Immediately after injecting the hormone, the brooders were randomly distributed into sixteen hapa installed in the farm pond. Courtship behaviour of fish began to show after 10hrs of injection and partial spawning started to occur within 1-2 hrs. The fecundity of each female was determined by random sampling of eggs in a 10ml graduated measuring cylinder from the total eggs released by the female. The number of total eggs in 1ml were counted and multiplied with total volume of eggs released. The fertilization rate of egg was determined by randomly taking sample of approximately 100 eggs in a glass petridish. Fertilized eggs were having intact nucleus inside the clear egg cells. After spawning the spent fish were removed from each respective breeding hapas. The fish were observed every hour after 5hrs of injection to check spawning.

Calculations
Fertilization rate (%) = [(Number of fertilized eggs)/(total number of eggs counted)]× 100
Hatching rate (%) = [(Number of eggs hatched)/(total number of eggs in the batch]× 100

Statistical Analysis
Statistical analysis was worked out by using SPSS version 16.0 for Windows. One-Way ANOVA was used to analyze the variance to determine the

relation between the hormone dosage with different parameters like fertilization rate, egg output and hatching rate.

RESULTS

Reproductive biology of *Bangana devdevi*

Gonado-somatic Index

The maximum value of GSI (1.17) was observed during August for males whereas for females the highest was observed during the month of July (2.24) {Table I}
.

Table I. Month-wise Gonado-Somatic Index of *Bangana devdevi*

Month	Male	Female
January	0.33	1.56
February	0.76	1.08
March	0.95	1.74
April	1.02	1.88
May	1.07	1.92
June	-	-
July	1.13	2.24
August	1.17	2.03
September	-	-
October	1.05	1.18
November	0.70	1.46
December	0.66	1.04

Fecundity

The length of *B. devdevi* ranges from 96.3 to 237.76 mm and body weight ranges from 15.11 to 153.73 g. The ovary weight varied from 0.76 to 61.02 g. The absolute fecundity ranged from 2830 to 22024 eggs whereas the relative fecundity ranged from 170 to 298 eggs per gram body weight. {Table II}.

The relationship between total length and fecundity and body weight and fecundity was established for *B. devdevi* as:

$$\log F = 118.9944 - 52.6391 \log L$$

$$\log F = 10.3661 - 4.1809 \log W$$

Table II. Fecundity of *Bangana devdevi*

Total length (mm)	Body weight (g)	Ovary weight (g)	Absolute fecundity	Relative fecundity with respect to body weight
237.76	153.73	61.02	26287	170
228	98.20	47.02	20370	207
212.89	86.28	44.25	15738	182
192.07	73.66	45.11	22024	298
159.38	44.27	1.15	7770	175
130.52	23.56	1.55	4428	188
122	15.91	0.76	2830	177
119.53	15.93	1.14	2734	171
116	15.11	0.81	2583	170
96.3	10.46	0.93	2089	199

Length at first maturity

Study on the length at first maturity is based on 22 matured females of *B. devdevi* respectively. A maturity curve was plotted by taking the cumulative percentage of mature females against their length groups. The length at which 50 % of the fish attain maturity was estimated to be 93 mm for *B. devdevi* (Figure 1).

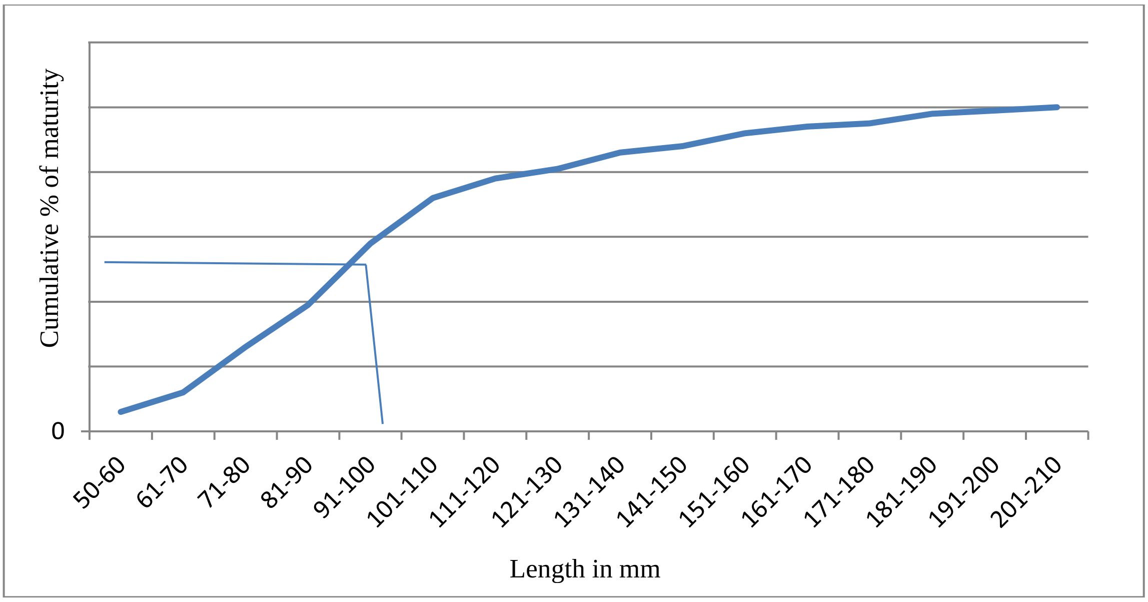

Fig. I. Length at first maturity of female *Bangana devdevi*

Maturity stages of *Bangana devdevi*

Stage I: The size of ranges from 0.9mm to 1.1mm with a mode at 1.02mm.

Stage II: The average mode of mature ova falls at 1.23mm with maximum size up to 1.3mm.

Stage III: The size of ova increases to maximum size of 1.5mm with a mode at 1.45mm.

Stage IV: The mode shifts to 1.59mm. There was slight increase in ova diameter to 1.7mm.

Stage V: Immature and maturing groups of ova are found with diameter ranging from 0.96mm to 1.72 mm. The immature eggs are widely separated from the mature ones indicating a large gap in their release once the mature eggs are shed.

Spawning periodicity

The ova diameter study was carried out to understand the spawning periodicity. The percentage of ova diameter frequency in different maturity stages of ovary was plotted against the ova diameter. The ova diameter frequencies showed an increase in diameter of ova with advancement of maturity stages. The stage-wise distribution of ova diameter is presented in Figure 2. All the mature ovaries gave bi-modal distribution showing spawning twice in a year.

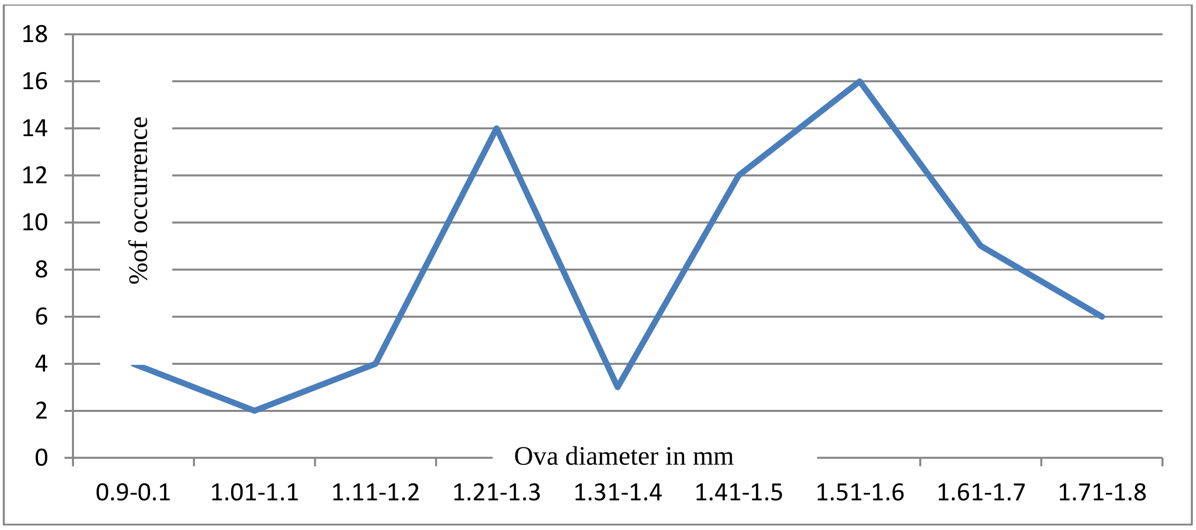

Fig. II. Percentage of ova- diameter frequency of *Bangana devdevi*

Sex ratio

Sex ratio (male: female) recorded for *B. devdevi* was 1.2. The analysis of sex ratio for the entire period of study indicates the marginal dominance of male over female in the studied species. The observed ratio was tested against 1:1 using Chi-square test for (n-2) degrees of freedom at 1% level of significance. The calculated Chi square values for *B. devdevi* was 0.04 indicating no significant difference in 1% level of significance.

Induced breeding

The result of optimisation of hormone for the induced breeding of *B. devdevi* using different three doses of Gonopro-FH is shown in Table 3. The highest egg output was found in T3 however the fertilization rate and hatching rate were found to be lowest among the three doses. In T2 the egg output was slightly lower than the T3 but the fertilisation rate and hatching rate was significantly higher than the T3. Among all the three doses T1 produced the lowest egg output, fertilisation rate and hatching rate. However, there were no significant difference in egg output, fertilization and hatching rates in T2 and T4 at (P<0.05). The control group doesn't produce any egg as they were not given any hormone. Spawning commenced 6–10 hrs after injection and was completed within 4–5 hours. The fertilized eggs were bluish white in colour, demersal and translucent. Unfertilized eggs were paler and opaque. Fertilized eggs were hatched out after 11–16 hours of fertilization at temperatures of 26.4–27.5°C. The hatchlings were transparent and measured 3.20–3.80 mm of total length with a large oval head, a well defined yolk sac and a short tail.

Table III: Induced breeding of *Bangana devdevi* injected with Gonopro-FH, carp pituitary extract (CPE) as positive control and negative control without any injection.

<table>
<tr><td colspan="2">Experimental group</td><td>Hormone dose for female ($mLKg^{-1}$)</td><td>Hormone dose for male ($mLKg^{-1}$)</td><td>Latency period (hr)</td><td>No. of egg released (,000)</td><td>Fertilization (%)</td><td>Hatching (%)</td></tr>
<tr><td colspan="2">T1</td><td>0.4</td><td>0.2</td><td>10</td><td>10.400±0.13[a]</td><td>90±0.40[a]</td><td>78.93±0.26[a]</td></tr>
<tr><td colspan="2">T2</td><td>0.5</td><td>0.25</td><td>8</td><td>12.325±0.05[b]</td><td>94.25±0.63[b]</td><td>89.03±0.14[b]</td></tr>
<tr><td colspan="2">T3</td><td>0.6</td><td>0.3</td><td>6</td><td>12.800±0.04[c]</td><td>86.75±0.63[c]</td><td>80.35±0.12[c]</td></tr>
<tr><td rowspan="2">T4 (CPE)</td><td>1st dose</td><td>2mgKg^{-1} BW</td><td>--</td><td rowspan="2">7</td><td rowspan="2">12.200±0.09[b]</td><td rowspan="2">93.75±0.85[b]</td><td rowspan="2">88.88±0.09[b]</td></tr>
<tr><td>2nd dose</td><td>4mgKg^{-1} BW</td><td>4mgKg^{-1} BW</td></tr>
<tr><td colspan="2">Control</td><td>0</td><td></td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Different subscripts indicate significant differences (p<0.05).

DISCUSSION

Determination of fecundity and the development of sexual maturity is fundamental to fishery science. Due to the importance of these parameters in the dynamics of populations (Hunter et al. 1992) they are commonly estimated for species of economic significance. The most suitable method of determining the reproductive cycle in female fishes is to observe seasonal developmental changes in the gonads (Sivakumaran1991, Karlou-Riga & Economidis 1996, 1997). In *Bangana devdevi,* GSI is high during July-August and maximum absolute fecundity observed was 26287 eggs per female. The relative fecundity was in the range from 170 to 298 ova per gram of female body weight. The highest value of GSI observed in the present study, indicates the peak spawning season which is in accordance to Sivakami (1995) in *Megalaspis cordyla.*

The ova diameter frequencies showed an increase in diameter of ova with advancement of maturity stages. All the mature ovaries gave bi-modal distribution showing spawning twice in a year which is the character of *Cyprinus rubrofuscus (koi carp)*, *Cyprinus carpio (common carp)*, *Osphronemus sp. (gourami)* etc.

The length at which 50% of the fish attain maturity was estimated to be 93 mm for *Bangana devdevi* respectively. Hence, the length less than the mentioned length should not be caught from the Thoubal River. Thus, giving them chance to mature at least once in their life time. Prabhu (1956) remarks that the spawning periodicities of teleosts has remarked that "fishes which spawn twice a year, in their ovaries in addition to the batch of eggs in the ripe condition there would another batch of eggs in which yolk formation has already taken place and would distinctly represent in the curve showing frequency of intra ovarian eggs. Such modes representing ova half the way to maturity have been found in more or less in the middle of total range in size of intra ovarian eggs in the whole ovary". Prabhu (1956) also states that the maturing eggs have already been differentiated into a definite batch of eggs from the general stock and that the interval between the two spawning period may not be a long one.

In the present investigation the mature ovaries of *B. devdevi* gave bi-modal distribution indicating two spawning period and as the distance between the mature and maturing stock is not very far, the spawning of both the batches of eggs appears to be not widely separated.

In the present study, sex ratio (male: female) recorded for *Bangana devdevi* is 1.2. The analysis of sex ratio for the entire period of study indicates the marginal dominance of male over female in the studied species. The occurrence of more female specimens indicates the peak spawning season. Hence, dominance of male over female may be due to less sampling during spawning season or males matured earlier. The dominance of male in the fishery was reported by Sreenivasan (1981); Premalatha (1993) for *Decapterus russelli* in Cochin waters and Bedajit (2005) for *Sepia prabahari* in Thoothukudi coast, Tamil Nadu.

Induced breeding in captivity of many indigenous fish species were conducted successfully using different hormone. The brooders having the age 2+ years and body weight as 100-250g attained full maturity during the month of July- August in captivity at 18-22°C water temperature. It breeds during the south west monsoon season in natural condition. The current results showed that successful spawning of *Bangana devdevi* occurred at the dose of 0.4ml/Kg to 0.6ml/Kg and the dose of hormone affected significantly the percentage of fertilization, egg output, hatching rate respectively. From the current study, 0.5ml/Kg body weight of female and 0.25ml/Kg body weight for male showed good results for induced spawning and hatching. Similar observation was also reported by Bedajit *et al.* (2010) in *Anabas testudineus* by using ovatide as inducing agent. It may be used as a standard dose for induced breeding of *B. devdevi* and can be effectively used of for the conservation of this species. It can be suggested to the farmers for commercial seed production of *B. devdevi* in captivity also. In this study, the latency period of *B. devdevi* was found to be 6-10 hours. Bashuda *et al*. (2017) observed the latency period of *B. dero* as 7-10 hours. Purkayastha *et al.* (2012) found that the latency period of *Ompok pabda* as 9–10 hours when given ovatide at 0.6 $mLKg^{-1}$ body weight in female. Fertilisation rate and hatching rate are extremely dependent on temperature and small changes in temperature can have large effects on developmental time and difference of temperature >3°C resulted in a 15–17 hour difference in hatching time. The objective of the present study was fulfilled. Gonopro-FH administered at 0.5$mLKg^{-1}$body weight produces the highest spawning rate, egg production and hatching rate in *B. devdevi.* The positive response of both males and females to a single dose of Gonopro-FH is significant for commercial seed production. This breeding protocol does not require a high investment, so it can be adopted by small farmers for seed production as well as for species restoration and conservation.

The results of this study on reproductive traits like sex ratio, size at first sexual maturity, GSI, fecundity and spawning season may be beneficial for species conservation and management strategies in rivers and tributaries. The present study also indicated that optimum dose of Gonopro-FH for normal spawning of *Bangana devdevi* is 0.5$mLKg^{-1}$. Since present study was limited to only a few trials, more researches may be necessary to optimize the dose for better production of *B. devdevi.* However, considering the present seed demand of *B. devdevi* in Manipur the present information may be effectively utilized for mass-scale seed production.

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REFERENCES

Bal, D. V., & Rao, K. V. (1990). Marine fisheries of India. Tata McGraw-Hill. Publishing company Limited, New Delhi pp. 211-212.

Basudha, C. H., Singh, N. G., Devi, N. S., & Sinthoileima, C. H. (2017). Induced breeding and embryonic development of an indigenous fish *Bangana dero* (Hamilton) in captivity using wova FH. *Int. J. Fish. Aquat. Stud*, ***5***(1), 428-432.

Bedajit, Y., (2005). Studies on population dynamics and stock assessment of *Sepia prabahari*, Neethiselvan and Venkataramani of Thoothukudi coast. M.Fsc. Thesis, TANUVAS: 78

Clark, F. N. (1934). Maturity of the California sardine (*Sardina caerulea*), determined by ova diameter measurements. *Calif. Div. Fish Game, Fish. Bull.*, **42**, 1-49.

Hora, S. L. (1936). On a collection of fish of the Naga Hills. *Rec. Indian Mus.*, **38**, 317-331.

Hunter, J. R. and Goldberg, S. R., (1980). Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax. Fish. Bull. U.S.,***77**: 641-652.

Hunter, J. R. (1992). Fecundity, spawning, and maturity of female Dover sole Microstomus pacificus, with an evaluation of assumptions and precision. *Fish. Bull.(Wash. DC).*, **90**, 101-128.

Jayaram, K, C. and Das, M. K., (1980). Systematic position of Labeo devdevi Hora with a description of the species (Pisces: Cypriniformes), *Bull. Zool. Surv. India.* **2**: 201-206.

Karlou-Riga, C. (1996). Ovarian atretic rates and sexual maturity of European horse mackerel, *Trachurus trachurus* (L.), in the Saronikos Gulf (Greece)., *Fish. Bull.*, **94**, 66-76.

Karlou-Riga, C., & Economidis, P. S. (1997). Spawning frequency and batch fecundity of horse mackerel, *Trachurus trachurus* (L.), in the Saronikos Gulf (Greece)., *J. Appl. Ichthyol*. **13**: 97–104.

Kottelat, M. (1989). Zoogeography of the fishes from Indochinese inland waters with an annotated check-list. *Bull. Zool. Mus. Univ. Arnst*., **12**(1): 1-55.

Kottelat, M. (1998). Fishes of the Nam Theun and Xe Bangfai basins (Laos), with diagnoses of a new genus and twenty new species (Cyprinidae, Balitoridae, Cobitidae, Coiidae and Eleotrididae). *Ichthyol. Explor. Freshwaters.*, **9**: 1-198.

Mukerji, D. D. (1933). Report on Burmese fishes collected by Lt.-Col. RW Burton from the tributary streams of the Mali Hka river of the Myitkyina district (Upper Burma). Part II**.** *J. Bombay nat. Hist. Soc.,* **37**(1): 38-80.

Murua, H., Kraus, G., Saborido-Rey, F., Witthames, P. R. P. R., Thorsen, A., & Junquera, S. (2003). Procedures to estimate fecundity of marine fish species from field samples in relation to reproductive strategy. *J. Northw. Atl. Fish. Sci*., **33**: 33-54.

Prabhu, M. S. (1956). Maturation of intra-ovarian eggs and spawning periodicities in some fishes. *Indian J. Fish.,* **3**: 59-90.

Premlatha, P., (1993). Observations on the carangid resources of the southwest coast of India, *J. mar. biol. Assn. India.* **35**: 157-166.

Purkayastha, S., Sarma, S., Sarkar, U. K., Lakra, W. S., Gupta, S., & Biswas, S. P. (2012). Captive breeding of endangered *Ompok pabda* with Ovatide. *J. Appl. Aquac*, **24**(1), 42-48.

Qasim, S. Z., (1973). An appraisal of the studies on maturation and spawning in teleosts from the Indian waters, *Indian J. Fish*., **20** (1&2): 166-181.

Singh, Y.B., Saha, H., Mandal, B., Tandel, R., 2011. Indoor-Induced breeding of climbing perch *Anabas testudineus* (Bloch, 1792) by ovatide for conservation and aquaculture *The Israeli Journal of Aquaculture,* Bamidgeh, 64:766-769.

Sivakumaran, K. P. (1991). Studies on the biology and population identification of *Rastrelliger kanagurta* (Curvier, 1817) (Pisces: Scombridae) from the Coastal Waters of India. PhD, Annamalai University, Porto-Novo, India.

Sivakami, S. (1995). Fishery and biology of the carangid fish Megalaspis cordyla (Linnaeus) off Cochin. *J. Mar. Biol. Ass. India,* **37**: 237-248.

Snedecor, G. W. and Cochran, W. G., (1967). *Statistical Methods* (6th edn.) Oxford and IBH Publishing Co., New Delhi, 593pp.

Sreenivasan, P. V. (1981). Maturity and spawning in Decapterus dayi Wakiya. *J. Mar. Biol. Ass. India*, **23**(1&2), 19-28.

Tamhane, A. V. and Somvanshi, V. S., (1998). Observations on maturity and spawning in Indian scad, *Decapterus russelli*(Ruppell, 1830) along north-west coast of India. *Bull. Fish. Serv. India,* **26**: 59-64.

Vladykov, V. D. (1956). Fecundity of wild speckled trout (Salvelinus fontinalis) in Quebec lakes *J. Fish. Bd. Can.,* **13**(16): 799-841.

STUDIES ON FISH PRESERVATION METHODS ADOPTED BY THE DEORI COMMUNITY IN DHEMAJI DISTRICT OF ASSAM

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ABSTRACT

Traditional fish preservation methods practiced by the tribal communities are based on Indigenous Technical Knowledge (ITK) of the community as well as the entire region. Due to lack of adequate scientific approach and exposure, these methods have been explored very little till date. Taking these aspects into account, the present study demonstrates the different methods adopted by the Deori community of Dhemaji district in Assam for preservation of locally available fish species during monsoon season in order to consume during dry seasons. The study was conducted from the month of May, 2021 to mid-September, 2021 through survey, field visits, personal interview and spot observation. The people of Deori community primarily preserve fishes in different forms locally known as- *Chucha, Aarhoi Chiya, Dujiba Chiya* and *Nakia Chiya*. Methods of preparation and preservation of these products are based on the principles of dehydration and fermentation. The fermented fish products are source of protein and used as delicacies in various ethnic cuisines due to their unique flavour and savory aroma. In the present context, ethnic fermented fish products of the tribals are gaining popularity even among the people of other communities of North-East India and beyond. Suggestions are put forward for promotion of marketing and commercialization of the ethnic food products. Sustainable utilization and management are very crucial and utmost necessary in every step right from the collection of fishes for sustainable development and conservation. Further, implications for creation of employment opportunities for the rural tribal people in the particular sector has been highlighted.

Keywords: Indigenous Technical Knowledge, Deori community, fermented fish, Northeast India

INTRODUCTION

The state of Assam situated in the north-eastern region of India is home to many indigenous communities and tribes. It is rich in natural resources with abundance of freshwater bodies like rivers, streams and floodplain wetlands locally known as beels that shelter a wide variety of fishes. Since time immemorial, people belonging to different tribes have been practicing different indigenous traditional methods of fish preservation and use of different herbal and animal products as medicines to cure different diseases. These are based on indigenous knowledge of different tribes that represent part of their culture. Indigenous Technical Knowledge (ITK) is adapted to the local environment and culture generated over the years based on experience and practice through centuries (Devi *et al.*, 2016).

Fish preservation is an age-old practice among the indigenous tribal communities of Assam. Dried and fermented fish products are good source of protein. Traditionally, they are used as delicacies in different ethnic cuisines for their unique flavour and savory aroma. Fish preservation is basically the method of increasing the shelf-life of fishes. The surplus fish after the flood are preserved by various methods by the different tribes (Sharma *et al.*, 2012). Different traditional techniques of fish processing are applied to preserve economic fish varieties abundantly available during monsoon season, for consumption during the dry winters and pre-monsoons (Muzaddadi , 2012). According to Ahmed (2016), apart from serving the purpose of consumption at home, the preserved products can also serve as a source of income to the rural people through marketing.

The Deori community is one of the notable tribal communities of Assam with their own traditions and culture, language and cuisine. As being sons of the native land of Assam, the Deori people have been living permanently in various places of the state within their own community depicted as Deori villages as well as with other communities of the region. Since ages, it has been observed that majority of Deori villages are organized at places just a kilometer or so away from a river. They are significantly engaged in agriculture but also engage in fishing activities in the nearby water bodies. When there is availability of abundant fishes after monsoon, they preserve the surplus ones by different traditional methods and techniques that have been passed on from generation to generation through practice.
The district of Dhemaji is situated on the north bank of river Brahmaputra in Assam. It is located

between 94°12'18" E and 95°41'32" E longitudes and 27°05'27" N and 27°57'16" N latitudes covering an area of 3237 sq. kms at an altitude of 104 m above the mean sea level. There is a large tribal population in the district belonging mainly to Deori, Mising, Sonowal-Kachari, Bodo, Lalung etc. communities. The Deori Community is distributed in numerous villages throughout the district. There is very less detailed information about the indigenous techniques of fish preservation by the Deori community in Assam. So far, little has been explored about their culture and traditions. Taking into consideration all these aspects, the objectives of the present study were as follows-

(1) To survey and collect data on the indigenous fish preservation methods adopted by the Deori community of Dhemaji district.
(2) To evaluate the process of indigenous fish preservation methods by the Deoris.

MATERIALS AND METHODS

Site Selection

Five Deori villages in Dhemaji district were selected as study sites viz.; Sripani village, Dhunaguri village, Gainadi village, Udaipur village and Raimyapur village for the present study conducted from the month of May,2021 to mid-September, 2021. The villages are located at a distance of 15-20kms from the main town of Dhemaji.

Selection of Respondents for Survey

Six Deori households from each village were surveyed with a total sample of 30. Survey was conducted through questionnaire and required information was collected.

Field Survey and Spot Observation

Primary data collection through field survey and spot observation personally. Field survey was conducted after every three weeks during the study period. Few of the techniques were personally observed on spot during the visit and photographs were taken.

Personal Interview

Secondary information were also collected through personal interview with the older members and women of the household.

RESULTS AND DISCUSSION

From the present study, it is noticed that the Deori community go fishing only for the purpose of consumption at home. They neither sell fish nor fish products. Fish is called *Chiya* by the Deoris. They use traditional method of fishing with the use of traditional fishing gears locally called as *Juluki, Poloh, Jakoi, Sepa, Khaloi, Thua, Dingora, Jal* (traditional fishing net) etc. These fishing practices and gears are eco-friendly and do not have any negative impact on the aquatic ecosystem.

There is no specific or particular season of the year to prepare preserved fish products by the Deoris. It might be any time of the year whenever there is abundance of fish available in the market or through fishing in the nearby rivers, beels, etc. Usually, during the period between mid-September to December, there is high availability of fishes in the region and from mid-December onwards, there is a slight decrease in fish availabity due to dry weather.

The Deori community preserve fish at household level by different traditional methods. These methods keep the fish suitable for consumption for more than a year or two. Principles involved in fish preservation are- dehydration and fermentation. Dehydration is the removal of water and moisture content from the fishes. Fermentation is the chemical process by which enzymes act to change the chemical properties of the organic substrates. It prevents the action of microorganisms involved in fish spoilage. The Deoris dehydrate the fishes on fire for all the methods. Clean and hygienic condition is maintained throughout the whole process of fish drying, product preparation and preservation. Unique flavour, aroma and texture of the prepared product is associated with the different ingredients used, smoking, type of firewood burnt for smoking, containers used for storage, fermentation, duration of preservation etc.

The different traditional indigenous methods of fish preservation adopted by the Deori community of Dhemaji district are described below-

A) *Chucha* Preparation and Preservation-

Medium-sized fishes of *Cirrhinus mrigala*, *Labeo bata*, *Labeo gonius*, *Labeo rohita*, *Eutropiichthys vacha*, *Mystus* etc. are first washed; dressed to remove scales, fins; gutted to remove viscera and intestine. Gutted fishes are cleaned properly by washing with clean water. Small-sized fishes such as *Puntius* sp., *Pethia* sp., *Amblypharyngodon mola*, *Chanda* sp. etc. are washed; viscera and intestine removed by squeezing the abdomen and washed with clean water again. All the cleaned fishes are kept on porous bamboo tray locally known as *Saloni*. The trays are placed on traditional bamboo roof above the fire place. Fire is adjusted to release heat required to dry the fishes in 4-5 hours. All the water and moisture content from the fishes must get evaporated completely. Nearly mature, tender petioles and leaves of *Colocasia esculenta* i.e., Taro are collected, cleaned and washed properly. They are cut into small pieces and fire-dried or sundried. Thereafter, the dried fishes and *Colocasia* in the ratio of 3:1 are mixed and ground together with a traditional tool called *Dheki* or a big-sized iron mortar and pestle to form a semi-solid paste. At this time, prematured bamboo are cut into hollow cylinders of size 2-2.5 feet locally called as *Bahor Chunga* (*Wuzu* by the Deoris) with one end closed at the node. The paste of dried fish and *Colocasia* should be kept in a sealed vessel for drying by placing the vessel on the bamboo roof above the fire-place for 3-4 days before stuffing into the bamboo cylinders. After drying, the product is stuffed inside bamboo cylinders; followed by stuffing with salt at the open end. This is followed by stuffing with sun-dried or fire-dried banana leaves; then with paddy straw. The open end is sealed by applying clay and covered with dried banana leaves. This prevent entry of flies and microorganisms. The dried fish product prepared with *Colocasia* stuffed into bamboo cylinders is traditionally known as *Chucha* by the Deoris. The prepared product is kept on the bamboo roof above the fireplace for 15 days before it is ready to be used. The sealed bamboo cylinders are permanently kept on these roofs to ensure exposure to hot kitchen smoke regularly. It keeps the product in good condition suitable for consumption for more than two years if maintained properly. If after a year or so, the product becomes very dry, then it should be taken out from the bamboo cylinders and grind with fire-dried *Colocasia esculenta* petioles and leaves, followed by re-stuffing into the bamboo cylinders to preserve further. For consumption, the fish product as per required amount is taken out for cooking from a bamboo cylinder followed by re-sealing of the cylinders. The product is cooked by packing with banana leaves, or on oil with vegetables; or added to different ethnic dishes to enrich its flavour.

B) *Aarhoi Chiya (Hukoti)* Preparation and Preservation-

It is prepared in the same way as Chucha but without adding *Colocasia*. Medium-sized fishes are washed properly, dressed by removing scales and fins, gutted to remove viscera and intestine; and washed again with clean water. Small-sized fishes are washed, viscera and intestine removed by squeezing the abdomen and washed with clean water again. The cleaned fishes are dried on a bamboo tray above the fire place. After drying, they are allowed to cool and ground into a semi-solid form by a traditional *Dheki* or a big-sized iron mortar and pestle. The ground product is kept in a sealed vessel exposed to smoke by placing it above the fire-place on a bamboo roof for 2-3 days. Thereafter, it is stuffed into bamboo cylinders, followed by stuffing with salt and dried paddy straw. The open end of the cylinder is sealed with clay and covered by dried banana leaf which prevent entry of flies and microorganisms. These cylinders are placed on bamboo roof for 8-10 days exposed to kitchen smoke regularly until it is ready to be used for consumption. The prepared fish product is traditionally called *Aarhoi Chiya* by the Deoris and locally called *Hukoti*. The sealed bamboo cylinders are permanently kept on bamboo roofs to ensure regular exposure to kitchen smoke. It is necessary for preservation and keeping the product suitable for consumption for more than a year. For consumption, it is cooked similar to *Chucha*.

C) *Nakiya Chiya* Preservation-

Medium-sized fishes of different species like *Cirrhinus mrigala*, *Labeo bata*, *Labeo gonius*, *Labeo rohita*, *Channa punctata*, *Channa striata*, *Anabas testudineus*, *Nandus nandus*, *Eutropichthys vacha*, *Wallago attu, Notopterus notopterus* etc. are washed properly; dressed to remove fins, scales; and gutted to remove viscera and intestine. Gutted fishes are washed properly with clean water. The cleaned fishes are kept on round porous bamboo trays and some strung to bamboo skewers. These are dried by hanging the bamboo tray above the fireplace. Dried fishes (known as *Nakiya Chiya* by the Deoris) are now shifted to another round non-porous bamboo tray locally called *Dola* for preservation. Thereafter, trays are covered with another *Dola* placed on bamboo roof above the fireplace to ensure regular exposure to kitchen smoke. It is necessary to keep the fishes in good condition for three-four months. For consumption, as per required quantity of dried fishes are taken out, washed with boiling hot water and cooked with various vegetables.

D) *Dujiba Chiya* Preparation and Preservation-

Small-sized fishes such as *Puntius* sp., *Pethia* sp., *Amblypharyngodon mola*, *Chanda* sp. etc. are washed with clean water, viscera and intestine removed by squeezing the abdomen. They are washed again properly. Cleaned fishes are dried on a bamboo tray above the fire place and ground by *Dheki*. The ground product is wrapped with a fire-dried banana leaf and kept in a big-sized air tight container or an earthen pot, stuffed with salt and sealed to keep it air tight. The prepared product is called *Dujiba Chiya*. For consumption, some amount of the product is taken out as per requirement, mixed with a little amount of water and packed with a banana leaf to cook. The cooked product could be mixed with mashed roasted vegetables or added to curries or may be used to prepare dry fish chutney

Table 1 Fish species utilized for different methods of preservation by the Deori Community

SCIENTIFIC NAME	LOCAL NAME	FAMILY
Amblypharyngodon mola	Moa	Cyprinidae
Anabas testudineus	Kawoi	Anabantidae
Chanda sp.	Chanda	Ambassidae
Channa marulius	Sal	Channidae
Channa punctata	Goroi	Channidae
Channa striata	Sol	Channidae
Esomus danrica	Darikona	Cyprinidae
Eutropiichthys vacha	Bacha	Schilbeidae
Labeo bata	Bata	Cyprinidae
Labeo gonius	Kurhi	Cyprinidae
Labeo rohita	Rohu	Cyprinidae
Mystus tengara	Hingora	Bagridae
Nandus nandus	Gedgedi	Nandidae
Notopterus notopterus	Kanduli	Notopteridae
Ompok pabda	Pavo	Siluridae
Pethia sp.	Pethia	Cyprinidae
Puntius sp.	Puthi	Cyprinidae
Rasbora daniconius	Donikona	Cyprinidae

Figure A) Traditional method of drying fishes in the kitchen of a Deori household; **B)** Dried fishes strung to bamboo skewers; **C)** Bamboo skewers placed beside fire-place: drying fishes on traditional bamboo roof (*Dhua Chang*) of Deori community; **D)** Dried fishes; **E)** Leaves and petioles of *Colocasia esculenta* (Taro); **F,G)** Grinding dried fishes together with dried *Colocasia esculenta* petioles and leaves by a traditional *Dheki* for *Chucha* preparation; **H)** Stuffing bamboo cylinders with ground paste of dried fish and dried *Colocasia*; **I)** Prepared *Chucha* and *Aarhoi Chiya* stuffed in bamboo cylinders placed on traditional bamboo roof hanged above fire place; **J)** 2-year and 1-year old *Chucha* and *Aarhoi Chiya* bamboo cylinders; **K)** *Chucha* taken out of bamboo cylinder

Sarmah *et al*. (2014) documented the preparation of two different dry fish products - *Chucha* and *Nabuda Chiya* preparation by the Deori tribe from locally available fish species. *Hukoti* is an indigenous dry fish product of the tribal communities of Upper Assam and is also used as painkiller and therapeutic to cure malaria by the locals of Assam (Sharma *et al.*, 2013). Muzaddadi and Basu (2012) mentioned about the use of fermented fish product *Shidal* to cure malaria by the tribals. Keishing and Banu (2015) documented the preparation technique and potential health benefits of *Ngari* which is a fermented fish product of Manipur.

CONCLUSION

At the present time, tribal ethnic fermented fish and plant-based food products are emerging as popular delicacies even among the non-tribal people. Thus, creating a huge demand for these products in the region. But there is a long way to go in order to meet this demand due to lack of business awareness and low production efficiency associated with the same. The indigenous methods and techniques involved in the production of different food items, beverages and use of animal and herbal products for ethno-medicinal purposes by the tribal communities are noteworthy. Scientific approach and research are immensely required in this domain. Awareness must be created among the tribal communities to adopt business strategies for marketing and commercialization of their ethnic products through various programs and initiatives under governmental and non-governmental organizations. This will certainly generate new employment opportunities for the rural tribal people on their homeland. Moreover, it would lead to emergence of markets throughout the state and other regions of the country based on ethnic food items, traditional cane and bamboo products etc. representing our rich heritage and culture.

REFERENCES

Ahmed S., Dora K.C., Sarkar S., Chowdhury S., & Ganguly S. (2016). Production process, nutritional composition, microbiology and quality issues of Shidal, a traditional fermentedindigenous fish product: a review. International Journal of Science, Environment and Technology. Vol.5(2): 589-598.

Basumatary J.D.H., Basumatary U.R., & Daimary L. (2021). Exploring indigenous knowledge tomeet sustainable development through the case of indigenous methods of fishing ofthe Bodo Community of Assam, India. Journal of Xian University of Architecture and Technology. Vol.13(5): 568-574.

Chowdhury N., Goswami G., Hazarika S., Pathak S.S., & Barooah M. (2018). Microbial dynamics and nutritional status of Namsing: a traditional fermented fish product of Mishing Community of Assam. Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. https://doi.org/10.1007/s40011-018-1022-9.

Devi R., Saha B., Pandit A., & Kashyap D. (2016). Perceived effectiveness of indigenous technical knowledge on fish production practices in Assam. Journal of Inland Fisheries Soc. India. 48(2): 56-67.

Geetha S., Rao V.G., Krishna N.M., Reddy N.R.S., & Babu K.R. (2014). Some aspects of biochemical and microbial analysis of sun-dried fish *Trichiurus lepturus*Linnaeus(1758) from the east coast of Vishakhapatnam. International Journal of Biological Research, Vol.4(4): 462-465.

Hazarika P., Ullah N., & Handique P.J. (2016). Biochemical quality assessment of ten selected dried fish species of North-East India. International Advanced Research Journal in Science, Engineering and Technology. Vol.3(1): 30-33.

Kakati B.K., & Goswami U.C. (2013). Characterization of the traditional fermented fish product Shidol of North-East India prepared from *Puntius sophore* and *Setipinna phasa.*Indian Journal of Traditional Knowledge. Vol.12(1): 85-90.

Kalita S., Kalita K.D., & Das B.K. (2020). Traditional fish preservation in South Western Assam in India. IOSR Journal of Humanities and Social Science. Vol.25(11): 09-21.

Keishing S., & Banu T. (2015). Fermented fish (Ngari) of Manipur- Preparation technique and its potential as a functional food ingredient. Elixir International Journal. Elixir Food Sci. 85: 34502-34507.

Mansur M.A., Rahman S., Khan M.N.A., Kamrunnahar M.S.R., & Uga S. (2013). Study on the quality and safety aspect of three sun-dried fish. African Journal of Agricultural Research, Vol.8(41): 5149-5155.

Muzaddadi A.U., & Basu S. (2012). Shidal-a traditional fermented fishery product of North-East India. Indian Journal of Traditional Knowledge. 11: 323-328.

Muzaddadi A.U., Taye R.K., & Bhattacharjya B.K. (2013). Traditional knowledge associated with Numsing, an ethnic fish product prepared by Mising tribes of Upper Assam, India.Indian Journal of Traditional Knowledge. Vol.12(1): 91-96.

Sarmah A., Bora S., Deori D.J., Abujam S.K., & Biswas S.P. (2014). Indigenous technique for preparation of dry fish and products by Deori Community. Journal of Experimental Biology and Agricultural Sciences. Vol.2(6): 618-622.

Sarojnalini C.H., & Vishwanath W. (1995). Nutritional characteristics of two fermented fish products- Hentak and Ngari of Manipur. Journal of the Indian Fisheries Association. (Proc.Nat.Symp. Aquacrops): 75-81.

Sharma P., Kashyap D., & Goswami U.C. (2013). Preparation and storage of salted and dried products of freshwater fish Gudusia chapra(Hamilton, 1822). Bioscan 8(2): 455-458.

Sharma P., Sarma J., Kalita K., & Phukan B. (2013). Hukoti- An indigenous dry fish product of tribal communities of Upper Assam. Indian Journal of Traditional Knowledge. Vol.12(1): 97-101.

Sonowal C.J. (2020). Indigenous Knowledge System of tribal people: a need-based plan of investigation and some instances from Assam, India. Journal of the Social Sciences.48(4): 1443-1457.

CULTURE OF ORNAMENTAL SNAKEHEAD SPECIES OF THE BRAHMAPUTRA DRAINAGE, NE INDIA: A VALUABLE OVERLOOKED RESOURCE OF FRESHWATER ECOSYSTEM

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ABSTRACT

Ornamental fish keeping is a popular hobby worldwide, supporting a significant global aquariumIndustry. Over one billion ornamental fish may be exported worldwide every year. To supply markets in the northern hemisphere, exotic pets and aquarium trades source a wide variety of species from countries on all continents, with a proportion of them taken directly from the wild. The freshwater species are one of the most threatened groups as freshwater species comprise an estimated 90% of all ornamental fish trade. Most wild caught aquarium fish originating from India come from the Eastern Himalayas and Western Ghats, hotspots known for their remarkable freshwater biodiversity and endemism. The harvest of freshwater fish in India is largely unregulated. Unlike marine species (11 of which, together with all syngnathidians (seahorses, pipefish, and seadragons) are listed on Schedule 1 of India's Wildlife (Protection) Act, 1972 [WPA] and thus protected from hunting and trade), none of the freshwater fish occurring in India(except for the freshwater pipefish, *Microphis deocata* [Teleostei: Syngnathidae]) are included under any of the wildlife schedules of the WPA. Trade report shows a new and emerging trade in an ornamental fish group (snakeheads, belonging to the genus *Channa*; Teleostei: Channidae), can be considered as the conservation risk. In view of this, we have provided the report on culture and management of two snakehead species (*Channa andrao* and *Channa stewartii*) collected from the Brahmaputra River drainage. The targeted snakehead species has been over-exploited from wild for aquarium trades worldwide butnone venture for their culture and breeding. A proper culture setup is very necessary for an efficient provision of breeding and juvenile management in fish farming. Establishing a proper sustainable culture system can contribute to the protection and restoration of threatened fish populations living in the wild. A well-managed and responsible aquarium industry for snakeheads can also create livelihood opportunities and a sense of environmental management for thousands of local communities in rural and often remote locations.

Keywords*:* Snakehead, Ornamental resource, Culture, Trade, Conservation

INTRODUCTION

The aquarium fish trade is a huge global industry (Tlusty et al., 2013), worth around 15–30 billion US$ (Penning et al., 2009) and involving 5300 freshwater and 1802 marine fish (Hensen et al., 2010; Rhyne et al., 2012a). Most wild caught aquarium fish originating from India come from the Eastern Himalayas and Western Ghat, hotspots known for their remarkable freshwater biodiversity and endemism (Allen et al., 2010; Molur et al., 2011). The Eastern Himalayan region encompassing the North East states of India is considered as a hotspot for endemic *Channa* diversity (Ruber et al.,2019). There are 15 valid species are known from this region (Lalhlimpuia et al., 2016) among which the commonly found snakehead species from Assam (Brahmaputra drainage) include *Channa gachua, C. marulius, C. punctata* and *C. striata*, while *C. aurantimaculata, C. barca, C. bleheri* and *C. stewartii* are rare (Goswami et al., 2006). *Channa andrao* and *C. stewartii* are among the commonly traded colourful members of *C. gachua* species-group (Praveenraj et al., 2019). Harrington et al. (2021) highlighted the issues associated with exploitation of poorly-known taxonomic groups (the genus Channa), species in ornamental trade that have restricted ranges and are rare. Aquaculture can be recognized as a long-term solution for the sustainable trade of these species minimizing the wild exploitation. Thus, the present study provides information regarding the monoculture of *Channa andrao* and *C. stewartii*. These findings can be used to develop the commercial culture of these important ornamental channid species.

MATERIALS AND METHODS

Collection and acclimatization

A total of 90 individuals of *Channa andrao* of size (5.9-10.3 cm) were collected from a local vendor of Laskarpara, West Bengal (26.4779N, 89.8198E) and 75 numbers of size *Channa stewartii* (13.8-18.4 cm) were collected from Laika Village, Dibrusaikhuwa (27.3953 N, 95.2003E) in Tinsukia

District of Upper Assam in the month of February 2019 and March 2019respectively. Data on water parameters, available aquatic vegetation and associated fish species inthe collection site were recorded that is necessary for laboratory propagation of the targeted species. The fishes were then transported to the Aquaculture and Biodiversity Centre (26.14 °N; 91.79 °E), Gauhati University in oxygen-sealed polythene bags with minimal stress. Prior-to- release the fishes were dipped in a potassium permanganate bath (1000mg/L) for 10–40 seconds (Noga, 1996). The brooders of both the target species were acclimatized to laboratory conditions separately in Fibre Reinforced Plastic (FRP) tanks (1.5 × 1 × 1 m^3) for 15 days before stocking management.

Stock management

Separate recirculating cement tanks (2m x 1.5m x 1.2m) filled with dechlorinated tap water and exposed to natural light for 14 hrs daily were selected for rearing of both the targeted species Vegetations (*Hydrilla verticillata, Pistia sp.* and determined by linear regression analysis and scatter diagrams of log length vs log weight were plotted. The length and weight of individual fish in each tank were measured at the start and every 15 days to monitor growth response according to the methods of Jobling (1983). The experiment was conducted for 90 days.

Statistical analysis of the data included the one-way analysis of variance (ANOVA) using MS Excel 2007 version for windows on PC.

RESULTS AND DISCUSSION

The present study reveals that both the targeted species *Channa andrao* and *C. stewartii* can tolerate wide range of pH, temperature and low oxygen level that makes them suitable for commercial culture. Water parameters recorded during the study period were as follows — pH: 5.8 ± 0.09, temperature: 23 ± 3.3ºC, DO: 5.3 ± 0.6 mg/l, and conductivity: 280–360µS/cm, Nymphoides *indica)* were introduced to stimulate a natural environment. Further, aquatic macrophytes would act as substrates for adhering eggs. Some shelters (some hollow pipes) for hiding were also provided in all the tanks for the fishes as they are burrowing in nature. Stocking density maintained for *Channa andrao* and *Channa stewratii* were respectively 10-20no.s/sq. meter (10,000-20,500/ha) and 7-10no.s/sq. meter (7,000-10,000/ha). Water parameters were monitored using YSI Professional Plus Multi-parameter water quality meter. The fishes were fed twice a day (at 3-4% average body weight) at 09:00 hrs and 17:00 hrs of Indian Standard Time (IST), respectively, with live feed (small fishes, earthworm, *Chironomus* larvae and *Tubifex* sp.).

Specific growth rate

Specific growth rate (SGR) of fish was assessed by the formula—[Final weight (in gm) – Initial weight (in gm) X 100] / Times (in days). The length-weight (log-transformed) relationships were

respectively. Initial and final average length (in cm) and weight (in gm), Specific growth rate (%) has been mentioned in Table 1. The survival of the fishes of both targeted species was 100% during the study period. Length and weight relationship has been shown in Fig 1 and Fig 2 for *Channa andrao* and *C. stewartii* respectively.

In the present study, growth rate recorded on acclimatized wild stock of *C. andrao* and *C. stewratii* under laboratory condition indicated a favorable response. An isometric growth rate was exhibited during the rearing period indicated that the prevailing environmental parameters were within the tolerance range for the targeted species. Breeding can be also induced by providing a suitable environment. Introducing floating plants and macrophytes helps to provide shelter as well as also stimulate a natural environment. Hence, the study supports that both the species can be cultured on large scale as ornamental fish to meet the global demand in asustainable way.

REFERENCES

Allen, D. J., Molur, S., & Daniel, B. A. (2010). The status and distribution of freshwaterbiodiversity in the Eastern Himalayas. Zoo Outreach Organisation, IUCN and Coimbatore, India, Cambridge, UK and Gland, Switzerland, 1-88.

Goswami, M. M., Borthakur, A., Pathak, J., 2006, Comparative biometry, habitat structure and distribution of four endemic snakeheads (Teleostei: Channidae) species of Assam, India. *Journal of Inland fisheries society of India,* 38(1), 1-8.

Harrington, L., Mookerjee, A., Kalita, M., Saikia, A., Macdonald D., & D'Cruze, N. (2021). Biological Conservation Risks associated with the global demand for novel exotic pets: a newand emerging trade in snakehead fish (Channa spp.) from India. *Biological Conservation,*265(2022) 109377.

Hensen, R. R., Ploeg, A., & Fossa, S. A. (2010). Standard Names for Freshwater Fishes in the Ornamental Aquatic Industry. OFI Educational Publication 5. Ornamental Fish International, The Netherlands, 146.

Jobling, M. (1983). A short review and critique of methodology used in fish growth and nutritionstudies. *Journal of fish biology,* 23, 686-703.

Lalhimpuia, D. V., & Lalronunga, S. (2016). *Channa aurantipectoralis*, a new species of snakehead from Mizoram, north-eastern India (Teleostei: Channidae). *Zootaxa,* 4147 (3), 343-350.

Molur, S., Smith, K. G., Daniel, B. A., & Darwall, W. R. T. (2011). The Status of Freshwater Biodiversity in the Western Ghats. International Union for Conservation of Nature (IUCN) Gland, Switzerland and Zoo Outreach Organization (ZOO), Coimbatore, India, 116.

Noga, E. J. (1996). Fish disease: Diagnosis and treatment. Mosby, St. Louis, Missouri.

Penning, M., Reid, G. McG., Koldewey, H., Dick, G., Andrews, B., Arai, K., Garratt, P.,Gendron, S., Lange, J., Tanner, K., Tonge, S., Van den Sande, P., Warmolts, D., & Gibson, C. (2009). Turning the Tide: A Global Aquarium Strategy for Conservation and Sustainability. World Association of Zoos and Aquariums, Bern, Switzerland.

Praveenraj, J., Uma, A., Moulitharan, N., & Singh, S. G. (2019). A new species of dwarf Channa(Teleostei: Channidae) from Meghalaya, Northeast India. *Copeia*, (107),61-70. https://doi.org/10.1643/CI-18079

Rhyne, A. L., Tlusty, M. F., Schofield, P. J., Kaufman, L., & Morris, J. A. Jr. (2012). Revealing the Appetite of the Marine Aquarium Fish Trade: The Volume and Biodiversity of Fish Importedinto the United States. *PLoS ONE 7:* e35808.

Rűber, L., Tan, H. H., & Britz, R. (2019). Snakeheads (Teleostei: Channidae) diversity and the Eastern Himalaya biodiversity hotspot. *Journal of Zoological Systematics and EvolutionaryResearch*, 1-31. https://doi.org/10.1111/jzs.12324

Tlusty, M. F., Rhyne, A. L., Kaufman, L., Hutchins, M., Reid, G. M., Andrew, C., Boyle, P., Hemdal, J., McGilvray, F., & Dowd, S. (2013). Opportunities for public aquariums to increase the sustainability of the aquatic animal trade. *Zoo Biology*.

Table 1 Specific growth rate (SGR) of *Channa andrao* and *C. stewartii*

Species	**Parameter**	**Initial average**	**Final average**	**SGR (%)**
Channa andrao	Total length (in cm)	6.762±1.31	14.2±1.333	5.99±1.76
	Total body weight (in gm)	5.684±1.56	13.167±1.37	
Channa stewartii	Total length (in cm)	16.046±1.603	22.63±1.539	6.846±1.64
	Total body weight 9in gm)	15.138±1.726	21.36±1.93	

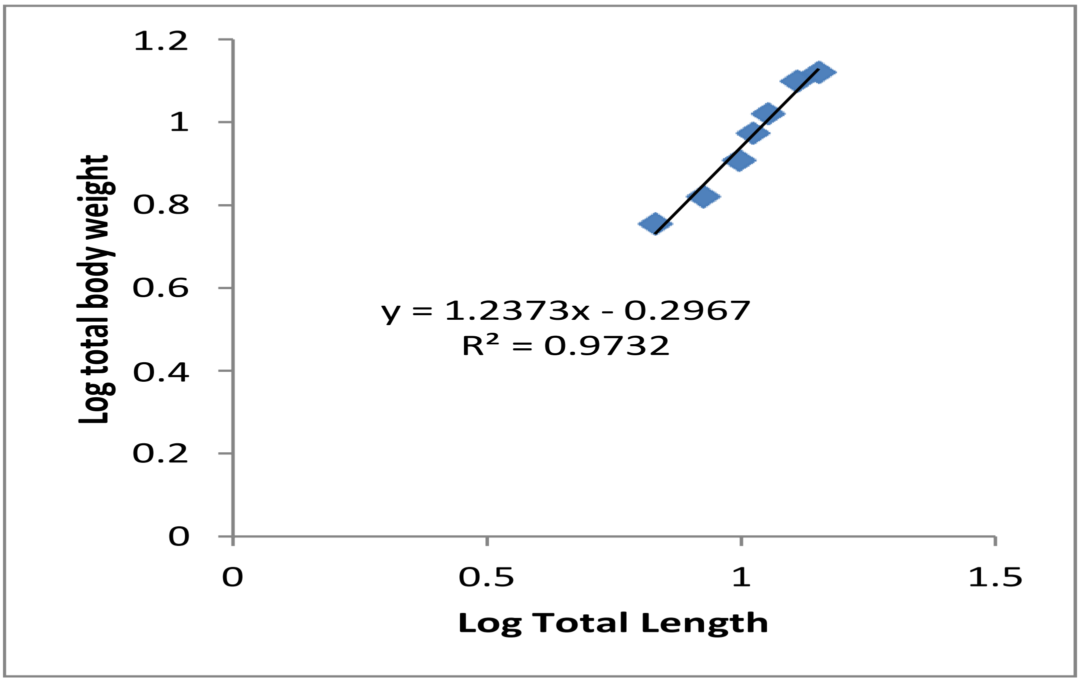

Figure 1 Length-weight relationship of *Channa andrao*

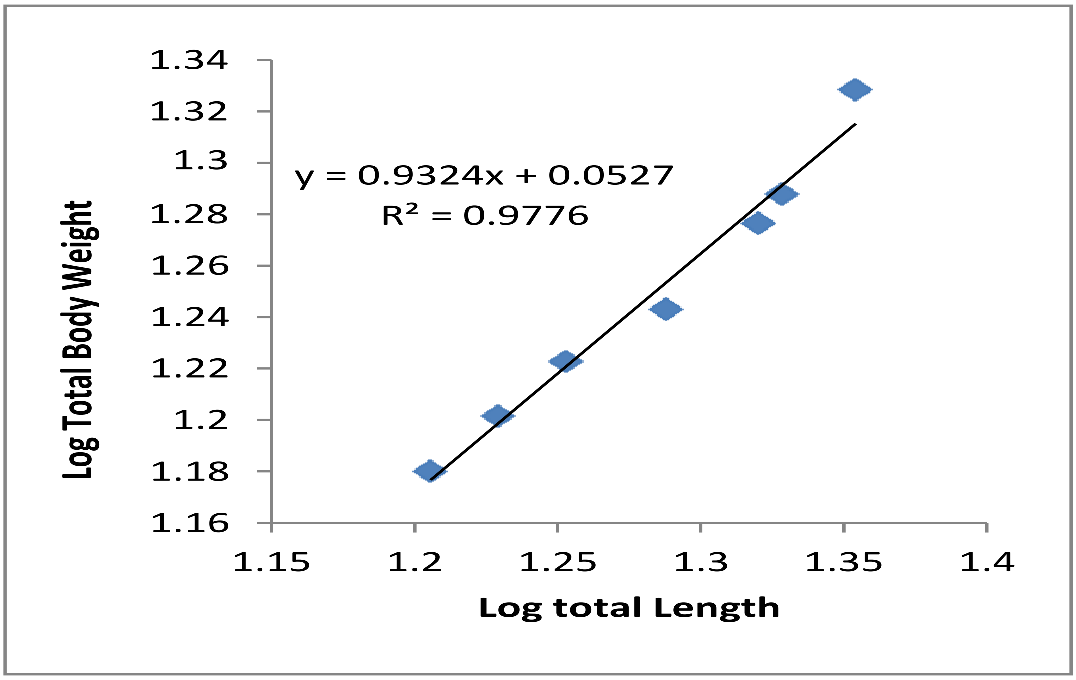

Figure 2 Length-weight relationship of *Channa stewartii*

ENHANCING SUSTAINABLE MANAGEMENT OF AQUATIC RESOURCES: "FRIENDS OF THE UMNGI RIVER" AND COMMUNITY, A NEW APPROACH TO RIVERINE BIODIVERSITY CONSERVATION

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INTRODUCTION

The Friends of The Umngi River, an Association of 20 villages under our organisation umbrella, with the village Chief and the village Secretary are the hardcore members of our organisation, and these village heads takes all the rules and regulations that all members of the village are part of the Friends of The Umngi River and their parts is to take care the area of the river that is close to their villages from illegal fishing. But from all these 20 villages Umpung village for a stretch of 3 Km. Took care with great endeavour and passion that is why we base our organisation at Umpung village as head office, because there are more fishes here, since all local villagers see this as a pride to safeguard the river. All these last seven years, we The Friends of The Umngi River, had tried to save the species of aquatic lives in this river with the help from the district authority and all the villages near the river are doing all we can. But, in order to truly repopulate our exotic fishes like the Golden Mahseer and Chocolate Mahseer we would need a hatchery for these fishes. If we are able to have a hatchery, then we could repopulate this river as well as other river in the state and would be able to cater to eco-tourism as well as to generate employment to the local youths through this. This is our new approach and enhancing our aquatic biodiversity with our local community on our role on aquatic biodiversity conservation in this great Umngi River. The research overview on Conservation effort for Golden Mahseer and Chocolate Mahseer through Hatchery will truly help us repopulate our river Umngi at a faster rate and this will help all other river as well by selling to other organisation/NGOs/Government Agency. After very long years from the year 2000 to 2020, I concluded that this river Umngi needs help to repopulate, and this can only be done with a local hatchery for golden and chocolate mahseer.

MATERIALS AND METHODS

Study Timeline

My Study Timeline that I had started was from the year 2000 till 2020 and my conclusion in this study was that this river Umngi needed to have a hatchery to repopulate this river in all its glory and our conservation effort with all other villages working hand together with our organisation "The Friends of The Umngi River".

Study area

The Geographic Scope for the Umngi River is the fact that the total length of this River is about 84 Km till our borders with Bangladesh and another 10Km from Bangladesh border to the lake and then from this lake it flows all the way with other rivers and series of lakes in Bangladesh all the way to the sea the Bay of Bengal. It has deep gorge and valley with a rough terrains upstream home for Golden and Chocolate Mahseer, *Labeo* and other small fishes, shrimps and crabs, frogs etc. While here near the Border with Bangladesh the terrain is rough but easy to trek and some part motor able all the way near the river banks. Whereby it's a great plain land. This River and its allied environment have a rich biodiversity both in flora and fauna all along the river system.

Species Covered

The species been studied are mainly fishes especially the Golden mahseer and Chocolate Mahseer and other fishes are *Bagarius* (Goonch), wild carp, wild silver carp, *Labeo*, *Garra*, *Balitora*, *Wallago*, eels, crabs, frogs and shrimps. All these species live in different parts of the river base on their own habitats ranging of temperature of the water, altitudes from sea level the terrains like stony areas, sandy areas and muddy areas. Also, some rather choose high currents and fast-moving water in the rapids and other in a slow flow viscosity of the river. So, all these species of aquatic life's live in different part of their habitat system adapted to their bodies. Even the depth of the river and shallow part of the river has fishes adapted in this river system as well. There are other fishes which migrate from Bangladesh during the rainy seasons and would go back before winter to Bangladesh areas. These are the species that are found all along the river Umngi. The river also shows recovery but at a slow rate whereby we as an organisation looking after the river together with all 20 villages living near this river are trying our best to stopped all illegal fishing especially netting, blasting of dynamites and using of chemicals in order to let the river heal itself in its biodiversity of life's, but we do allow only angling in this river to support the livelihood of the locals for food by angling.

Study Methodology

The method which I used was by tagging the few species of fishes as well as by trying with sonar method this help me to track them down both in rainy seasons and dry seasons to study their habitats. With this method I am able to know what types of fishes live in colder areas of the river and at a higher altitude from the sea level and from my studies in this river Umngi found out there are about 65 species of aquatic life's here, all of which live in different parts of the river depending on their adaptations to their habitats, for the whole stretch of 84 Km of this Umngi river. Also, by banning all illegal fishing helps my studies to find out their habitats also, this help in repopulate the aquatic lives in this river but it is a slow healing from over fishing. It is here that if we as an organisation and with Umpung village donating their village land for hatchery will help to repopulate the aquatic life's here in this Umngi river as well as other river in the state or even to the whole country as well. So, in this river we allow only angling which at times we have to organise awareness camps for all the villagers to educate them on saving this river and taking care of it. Also, to truly find out its true scientific names and family gender we will need the help of other institution in researching the aquatic life here. So, unless we are able to construct the hatchery ponds and the likes of it at the earliest will help this river very much to repopulate again to its glory again. As of now after seven years of conservation effort we sees that it is coming back to life again and many ardent anglers are coming to this river for angling such that one of the land owner had setup an eco-camps for angling and this open up to tourism and here we conduct adventure tourism and this helps generate incomes to the land owner of the eco camp as well as giving employment to the local youths such as guides, lifeguards, and for anglers they have to give donations for angling in this river here at Umpung village.

The details of my studies are specified to aquatic life and their habitats, and I classified them accordingly with temperature of the water and altitude from sea level, into two categories: 1. Local aquatic fishes and 2. Migratory fishes.

A) Local Fish: Here again I had classified them into three categories and they are: i). Fishes who usually live or are found mostly in fast moving water in the river like rapids, where there are only stones and few sand on the river beds are the Golden mahseer, Chocolate Mahseer, small minnows and Goonch a giant cat fish known as *Bagarius*. Fishes who live in the slower velocity/viscosity of the river which have more rocks and sands example of these fishes are the Calbasu, Tor species, wild pool Barb, Wild Silver Carp, Loach, Mottled Eel, Spotted eel, *Labeo* Species, Rohu Species, Glass fishes, Spike eels, Snake heads, popper fish and long mouth fish. iii). The fishes that live in the most gentle part of the river where there are mostly sands are the Wallago, *Glyptothorax*, Tengra, Bengal Loach, Magur, Silver Carp and small olive Barb.

B) Migratory fish: The Migratory fishes are the fishes that come from Bangladesh where there the river bed have mixtures of sands and mud and these fishes would come to our part of the river and country where they would spawn out and would mostly go back before the winter season, though some do stay back till the rainy season comes and the water level is way higher went they will go back to Bangladesh from lakes and rivers. This comes in many varieties of fishes both big and small species. Examples are the Wild Silver Carp, Wallago, Goonch, Magur, Labeo, Rohu, Pool Barb, Olive Barb and Asian Snake Head. All of these species and many more mostly come during the high level rises of the river in the rainy season from July and August every year and now we see the population of all type of fishes and some would choose to stay here this is because of our protection and conservation. But to be better equip we will need a hatchery for our species to thrive in our river.

REMARKS

The key observations and findings for these last ten years is the fact that the population of the aquatic life's and our biodiversity is becoming better but the healing process of this river is slow since we needed the hatchery especially for Golden Mahseer and Chocolate Mahseer, such that we could speed up to repopulate this river with our exotic Golden Mahseer and Chocolate Mahseer for a start and for other fishes like Calbasu and wild carp will start in the future as and went we are setup properly. The Main observations and findings are the Golden mahseer and chocolate mahseer our local exotic fishes and they have been looked after and their migration pattern is like this: The Golden Mahseer would come down from high upstream of the main river during the rainy seasons and would go back to their home ground before the rain stopped. But they would never go the small river or tributaries also they would never go beyond high elevation where the temperature is colder for them. But their population for the last ten years had considerably better now than before. Also, unlike the golden mahseer the chocolate mahseer would come down from high upstream during the first level rise of the river and would go back to their home ground by the early winter seasons. But Chocolate Mahseer would migrate even to small streams apart from the main river and are found in all rivers and streams and also, they would go higher than the Golden

Mahseer even to colder temperature of the river right to the sources of this UmngiRiver. but as i had seen we truly needed a hatchery for these great fishes so that we can repopulate this river and many other rivers of our state. As this in turn would generate employment via for taking care of the hatchery and also, we would be able to sell to other organisations, Government to repopulate other rivers as well.

The key threats are the fact that about 5 species in the last 20 years had been extinct from this river and many more are endangered this studies let me and my team to form a group working hand in glove with the government or any other group/groups from domestic to national or international level to save this river Umngi so that the future generation would still see what this river is capable to hold the aquatic life's and a treasure of biodiversity. The main fact of fishes and aquatic life was dying back in year 2000 went i first came here was from due to over fishing in so many method like using of dynamites, chemicals, fish net and fish trap to catches fish. It is here i decided to come back here and start my effort first by studying this river and the aquatic biodiversity it can hold and support, so after 2015, I had to approach the government to help me form an association to protect this river Umngi and by applying the law for protection of the river by banning the use of Chemical, fish net, fish trap and Blasting of dynamite in this river so that we can protect the aquatic species from extinction. So, we start our conservation effort with 20 villages and for about 30 Km. All villages are all close to the river along the river, and the Government also after many appeals enacted the section 144 CrPc of the Indian penal code to banned fish net, use of chemicals, fish traps of all form and blasting of dynamites in this river, we allow only angling by fish rod and a hook and we the association of the friends of the Umngi river together with all these 20 villages had to work hard to see this law been acted and Umpung Village is very active to see and safeguard this river so here we are today this law still till date is standing and also we have a 100 metres plus as a sanctuary where no one is allow to fish, at Umpung village. But in the most remote areas the rampant fishing by all method is still used till date which we as an association tried to conserve this part and all part for 84 to 90 Km to protect and save it and from time to time tried to reach out to other villages high upstream beyond our reach and all are happy to conserve this river Umngi. While the opportunity from the effort of conservation resulted in eco-tourism bringing income and job opportunity. The fact that in Umpung the land owner had started an eco-camp to cater to tourism like, angling, kayaking, rafting, boating, trekking and sightseeing in our local areas. These surely bring job opportunity and incomes to the local people of the village as well as food from the river by angling. So, we can boost this opportunity for the local people via eco-tourism and if the hatchery is setup, then this will provide jobs and incomes to our organisation taking care this river Umngi.

KEY RECOMMENDATIONS AND CONCLUSIONS

The Umngi River and our aquatic biodiversity after these last ten years the river is healing and repopulating itself with our help of our organisation and the law which we work hand in glove with the government, to stop all illegal means of fishing allowing only angling. But the repopulating process by nature is slow and now days we could see fishes went the river water is clear and went it is not raining. With our organisation of twenty villages, we look forward at Umpung village to setup a hatchery for Golden Mahseer and Chocolate Mahseer. This is because these are the main local fishes and they would migrate only in our rivers upstream and downstream but would not go down to Bangladesh side of the river, also, they are still in need of help to raise their population. We as an organisation do looks for funds both for hatchery for this aquatic biodiversity and for creating awareness by conducting programs to other areas of the river villages so that the masses would be aware on how to safeguard this great river. This would help create jobs, employments, and incomes via eco-tourism, angling, kayaking and rafting in this river. the other part if we are able to setup or start the hatchery, we would be able to sell part of the raise in the hatchery to others who would want to buy from us, this would raise incomes and we could employ youths from the village to work in this hatchery facility. So, my final conclusion is the fact to speed up the repopulation process we would need a hatchery for all of these local fishes to repopulate this great aquatic biodiversity such that this river will be at its glory again.

SUSTAINABLE AQUACULTURE FOR FOOD AND LIVELIHOOD (SAFAL)

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ABSTRACT

Even though fish farming is well established in India, there are bottlenecks in the technical and financial capacity of fish producers as well as in the access to quality fingerlings, feeds and financial services. This slows down the expansion and sustainable development of aquaculture and the supply of fish products to the population. Fish is an important source of nutrients for humans and due to its competitive price, it is of exceptional importance for vulnerable parts of the population. The project "Sustainable Aquaculture for Food and Livelihood (SAFAL)" aims to promote sustainable and resource-efficient aquaculture, to increase availability of fish on local markets accessible for the food insecure. This shall be achieved by increasing production and generating more income and employment in the fish value chain. SAFAL is implemented in the States of Assam and Odisha, because their aquaculture sectors have an exceptional potential for growth in a sustainable way. The state of Assam in the North East Region (NER) of India produces 71% of the total fish production in the NER. The current aquaculture productivity ranges around 500 kg/ha and has a potential for doubling within a short time. In East India, the state of Odisha also has a long tradition in fish farming. To satisfy the market demand for fish products, Odisha currently depends on imports from neighbouring states (especially Andhra Pradesh), although the aquaculture sector has the potential to meet this demand. To support the development of the aquaculture sector, advisory services and financial literacy among producers shall be improved and production techniques shall be adapted to combat the challenges of climate change.

Keywords: BMZ, GIZ, sustainable, aquaculture, India, training, income, FPO, SHG

The Indo-German Cooperation project SAFAL is part of the Global Program "Sustainable Fisheries and Aquaculture" (GP Fish) under the special initiative "One World No Hunger" (SEWOH). The target groups of SAFAL are small-scale fish farmers, Farmer Producers Organization (FPOs), Self Help Groups (SHGs) and Aquaculture Service Providers (ASPs).

The following activities are foreseen:

1. **Trainings** on aquaculture techniques, business education and organizational structures of fish farmers and multipliers to improve productivity, profitability and the ability to successfully access financial services provided by government schemes.
2. **Organizational capacity building** for FPOs, SHGs and ASPs, to diversify their income generating activities, their services to farmers and to strengthen their organizational structure.
3. **Support the policy framework,** which provides the frame for the development of a sustainable and resource-efficient aquaculture. Sharing of experiences from project implementation and the support of a multi-stakeholder platform shall promote knowledge exchange among aquaculture stakeholders, government agencies, civil society organizations and academia.

The Ministry of Fisheries, Animal Husbandry & Dairying (MoFAHD) will be the main partner at the national level and will coordinate with the fishery departments of Odisha and Assam. Further important actors at state and local level are the Assam State Rural Livelihood Mission (ASRLM), Odisha Livelihood Mission (OLM), NGOs, the Central Institute of Freshwater and Aquaculture (CIFA), Odisha, College of Fishery Science, Assam, as well as Central Inland Fishery Research Institute (CIFRI), Assam.

The Global Programme Sustainable Fisheries and Aquaculture is implemented in **nine** different countries of Africa and Asia. The global programme is part of the Special Initiative "One World No Hunger" (SEWOH) of the German Federal Ministry for Economic Cooperation and Development (BMZ). The programme works along the fish value chain and involves all stakeholders — from fisheries authorities to pond farmers to create new and sustainable livelihoods in fishing, fish processing and other key sustainability aspects.

GIZ, on behalf of the German Federal Government, is a global service provider in the field of international cooperation for sustainable development. For over 60 years, GIZ has been working jointly with partners in India for sustainable economic, ecological, and social development. The focal areas of the Indo-German cooperation are Energy, Environment, Climate Change and Biodiversity, Sustainable Urban and Industrial Development, and Sustainable Economic Development.

As part of the Indo-German Technical Cooperation, the project "Sustainable Aquaculture for Food and Livelihood (SAFAL)", is planned for implementation in Assam and Odisha in cooperation with the Ministry of Fisheries, Animal Husbandry and Dairying, Govt. of India. The project aim is to provide technical training on sustainable and resource-efficient pond management as well as business development training for Farmer Producer Organisations (FPOs), women Self Help Groups (SHGs) and Aquaculture Service Providers (ASPs) to increase fish production and income along the entire value chain.

SAFAL is in the sector of rural development and food security and is part of the Special Initiative "One World No Hunger" (SEWOH). The project objective is to provide more fish products and higher income from sustainable and resource-efficient pond-based aquaculture for the food-insecure population in Assam and Odisha.

The project promotes availability and access to fish as a nutrient-rich food, contributing to Sustainable Development Goal (SDG) 2 (zero hunger). The project also contributes to SDG 1 (no poverty) through productivity enhancement activities, improved business skills and promotion of income generating activities. Target groups are small-scale fish producers, Farmer Producer Organisations (FPOs), multipliers and policy-makers. The political partner is the Ministry of Fisheries, Animal Husbandry and Dairying (MoFAHD). It also supports the political partner's (i.e., MoFAHD) objectives of organising small producers in FPOs and increasing aquaculture production. Sustainable aquaculture as a commercial activity creates jobs and income opportunities in rural areas. At the political level, the project promotes dialogue and knowledge exchange in the sector to support the sustainable development of aquaculture through an appropriate policy framework and to prevent potential negative social and environmental impacts.

Key outputs are an **increased production of fish** from sustainable aquaculture and the associated **increase in income** and demand for labour. The political and institutional framework conditions for the implementation of sustainable and resource-saving aquaculture shall be improved. Project duration is from 05/ 2021 to 06/2024.

The strategy paper of the National Bank for Agriculture and Rural Development (NABARD) from 2018 emphasizes the importance of FPOs to provide small producers with access to markets and financing mechanisms. Even though pond-based aquaculture is well established, bottlenecks exist in the provision of fingerlings, feed and financing mechanisms, which limit the expansion of aquaculture and the supply of fish products to the population.

The SAFAL project of the Global Programme for Sustainable Fisheries and Aquaculture (GP Fish) supports small farmers, public and private service providers (Aquaculture Service Providers, ASPs) and other actors in the value chain (e.g., hatcheries, feed producers, fish traders) in the states of Assam and Odisha. SAFAL aims at increasing the availability of fish for the nutritionally insecure population through sustainable aquaculture in small-scale pond farming. The promotion of FPOs and Self-Help Groups (SHGs), in which small-scale producers are organized, improves access to knowledge (technical and business management), resources (fingerlings and feed) and financial services. It also supports the political partner's (i.e., MoFAHD) objectives of organising small producers in FPOs and increasing aquaculture production. Sustainable aquaculture as a commercial activity creates jobs and income opportunities in rural areas. At the political level, the project promotes dialogue and knowledge exchange in the sector to support the sustainable development of aquaculture through an appropriate policy framework and to prevent potential negative social and environmental impacts.

At the same time, the SAFAL programme promotes multi-stakeholder partnerships to achieve positive impacts for different stakeholders in the aquaculture value chain. In doing so, positive impacts are sought at various levels:

- **Ecological sustainability**: e.g., promoting environmentally and climate-friendly aquaculture farming

- **Social sustainability**: e.g., creating jobs and improving working conditions, especially for young adults and women.

- **Economic sustainability**: e.g., increasing production and income from sustainable fish farming; strengthening the resilience of smallholder farms to climate fluctuations and economic crises; strengthening local value creation and international marketing of Indian fish.

Over 2 years, SAFAL aims to reach out through its various activities in Assam and Odisha, covering at least 4625 acres of pond area under farming. For that, SAFAL is working together with 3 partner NGOs in Assam and Odisha. Together with the NGO partners, SAFAL project is working on developing a customised sustainable mechanism to support farmers, SHGs and build a sustainable business model of FPOs via developing a strong aquaculture-based Community Resource Person (CRP) and master trainers for CRPs. In addition, support is provided to develop training modules and learning material for CRPs, master trainers and farmers.

From the beginning, the project implements a result-based monitoring system which monitors the entire change process of the project. Furthermore, this system is used to manage the project and acts as the basis for project evaluations and for reporting to the German Federal Ministry for Economic Cooperation and Development. It also contributes to intra-project learning. Results-based monitoring not only observes the results achieved at the end of the project term, but also traces process developments and therefore monitors the entire course of the project.

In the beginning of the project, a baseline study has been conducted to contribute to the result-based monitoring system. This survey collected information from the different target groups. In addition to fish producing households, the survey team conducted interviews with consumers (non-fish-producing households) and other value chain actors. Further, persons in charge of FPOs and SHGs were interviewed. All target groups were surveyed within the same region of the producers. The information obtained from the target groups forms the basic framework for project management. For each target group a specific survey was developed. The questionnaires are designed for mobile data collection using Kobo Toolbox on android tablets and were conducted with the help of enumerators. For the baseline study over 1900 people were interviewed, including around 900 fish producers, 200 value chain actor and 600 consumers.

The surveys focused on the following topics:

- Food insecurity
- Purchasing and consumption behaviour regarding fish
- Economic information (only producer and value chain actor)
- Technical information (only producer and value chain actor)
- Training needs (only producer)

Finally, this project provides an understanding of the different target groups, shape the sustainable customised support and monitors the increase in fish production and income along the entire value chain.

In conclusion, the project aims to provide technical support with via replicable and scalable mechanism for empowering farmers. This is expected to lead towards enabling them to make an informed decision on risk, investment and access to finance through the technical and financial knowledge gained on sustainable aquaculture practises.

HISTOPATHOLOGICAL ALTERATIONS IN THE LIVER AND KIDNEY TISSUES OF LABEO ROHITA (HAMILTON, 1822) INFECTED BY ARGULUS FOLIACEUS

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ABSTRACT

The present investigation was carried out in pathological and histological alteration findings from acute and chronic infection in *Labeo rohita* naturally infected with *Argulus*. Fish samples were obtained from fish farmers of Kamrup district of Assam. The clinical signs in infested adult fish were lethargy, anorexia, poor growth, erratic swimming and mortality. Histological study revealed marked alterations in liver and kidney tissues in comparison to normal architectures observed in control fish. Degeneration of blood vessels, hypertrophy, increased pyknotic nuclei and lesions were observed in liver. In the kidney, shrinkage of the glomerulus, and hyaline degradation were observed. These results can suggest that histopathological variations influenced by the *Argulus foliaceus* in *Labeo rohita* can act as a susceptible to diseases, a potential threat to fish farmers and lead to economic loss.

Keywords: histology, *Argulus*, *Labeo rohita*

INTRODUCTION

Parasitic infestation is the most significant disease affecting in aquaculture system and it causes economical losses for this growing industry in intensive culture systems causing great losses in fish stocks (Ruane *et al*., 1999) in several countries. Fish may be infected by the parasites as final or intermediate hosts in a parasitic life cycle (Hoffman, 1999; Smith and Roberts, 2010). *Argulus*, Fish lice are the common name for branchiurid ectoparasite of fish. The genus *Argulus* is a crustacean ectoparasite of freshwater fish. *Argulus* is the only large (5–10 mm long) external fish parasite, except for leeches and a few isopods, that can move freely over the surface of a fish (Ruane *et al*., 1999). The occurrence of argulosis is season dependent. They get attached to the host by pressing their shield-like cephalothoraxes onto the skin like a sucker. The second antennae and millipedes are used as clamps.

Outbreaks of epizootics have been reported worldwide, causing mass mortalities, and having serious economic implications in northeast India. *Labeo rohita*, a freshwater major carp fish inhabits both shallow and running water, mostly surface feeders, has fusiform body shapes, a delicious and abundant fish species in the Indian freshwater ecosystem has pronounced economic importance to the Indian aquaculture system. The parasitic community of fish show considerable variation in the environmental conditions in which fish live (Hossain *et al*., 2008). Certain environmental conditions are more conducive to disease among which water temperature is one of the important criteria associated with disease outbreaks.

In addition to affecting the blood parameters of the fish, ectoparasites adversely affect the health of the fish by causing histopathological damage in the fish tissues where they locate (Timur *et al*., 2005; Korun, 2006; Koyuncu, 2006; Bamidele, 2007; Adeyemo and Agbede, 2008; Raissy and Ansari, 2011). Fish ectoparasites commonly lead to acute or chronic inflammation, degenerative changes, necrosis arising out of vascular pathology (haemorrhage) and hyperplasia (Feist and Longshaw, 2005).

MATERIALS AND METHODS

During the routine sampling programme on fish health monitoring in the fish farm of Kamrup district, Guwahati, a case of *Argulus* infection in Indian major carp, *Labeo rohita* was recorded in a pond. The infected specimens of carp were brought to the laboratory in live condition and thorough patho-anatomical and histo-pathological observations were made. Macroscopically inspection of the infected specimens including examination of the fins, skin, mucous and blood for ectoparasitic forms was followed by an examination of fresh tissues of liver, kidney, and gill. Collection and preservation of *Argulus* followed by Aalberg *et al*. (2016). Identification of the genus *Argulus* followed by Hoffman (1977), Rushton-Mellor *et al*. (1994) & Aalberg *et al*. (2016). Study of the physico-chemical parameters of the study area followed by APHA (2005). Histopathological study followed by Stockopf's method (1993).One sample was collected with a syringe containing anticoagulant 10%-EDTA and the other without it. These procedures were carried out within 0.8-1.2 minutes to minimise stress.

Tissue samples from the internal organs were also fixed in Bouin's fluid for histo-pathological studies. Paraffin-embedded sections were cut by a Rotary microtome and stained with haematoxylin and eosin (H & E). The histological preparations were examined under a light microscope and photomicrographs of the stained preparations were made.

RESULTS

The parasite was identified as *Argulus foliaceus* of based on morphological characters. This parasite is 5.9 mm long and 5 mm wide. It has a flattened, oval body which is almost entirely covered by a wide carapace. Compound eyes are prominent, and the mouth parts and the first pair of antennae are modified to form a hooked, spiny proboscis armed with suckers. The ectoparasite infection is observed during the month of December – March when the water parameters recorded slightly under fall which was probably due to a decrease in temperature level. Some of the water parameters recorded were as follows:

Five to twenty-five *Argulus* were found attached to the skin of infected fish, averaging 19.0 ± 14.6 (mild infection). However, as parasite removal was performed after blood withdrawal, some crustaceans from the hosts' bodies could have been lost. *Argulus* were found attached to the integument and gill of the fish host and visual examination revealed no macroscopic lesions. The control group was free from parasites.

The normal liver is made up of a continuous mass of hepatocytes arranged in irregular cords. The hepatic cells are polygonal in shape with distinct nuclei. The nuclei of the liver cells are vesicular with a large nucleolus, numerous bile ductules, blood capillaries and sinusoids. Marked toxic effects were observed at the structural and cellular level in the liver from the affected site. The disintegration of cell boundaries and slight dilation of blood sinusoids were observed, and many damaged hepatic cells and intracellular vacuolation were also apparent. Swollen hepatocytes, lose the connection between the cells and increase the accumulation of pyknotic Nuclei were also seen in some areas.

The histo-pathological observation of liver in infected *Labeo rohita* showed marked degenerative changes *viz.*, vacuolization in the cytoplasm, degeneration of hepatocytes at the periphery and change in the shape of the hepatocytes. The decrease in the diameter of the hepatic cell was due to shrinkage of the cell. The nuclei became pyknotic and eccentric.

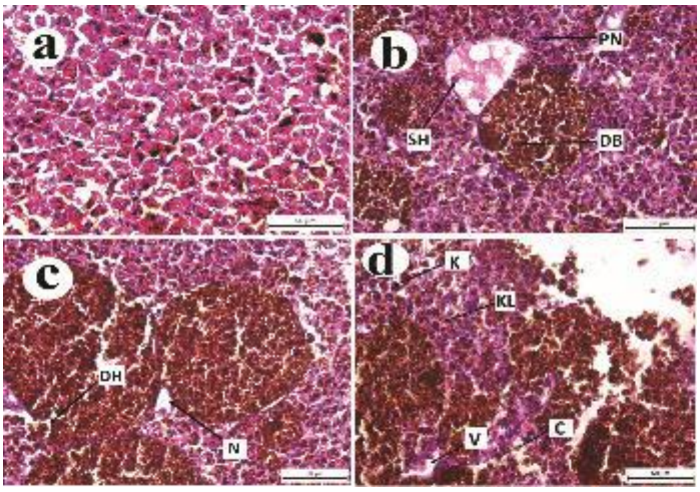

Fig. 1 T. S. of liver (a) Control showing normal H- renal hepatocyte, BS- blood sinusoids and (b) affected liver tissue showing BH- blood haemorrhage, DH- degradation of hepatic parenchymal cell, PN- pyknotic nuclei increases, N- necrosis, BD- blood vessel disrupted, DB- dilation of blood vessel, V- parenchymal vacuolisation.

The histological structure of the kidney of control fish showed a large number of uriniferous tubules composed of cuboidal epithelial cells having a central or marginal nucleus and eosinophilic cytoplasm. The renal corpuscle is comprised of a glomerulus surrounded by a single-layered Bowman's capsule. Many blood capillaries and vessels containing blood cells were seen. The histopathological abnormalities in kidney includes enlargement of renal tubules and hyperplasia. Kidneys were also showed disturbed organization of Bowman's capsule and renal tubule such as shrunk renal tubules.

On microscopic examination the kidney of the fish *Labeo rohita* infected with parasite demonstrated necrosis of cell and renal tubules, cloudy swelling in renal tubules, degeneration of cytoplasm within pyknotic nuclei, and disorganization of connective tissue (haemopoietic tissue). The disintegration of cell membrane, hypertrophy of nuclei, vacuoles, and the swelling of glomeruli also appeared.

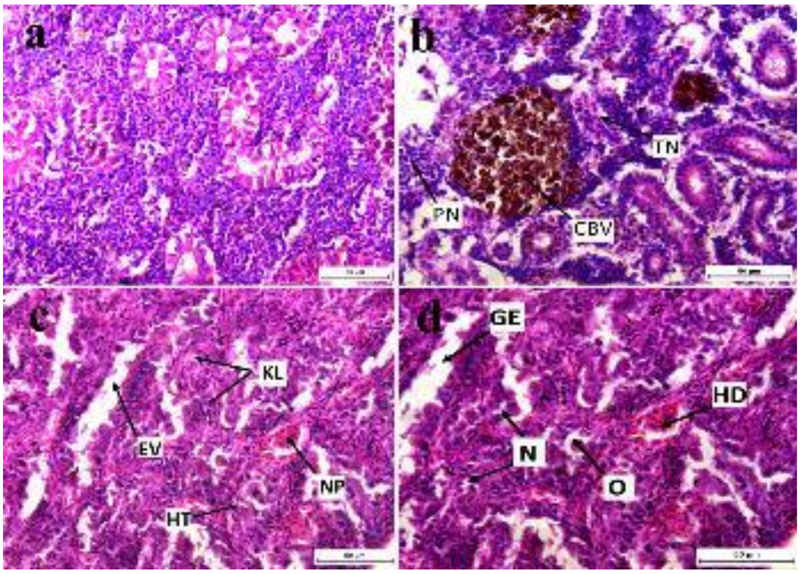

Fig. 2 T. S. of kidney (**a**) control showing normal RC- renal corpuscles, RT- renal tubules; (**b**) to (**d**) affected kidney tissue showing, TN- tibular necrosis, N- necrosis, GE- glomerular expansion, KL- karyolysis, HT- hypertrophy, CBV- congestion of blood vessels, NP- nuclear pyknosis, HD – hyaline droplets degeneration.

DISCUSSION

The present investigation describes histopathological changes in a case of ectoparasite infection in Indian major carp, *Labeo rohita* Hamilton, which probably forms the first report on the subject from Assam. Parasitic infestation and disease are one of the major problems of fish culture that can cause mass mortality in culture operations. Water variables were observed to optimum level except for the conductivity level and the temperature. Conductivity indicates the freshness of the water. Physico-chemical parameters help in maintaining proper immune response in fishes (Bhatnagar *et al*. 2013). The results of water temperature in the present investigation concur with the earlier study that reported that water temperature, pH and dissolved oxygen are the three main parameters that are related to disease infestation as they fluctuate rapidly (Banerjee et al. 2010).

Pathomorphology of the liver revealed diffuse severe sinusoidal congestion, dilation of the blood vessel, blood haemorrhage, multifocal mild vacuolation of hepatocytes (fig. 1) and multifocal necrosis of hepatocytes. *Argulus*, an ectoparsite which feed on blood and other body fluids of host species and causes further harm to the fish by injecting digestive enzymes that can lead to systemic. These results are in consensus with the observations revealed by (Roberts, 2001; Eissa, 2002; Noga, 2010). Liver is the main organ for detoxification therefore, slight alteration in the liver be useful as markers that indicate the proper environmental stressors. Disintegrated blood vessels, disrupted hepatocytes, hyperplasia of present findings have similar observations reported by Sarkar *et al*. (2005) in *Labeo rohita* in toxicity study.

Kidney cell damage in *Labeo rohita* due to the infestation of *Argulus foliaceus* can be seen in Fig.2. The damages were necrosis, hyaline degeneration, hypertrophy, congestion of blood vessels, nuclear pyknosis etc. Necrosis is the death of tissue cells (Hong *et al*., 1998) which have been due to the toxin material released by the parasite. Necrosis results in the formation of red coloured tissue as the effect of excessive erythrocytes due to the inflammatory response in active tissues around the necrosis. Kidney damage in the form of hyaline degeneration is characterized by the appearance of hyaline droplets in the tubular lumen, swollen tubular cells, shrinking tubular lumen, nuclear membrane and pink colour in hematoxylin-eosin staining. Kidney tissue damages such as hemorrhages, Glomerular destruction, pyknotic nuclei in fishes are the common histological effect due to the parasitic infection (Alvarez-Pellitero and Sitja-Bobadilla, 1993). As the parasite feed on hosts blood and in that process it release toxin which causes severe damage in tissues which may lead to the abnormal metabolic activity in fishes resulting in slower growth and sometimes death of the organisms. Similar results were stated earlier (Veeraiah, 2001), when *Labeo rohita* was exposed to cypermethrin.

To our knowledge, the present study is the first report of *Argulus foliaceous* infection in Assam, northeast India. It has been reported that high stocking density of fingerlings is another reason for ectoparasitic disease outbreaks (Hossain et al.,2008). High stocking density increases the chance of ectoparasite transmission from fish to fish easily as it increases the availability of hosts for infection. Further, an increase in stocking density leads to unhygienic conditions of the pond, competition for and sometimes excess food deposits in the pond and excess excretion in the environment which leads to changes in water parameters. Rohu has been found to be the most susceptible species among all Indian carp (Dey, 1989). Thus, it can be summarised that the water quality has a great impact on the abundance of parasitic infestation and their ability to survive on the host. Therefore, the stocking density and water quality should be maintained in proper conditions to avoid a parasitic infestation in the aquaculture system.

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REFERENCES

Aalberg, K., Koščová, L., Šmiga, Ľ., Košuth, P.Koščo, J., Oros, M., Barčák, D., Lazar, P. (2016) A study of fish lice (*argulus* sp.) infection in freshwater food fish. *FOLIA VETERINARIA*, 60 (3), 54—59,

Adeyemo, A.O. and Agbede, S.A. (2008) Histopathology of tilapia tissues harbouring Clinostomum tilapiae parasites. *African Journal of Biomedical Research*, 11, 115-118. https://doi:10.4314/ajbr.v11i1.50677

Alvarez-Pellitero P, Sitja-Bobadilla A. (1993) Pathology of Myxosporea in marine fish culture. *Diseases of Aquatic Organism*, 17, 229–232

APHA. Standard methods for examination of water and wastewater, 21st Edn. [AWWA, WPCF, Washington DC, USA; 2005].

Bamidele, A. (2007) Histopathological study on the parasitised visceral organs of some fishes of Lekki Lagon, Lagos, Nigeria. *Life Science Journal*, 4 (3), 70-76.

Banerjee S. and Bandyopadhyay P.K. (2010) Observation on prevalence of ectoparasites in carp fingerlings in two districts of West Bengal. *Journal of Parasitic Diseases,* 34 (1), 44–47 https://doi. 10.1007/s12639-010-0003-6

Bhatnagar, A. S.; Krishna, A. G. G. (2013) Effect of Extraction Solvent on Oil and Bioactives Composition of Commercial Indian Niger (Guizotia abyssinica (L.f.) Cass.) Seed. *Journal of the American Oil Chemists' Society*, 90 (8), 1203-1212.

Dey, R.K. (1989) Histopathology of Argulosis in the Indian major carp, *Labeo rohita* (Hamilton). Proc. Natl. Sem. On "Forty Years of Aquaculture' in India: 7-9 SVP/6.

Eissa, I.A.M. (2002) Parasitic fish diseases in Egypt. El- Nahda ElArabia Publisher, 32 Abd ElKhalek Tharwat street, Cairo, Egypt.

Feist, S. W. & Longshaw, M. (2005) Myxozoan diseases of fish and effects on host populations. Acta Zoologica Sinica 51, 758–760.

Hoffman, G. L. (1977) Argulus, a Branchiuran Parasite of Freshwater Fishes. Fish Disease Leaflet No. 49. U. S. Fish and Wildlife Service. Washington, D.C. 9 pp.

Hoffman, G. L. (1999) Parasites of North American freshwater fishes. 2nd edition, Ithaca (NY), Cornell University Press, 539 pp

Hong, J.R., Lin, T.L., Hsu YL, Wu, J.L. (1998) Apoptosis precedes necrosis of fish cell line with infectious pancreatic necrosis virus infection. *Virology*, 250,76–84.

Hossain, M.D, Hossain M.K, Rahaman M.H., Akter A., Khanom D. A. (2008) Prevalence of ectoparasites of carp fingerlings at Santaher, Bogra. *University Journal of Zoology, Rajshahi University*, 27, 17–19.

Korun, J. and Akaylı, T. (2004) A case of parasitic isopoda: Ceratothoa oestroides on the cultured sea bass (Dicentrarchus labrax L.) and seconder bacterial infections. *Turkish Society for Parasitology*, 31, 123-132.

Koyuncu, C.E. (2006) The infection of *Trichodina* sp. in some of the aquarium fishes (Carassius auratus L., 1758) in Mersin district. E.U. *Journal of Fisheries & Aquatic Sciences*, 23, (3-4), 327–330.

Noga, E.J. (2010) Fish disease diagnosis and treatment. 2nd ed., Mosbyyearbook, Inc. watsworth publishing Co., USA. 366 pp.

Raissy, M. and Ansari, M. 2011. Histopathological changes in the gills of naturally-infected *Capoeta aculeata* (Cuvier and Valenciennes, 1844) with parasites. *African Journal of Biotechnology*, 10 (68), 15422-15425.https:// doi:10.5897/AJB11.1838

Roberts, R.J. (2001). Fish Pathology 3rd ed., W.B. Saunders, An imprint of Harcourt Publishers.

Sarkar, B.; Chatterjee, A.; Adhikari, S.; Ayyappan, S. (2005), Carbofuran and cypermethrin induced histopathological alterations in the liver of Labeo rohita (Hamilton) and its recovery. *Journal of Applied Ichthyology*, 21, 131–135.

Smith, S. A., Roberts, H. E. (2010) Parasites of fish. In: Fundamentals of Ornamental Fish Health. Roberts H. E. (ed). Hoboken (NJ): Wiley-Blackwell, pp. 102-112.

Sophie K. Rushton-Mellor (1994) The genus Argulus (Crustacean: Branchiura) in Africa: identification keys. *Systematic Pathology*, 28, 51-63,

Timur, G., Güvener, R.P. and Korun, J. (2005) A histopathological study of Pleistophora spp. infection in a platy fish (Xiphophorus maenlatus). *The journal of the Faculty of Veterinary Medicine University of Istanbul*, 31 (2), 9-18.

Veeraiah, K. (2001) Cypermethrin Toxicity and its impact on histochemical and Histological changes in the Indian major carp *Labeo rohita*(Hamilton). Ph.D Thesis, Nagarjuna University, Guntur, India.

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