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Geospatial Mapping and Health Status of Some Important Ornamental Fish Habitats of Upper Assam, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

To conserve and manage water resources, it is crucial to create a record of water bodies and their catchments, which can be accomplished through digitized maps. The research focused on five rivers - River Dibru, River Sessa, River Burhidihing, River Brahmaputra, as well as two wetlands of Upper Assam - Maguri Beel, and Mer Beel. These water bodies were chosen based on their abundant fishery resources. Each selected water body was divided into three segments, and one sampling station from each segment was selected for monitoring water quality and recording fish species. The distribution of the catchment area was analyzed in the form of raster maps and geomorphology maps. Based on fish landings, the water bodies were identified and classified, and fish samples were collected through regular field surveys. Over the period from January 2021 to

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December 2022, eleven physicochemical parameters of the selected water bodies were recorded seasonally to assess the health status of each water bodies. Similarly, the health status and growth coefficient of each fish specimen was done.

Water parameters were mostly within the standard limits and demonstrated only a narrow range of seasonal variation. In the studied water bodies, 49 ornamental fish species representing 32 genera under 18 families and 8 orders were found. Among the water bodies, River Dibru had the highest number of ornamental fish species at 46. The order Cypriniformes was dominant in all the studied sites.

Keywords: Mapping; water parameters; cyriniformes; Assam.

1. INTRODUCTION

The North-Eastern Region (NER) of India is rich in diverse geographical features and is considered to be one of the major hotspot regions for biodiversity [1]. This region is home to over 300 species belonging to 132 genera across 38 families [2 ,3]. Assam, a significant part of this biodiversity hotspot, boasts a rich variety of fish and other aquatic resources such as rivers, streams, ponds, low-lying areas, and paddy fields [4]. Despite this richness, there has been very little conservation work focusing on the management and preservation of these wetland resources in Assam. For the effective conservation and management of these wetland resources, it is crucial to have an inventory of wetlands and their catchment areas [5]. Digital mapping has proved to be a powerful tool for storing and analyzing essential data. Geographic information is vital for making informed decisions regarding aquaculture, including site selection, species choice, and conservation strategies. Studies suggest that Geographic Information Systems [6,7]. (GIS) is becoming increasingly popular as an effective tool for decision -making in aquaculture development and sustainability [8,9]. The diversity of fish in a given aquatic ecosystem is considered an indicator of its overall health. Diversity indices provide a numerical method for understanding the structure of aquatic communities, including macro-invertebrates, phytoplankton, and fish, by taking into account the relative abundance and distribution of different species within the community [10,11]. The primary objectives of this study are to map selected wetlands and rivers with high fish diversity using remote sensing and GIS, and to assess the health status of these water bodies.

2. METHODS AND METHODOLOGY

Ground truthing of the selected water bodies was conducted to map the aquatic resources. This involved verifying the remotely sensed data with the actual field survey to estimate the health status of the water bodies. A total of 11 abiotic parameters including water and air temperature, pH, water depth, water current, transparency, conductivity, dissolved oxygen (DO), free CO_2, alkalinity, and total hardness were recorded using standard methods (APHA, 2005) seasonally (monsoon, post-monsoon, winter, and pre-monsoon) from January 2019 to December 2021. A GPS device was used to locate the study areas, which included five rivers and two wetlands. Google Earth images were used to find the water bodies. The health status of each ornamental fish species was determined following Biswas [12].

3. RESULTS

The ground truthing of sampling sites was done to verify the remotely sensed data with the ground reality or field survey. The observations have been summarized below:

The **R. Sessa** is a slow-moving open stream with co-ordinates N 27°20´19.4˝ - E 94°51´45.9˝, flowing through the Tinsukia and Dibrugarh districts before meeting the R. Burhidihing. The river gets most of its water from rain and almost comes to a standstill during the winter. It has varying water discharge and velocity, making it a highly productive stream. During the non-rainy season, the river is mostly occupied by water hyacinth. Jeng fishing is common in the slow rivers during the post-monsoon and winter. R. Sessa is rich in ornamental and upland fish species such as *Erethistes pussilus, Hara hara,* and *Sisor rabdophorus.*

As for the **R. Burhidihing,** it is the largest open stream with coordinates N 27°18´39.3˝ - E 94°53´02˝, a south-bank tributary of the R. Brahmaputra and about 380 km long in Upper Assam. The river originates at 2,375m above sea level in the Eastern Himalayas (the Patkai Hills), flowing through Arunachal Pradesh and then entering the Tinsukia and Dibrugarh Districts in Assam before reaching its confluence with the Brahmaputra at Dihingmukh. Its watershed covers about 6,000 km^2. It is a meandering river with sinuosity of 1.6, causing the river banks to shift along its meandering bends. The river has become shallower with lower current velocity, and the bank area is predominantly composed of unstable soil dominated by sand. Bank erosion is noticeable on the left side of the river.

R. Brahmaputra: At Nimatighat, with the geographical coordinates N 26°51'31" E 94°14'55.4", there is a high rate of erosion of the river bank, and the river is very wide and highly braided. The Water Resources Department (WRD) is implementing anti-erosion measures using geo-bags, and the river bank is surrounded by a huge embankment to control flood water. In winter, the river becomes very shallow, and sand bars are prominently visible. Nimatighat is a significant fish landing center in upper Assam, with fish mostly coming from Majuli. Various types of food and ornamental fish have been recorded at Nimatighat.

The **R. Jia Bhorali** is a significant tributary of the Brahmaputra River located in the northern bank region. Its geographical coordinates are N 27°34'36.2" - E 95°23'42.9". Originating in the lower Himalayas in Arunachal Pradesh, it is known as the Kameng River and spans approximately 264 km. The river enters the Sonitpur district of Assam and eventually meets the Brahmaputra River at Tezpur, east of the Kolia Bhomora bridge. The Jia Bharali serves as a trans-boundary river for the Nameri National Park and tiger reserves in Assam. This river features diverse habitats, including alternate riffles and pools, which support a wide variety of upland and hill-stream fish fauna. The deep pools are home to upland fish species such as *Bangana dero*, *Labeo pangusia*, and *Neolissocheilus hexagonolepis*. In addition to these, the gravel beds of riffles provide habitats for hill-stream fish genera like *Garra*, *Lepidocephalichthys*., *Danio*, and *Barilius*.

Mer Beel is located over a 207.506 hectare area with geographical coordinates at N 27°00´37.6 - E 92°39´25.9˝. The beel consists of a large swampy area with a variety of macrophytes and medicinal plants. There are also grass and fallow land areas as well as human settlements. Common wildlife in the vicinity includes leopard, python, and during winter, Mer Beel becomes a hotspot for migratory birds. It is home to numerous small and air-breathing fishes as well as giant catfish. The area has also become a popular tourist destination, and is known for hosting ornamental fish species such as *Channa aurantimaculata, C. bleheri,* and *C. stewartii*.

The R. Dibru river originates from the Naga Hills and Meghalaya, located on the south side of the valley with coordinates N 27°35´39.7˝- E 95°19´32.8˝. It is bounded on the north by the Brahmaputra and Lohit rivers, covering an area of about 1,535 km^2. The river course has undergone significant changes around Dibru-Saikhowa National Park, with sand bars showing considerable changes, especially downstream beyond Rangagora Tea Estate. The river bank area is composed of unstable soil dominated by sand, and erosion on the left bank is highly noticeable due to dense population. The river forms several wetlands due to changes in its course, including the Maguri Beel. Fishing is a significant livelihood for the local population, and eco-tourism also provides opportunities for many youths. Aquatic pollution is detected post-monsoon.

Maguri Beel: It is an open wetland with geographical coordinates N 27°18´57.8˝ - E 95°12´08.8˝, blessed with diverse ecosystems and abundant ichthyo-faunal diversity. The wetland is connected to the Dibru river, which flows from east to west through the area near the confluence of the three rivers that form the Brahmaputra. It is one of the most threatened floodplain wetlands and is facing severe over-exploitation. The wetland is surrounded by swamp forests, semi-evergreen forests, deciduous forests, and wet evergreen forests, covering an area of 167.40 hectares at Full Storage Level (FSL) and 117.18 hectares at Dead Storage Level (DSL). The beel is highly infested by aquatic vegetation, predominantly *Eichhornia crassipes* and *Nelumbo nucifera*. It is a major source of fisheries, particularly for endemic and rare ornamental fish such as *Channa bleheri, C. stewartii,* and *C. aurantimaculata*.

Table 1. Condition (K) factor and growth co-efficient(b) of ornamental fish species

SL. No.	Fish species	PRM		M		PSM		W	
		Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value
1.	*Paracanthocobitis botia* (Hamilton,1822)	2.47	1.33±0.14	2.97	1.57±0.22	2.74	1.31±0.16	2.45	1.12±0.05
2.	*Lepidocephalichthys guntea*(Hamilton,1822)	2.65	1.21±0.92	2.84	1.44±0.16	2.54	1.22±0.17	2.52	1.17±0.17
3.	*Canthophrys gongota*(Hamilton,1822)	2.61	1.14±0.31	2.89	1.67±0.17	2.81	1.53±0.09	2.52	1.03±0.23
4.	*Botia dario*(Hamilton,1822)	2.77	1.01±0.45	3.15	1.44±0.63	2.44	1.23±0.07	2.31	1.0±0.06
5	*Trichogaster fasciata*(Bloch & Schneider)	2.73	1.17±0.17	2.97	1.78±0.32	2.32	1.34±0.21	2.57	1.13±0.18
6.	*Trichogaster lalia*(Hamilton,1822)	2.71	1.34±0.54	2.86	1.38±0.18	2.66	1.55±0.23	2.54	1.21±0.05
7.	*Xenentodon cancila*(Hamilton,1822)	2.88	1.37±0.05	3.13	1.89±0.22	2.65	1.28±0.19	2.52	1.14±0.23
8.	*Mystus tengara*(Hamilton,1822)	2.73	1.43±0.04	3.15	1.81±0.24	2.56	1.28±0.41	2.52	1.07±0.7
9.	*Mystus vittatus*(Bloch,1794)	2.61	1.11±0.11	2.32	1.90±0.18	2.53	1.71±0.12	2.63	1.0±0.22
10.	*Mystus cavasius*(Hamilton,1822)	2.47	1.82±0.14	2.64	1.87±0.24	2.55	1.37±0.43	2.51	1.07±0.42
11.	*Chanda nama*(Hamilton,1822)	2.45	1.76±0.04	2.46	1.99±0.15	2.67	1.27±0.13	2.41	1.21±0.19
12.	*Parambasis ranga*(Hamilton,1822)	2.98	1.28±0.23	2.76	1.35±0.14	2.72	1.18±0.34	2.42	1.02±0.06
13.	*Gudusia chapra*(Hamilton,1822)	2.56	1.13±0.06	2.67	1.22±0.28	2.58	1.46±0.02	2.28	1.01±0.13
14.	*Channa punctata*(Bloch,1793)	2.76	1.22±0.77	2.98	1.72±0.19	2.35	0.98±0.09	2.32	0.97±0.23
15.	*Channa stewartii*(Playfair,1867)	2.57	1.16±0.09	3.06	1.87±0.22	2.52	1.33±0.22	2.12	0.83±0.22
16.	*Channa gachua*(Hamilton,1822)	2.55	1.11±0.04	3.21	1.98±0.55	2.56	1.09±0.87	2.33	0.97±0.18
17.	*Gagata cenia*(Hamilton,1822)	2.57	1.23±0.07	2.56	1.41±0.12	2.51	1.54±0.05	2.54	1.58±0.18
18.	*Devario devario*(Hamilton,1822)	2.56	1.17±0.98	2.67	1.51±0.07	2.56	1.57±0.04	2.21	0.97±0.05
19.	*Puntius sophore*(Hamilton,1822)	2.36	1.03±0.02	2.99	1.47±0.33	2.61	1.33±0.15	2.43	1.03±0.17
20.	*Cabdio jaya*(Hamilton,1822)	2.42	1.15±0.09	2.88	1.44±0.9	2.64	1.43±0.22	2.49	1.02±0.17
21.	*Salmophasia bacaila*(Hamilton,1822)	2.58	1.17±0.16	3.13	1.99±0.12	2.56	1.33±0.21	2.33	1.16±0.09
22.	*Parambassis lala*(Hamilton,1822)	2.51	1.04±0.22	2.61	1.34±0.16	2.51	1.22±0.02	2.28	0.88±0.18
23.	*Glossogobius giuris*(Hamilton,1822)	2.52	1.11±0.22	3.24	1.84±0.03	2.61	1.32±0.91	2.33	1.19±0.13
24.	*Macrognathus aral*(Bloch &Schneider)	2.53	1.04±0.34	3.28	1.81±0.33	2.68	1.55±0.33	2.45	1.01±0.23
25.	*Mastacembelus armatus* (Lacepede,1800)	2.56	1.19±0.03	3.11	1.78±0.17	2.62	1.48±0.92	2.24	0.90±0.11

SL. No.	Fish species	PRM		M		PSM		W	
		Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value	Mean "b" value	Mean "K" value
26.	*Macrognathus pancalus*(Hamilton,1822)	2.37	1.03±0.21	2.82	1.33±0.12	2.51	1.23±0.03	2.21	0.99±0.17
27.	*Nandus nandus*(Hamilton,1822)	2.59	1.13±0.67	2.76	1.63±0.13	2.51	1.62±0.03	2.53	1.03±0.02
28.	*Ompok pabda*(Hamilton,1822)	2.88	1.24±0.44	3.45	1.78±0.32	2.71	1.42±0.01	2.35	1.04±0.16
29.	*Pseudotropius atherinoides*(Bloch,1794)	2.63	1.44±0.44	3.13	1.78±0.55	2.38	1.16±0.03	2.34	1.02±0.5
30.	*Ailia coila*(Hamilton,1822)	2.51	1.05±0.04	3.19	1.66±0.44	2.59	1.45±0.04	2.19	0.85±0.55
31.	*Leiodon cutcutia*(Hamilton,1822)	3.24	1.79±0.02	2.67	1.41±0.93	3.41	1.88±0.22	2.50	1.08±0.03
32.	*Erethistes hara*(Hamilton,1822)	2.55	1.75±0.03	3.51	1.98±0.09	2.96	1.55±0.04	2.22	0.78±0.02
33.	*Ompok bimaculatus*(Bloch,1794)	2.55	1.11±0.34	2.61	1.18±0.06	2.49	1.22±0.05	2.51	1.05±0.33
34.	*Channa bleheri*(Vierke,1991)	2.67	1.42±0.03	2.87	1.61±0.03	2.59	1.32±0.55	2.09	0.87±0.07
35.	*Lepidocephalichthys thermalis*(Valenciennes)	2.63	1.32±0.06	3.14	1.88±0.02	2.97	1.39±0.33	2.51	0.99±0.02
36.	*Mystus dibrugarensis*(Chaudhuri,1913)	2.67	1.11±0.06	2.68	1.56±0.04	2.56	1.06±0.05	2.61	1.02±0.62
37.	*Channa marulius*(Hamilton,1822)	2.57	1.19±0.05	2.81	1.87±0.02	2.67	1.46±0.55	2.47	1.04±0.04
38.	*Channa striata*(Bloch,1793)	2.67	1.22±0.04	2.78	1.45±0.44	2.76	1.33±0.04	2.58	1.08±0.66
39.	*Amblypharyngodon mola*(Hamilton,1822)	2.33	1.17±0.22	2.51	1.45±0.02	2.56	1.01±0.03	2.27	1.00±0.04
40.	*Barilius barila*(Hamilton,1822)	2.59	1.22±0.18	2.72	1.33±0.67	2.45	0.98±0.19	2.13	0.87±0.16
41.	*Esomus danricus*(Hamilton,1822)	2.47	1.25±0.07	2.56	1.17±0.46	3.34	1.98±0.35	2.33	0.91±0.34
42..	*Rasbora daniconius*(Hamilton,1822)	2.66	1.18±0.9	2.82	1.33±0.14	2.73	1.23±0.14	2.45	1.04±0.05
43.	*Securicula gora*(Hamilton,1822)	2.76	1.24±0.07	2.98	1.45±0.56	2.67	1.29±0.54	2.36	0.88±0.29
44.	*Osteobramacotio cotio*(Hamilton,1822)	3.01	1.91±0.23	3.15	1.56±0.05	2.76	1.29±0.26	2.15	1.21±0.09
45.	*Pethia ticto*(Hamilton,1822)	2.98	1.33±0.06	3.56	1.78±0.17	3.31	1.88±0.27	2.18	0.99±0.23
46.	*Systomus sarana*(Hamilton,1822)	2.54	1.21±0.35	2.78	1.33±0.03	2.72	1.44±0.03	2.42	1.08±0.15
47.	*Cabdio morar*(Hamilton,1822)	2.59	1.33±0.06	2.82	1.44±0.15	2.62	1.23±0.17	2.51	1.05±0.21
48.	*Badis assamensis*(Hamilton,1822)	2.67	1.56±0.09	3.21	1.98±0.18	2.78	1.23±0.06	2.73	1.0±0.05
49.	*Badis badis*(Hamilton,1822)	2.87	1.67±0.03	3.63	1.85±0.29	3.21	1.56±0.42	2.55	1.26±0.21

The highest "K" value in the monsoon season was recorded in *Chanda nama* (1.99 ± 0.15), and the lowest was recorded in *Ompok bimaculatus* (1.18 ± 0.06). In the pre-monsoon season, the highest K value was recorded in *Osteobrama cotio cotio* (1.91 ± 0.23), and the lowest in *Botia dario* (1.01 ± 0.45). During the post-monsoon season, the highest "K" value was found in *Esomus danricus* (1.98 ± 0.35), and the lowest in *Channa punctata* (0.98 ± 0.09). In the winter season, the highest "K" value was recorded in *Gagata cenia* (1.58 ± 0.18) and the lowest in *Erethistes hara* (0.78 ± 0.02). Gender differences in the "K" value were not evident in different seasons. However, females during breeding seasons were relatively heavier than their male counterparts and eventually had a higher "K" value.

4. DISCUSSION

Water body mapping in Assam and Northeast India lacks specific records on water bodies related to ornamental fish resources. The use of Global Positioning System (GPS) has become crucial in modern mapping and monitoring of water bodies, replacing conventional data-gathering techniques. Reports indicate that Geographic Information System (GIS) is increasingly popular for decision-making models in aquacultural development, endorsed by the Food and Agriculture Organization (FAO) of the United Nations [13,14]. Advanced mapping techniques, including GIS and remote sensing, were applied to create maps of the catchment areas of the studied water bodies, providing detailed information on their significance. Raster maps and geomorphology maps were used to analyze the area distribution of the catchment area. Proper planning in aquaculture, such as site selection, species selection, and conservation approaches, necessitates consideration of geographical features, including the diversity of natural resources [14-18].

Water temperature plays a crucial role in regulating both abiotic and biotic factors in a water body, as noted by several authors [19,20]. Changes in temperature can affect the pH, dissolved oxygen (D.O.) content, and water hardness [21]. Throughout our observation, the average temperature fluctuated between 15ºC and 29ºC, which fell within the permissible range (15º to 35ºC) according to WHO guidelines [22]. Our study revealed seasonal variations in air and water temperature across different water bodies [23]. According to Rahman [10], the ideal range for water temperature to support aquatic life is 26-31 ºC. pH showed a narrow range of fluctuation throughout the season, varying from 7.0 to 8.3, meeting the prescribed range limits [24]. Higher pH values were predominantly recorded during winter and pre-monsoon in all the areas under study. On average, pH values were slightly alkaline (7.65) in all studied water bodies. The electrical conductivity (EC) in all water bodies ranged from 67 to 142 µS/cm. River water's EC is consistently higher during monsoons (Boruah & Biswas(22) . In our findings, EC values remained within the permissible limits of < 300 µS/cm. The Dissolved Oxygen (DO) content was mostly above the desirable lower limit (6 mg/l) across all water bodies, exhibiting significant seasonal variations. Higher values of dissolved oxygen were observed during the monsoon, while lower values were witnessed in winter and pre-monsoon. The range of dissolved oxygen was from the highest, 11.6±0.05 mg/l in R. Dibru, Guijan ghat, to the lowest, 6.22±0.08 mg/l in R. Sessa. These values were within the permissible limit (BIS, 1982), with similar findings reported by Sarmah et al. [11]. The acceptable limit of free CO_2 in surface water is 10mg/l. The average range of free CO_2 under study was 1.58-4.4 mg/L, with the maximum free CO_2 at 4.6 mg/L in R. Dibru, Guijan ghat, and the minimum at 1.58 mg/L in R. Burhidihing. The total hardness values in the study were within the permissible range (600 mg/L) according to standards [23]. The highest hardness (21±0.05 mg/l) was measured in R. Sessa during pre-monsoon, while the lowest (5.3±0.05 mg/l) was during winter in R. Dibru. The minimum total alkalinity recorded was 50.6±0.1 mg/l in R. Brahmaputra, Nimatighat, during monsoon, while the maximum alkalinity was recorded in R. Dibru during winter. Our findings align with those of Sarmah [17], who reported a similar seasonal fluctuation pattern in alkalinity in their studied wetlands in Upper Assam.

Morphometric-based condition indices (K or Kn) are commonly used to evaluate the robustness of fish, as well as their feeding and living conditions [25-27]. The condition factor (K) is an indicator of a fish's overall well-being, with values greater than 1 indicating good health [26,28]. The condition factor is based on the hypothesis that fish with a higher weight for a given length are in better physiological condition [29]. Factors affecting the condition factor include the fish's age, sex, season, maturation stage, gut fullness, and type of food consumed. A study found that the highest number of healthy fish was observed during the monsoon season, while the lowest number was found in winter, possibly due to food scarcity [30-32]. Sex differences had minimal impact on the relationship between the K-factor and body composition. Still, seasonal variance, especially during the breeding season, K-value was found on the higher side in gravid females. These findings align with previous studies on the condition factor of several ornamental fish species from the Brahmaputra basin [13-21,26], [22,33].

5. CONCLUSION

For conserving and managing water resources, it is important to have an inventory of water bodies and their catchments and this was achieved through digitized maps. To conserve these living jewels in their natural habitat, proper implementation of conservation strategies should be implemented. Strict implementation of the existing fishery and Environmental laws which prohibit illegal fish killing by poisoning the water or by using explosives is required. Regulation of fishing is one of the key factors for fisheries management; the others are environmental management for protecting the aquatic environment and artificial stock enhancement by ranching etc. People should be aware of the fact that fishery resources are exhaustible; therefore, controlled fishing is necessary for conservation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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