Journal of Applied and Natural Science
16(4), 1801 - 1811 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Habitat predilection of loach species *Aborichthys uniobarensis* through analysis of physicochemical parameters in Poma River, Arunachal Pradesh, Northeast India

Krima Queen Machahary
Department of Zoology, Rajiv Gandhi University, Rono Hills, Doimukh (Arunachal Pradesh), India
Awarlin Chetia
Department of Zoology, Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya, Amjonga, Goalpara (Assam), India
Debangshu Narayan Das*
Department of Zoology, Rajiv Gandhi University, Rono Hills, Doimukh (Arunachal Pradesh), India

*Corresponding author. E-mail: dndas2011@gmail.com

Article Info
https://doi.org/10.31018/jans.v16i4.6023
Received: July 25, 2024
Revised: December 4, 2024
Accepted: December 10, 2024

How to Cite
Machahary, K. Q. *et al.* (2024). Habitat predilection of loach species *Aborichthys uniobarensis* through analysis of physicochemical parameters in Poma River, Arunachal Pradesh, Northeast India. *Journal of Applied and Natural Science*, 16 (4), 1801 - 1811. https://doi.org/10.31018/jans.v16i4.6023

Abstract
The Poma River in Arunachal Pradesh serves as the primary habitat for *Aborichthys uniobarensis*, an ornamental fish species endemic to biodiversity hotspot. The present study aimed to investigate the habitat characteristics of *Aborichthys uniobarensis* within the Poma River. Given the species' predominant presence in this river, understanding the water quality of the Poma River is crucial for further biological research, and of course conservation aspect of this fish species within *in-situ* as well *ex-situ* habitat. Over a two-year period (January 2018 to December 2019), the study assessed various physicochemical parameters (pH, water temperature (WT), dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), free carbon dioxide (FCO_2), alkalinity, total hardness, electrical conductivity (EC), and salinity) at three sites along the Poma River with seasonal comparisons. Water samples were randomly collected in the morning between 6 a.m. to 10 a.m. Samples were analysed based on the standard methods of APHA (2012). The results indicated consistent conditions across sites but significant variations by season and year (Kruskal-Wallis and Mann-Whitney tests). Minimum values recorded were pH 6.29, WT 18.62°C, DO 6.55 mgL^{-1}, BOD 3.85 mgL^{-1}, TDS 29.78 mgL^{-1}, FCO_2 3.89 mgL^{-1}, alkalinity 37.25 mgL^{-1}, total hardness 23.71 mgL^{-1}, EC 57.22 μs/cm, and salinity 0.05 ppt, while maximum values were pH 7.42, WT 25.43°C, DO 7.80 mgL^{-1}, BOD 5.42 mgL^{-1}, TDS 71.12 mgL^{-1}, FCO_2 6.48 mgL^{-1}, alkalinity 59.34 mgL^{-1}, total hardness 45.62 mgL^{-1}, EC 117.33 μs/cm, and salinity 0.07 ppt. Simpson correlation tests revealed significant positive and negative correlations among the parameters. PCA analysis highlighted that WT, DO, pH, TDS, BOD, and FCO_2 (both physical and chemical factors) have a greater influence on supporting *A. uniobarensis,* other fish species and the overall health of the river. As the values of habitat parameters were within the acceptable range, the River Poma is congenial for *A. uniobarensis* along with other species available in this particular riverine habitat.

Keywords: *Aborichthys*, Nemacheilidae, physicochemical, Principal Component Analysis, water quality

INTRODUCTION

Arunachal Pradesh, a state located in the north-eastern region of India, is a part of the eastern Himalayan belt. The state is considered one of the hot spots of freshwater fish biodiversity (Kottelat and Whitten, 1996; Singh *et al.,* 2018; Gurumayum, 2021). *Aborichthys uniobarensis* is an elongated river loach that belongs to the family *Nemacheilidae*. This species was recently described from the Senki River within the Itanagar Wildlife Sanctuary of Arunachal Pradesh and is known to occur in moderate to fast-flowing rivers and hilly drainages consisting of gravelly bottoms (Nanda *et al.,* 2021). Like other nemacheilid loaches, it has potential ornamental value in the aquarium trade due to the presence of varied banding patterns, spots, and irregular black marks, pinkish tail, and feeding behavior that give it an attractive appearance (Abujam *et al.,* 2022).

So far twelve species of *Aborichthys* have been described from the various water bodies of Arunachal Pradesh, viz. *A. boutanensis, A. kempi, A. elongatus, A. garoensis, A. tikaderi, A. cataracta, A. verticauda, A. waikhomi, A. iphipaniensis, A. kailashi, A. pangensis,* and *A. bajpaii*, and some are also reported to be distributed in the Ganga-Brahmaputra drainage of northeastern India, Bhutan, and Putao in Myanmar (Shangningam *et al.,* 2019; Singh and Kosygin, 2022). However, the demand for *A. uniobarensis* was higher than that of other species in the context of wild collection for ornamental fish trade. So, there is an urgent need to explore its wild habitat parameters to standardize captive breeding and enhance *in-situ* conservation efforts.

Habitat parameters study is important to conserve freshwater fishes in the *in-situ* habitat as they are tremendously sensitive to the quantitative and qualitative alteration of water quality (Laffaille *et al.,* 2004; Sarkar *et al.,* 2008; Kang *et al.,* 2009). The Poma River, situated in a breathtaking location near the rapidly developing capital region, serves as a popular recreational spot, attracting local tourists almost year-round. Increased anthropogenic activities such as unplanned human settlement in river riparian vegetation, habitat fragmentation and deforestation, the establishment of stone-crushing factories in the area, and unsustainable fishing all contribute to environmental deterioration and habitat loss. Each fish species has a particular reproduction strategy adapted to reproduce under the most changeable environmental conditions (Nikolsky, 1980; Kachari, 2021). Similar works are accomplished in different aquatic systems of Arunachal Pradesh (Das *et al.,* 2014; Kachari *et al.,* 2014; Loyi *et al.,* 2015; Ering *et al.,* 2018; Bui and Lodhi, 2020; Kachari, 2021; Kiron *et al.,* 2021; Kunal *et al.,* 2021; Gaur *et al.,* 2022; Kiron, *et al.,* 2022). However, there is no documented information on the status of the water quality of Poma River to date. *Aborichthys uniobarensis* is a promising ornamental fish, and research on its habitat predilection is crucial for future conservation efforts, domestication, and trade. In view of this, the present study was conducted to unfold the *in-situ* habitat parameters of *A. uniobarensis* in Poma River of Arunachal Pradesh, northeast India.

MATERIALS AND METHODS

Study area

Arunachal Pradesh is located in the extreme east of India, 91°30" - 92°40" E and 26°54" - 28°01" N covering the area of 83,743 km^2. The river Poma comprises many unnamed small streams and rivulets coming from the hilly terrains of Arunachal Pradesh, flowing through the hilly and forested area to meet the Papum River, and finally draining into the Brahmaputra River at Tinsukia District of Assam (Gurumayum, 2021).

During the study period 2018 and 2019 (January - December), different aquatic bodies such as Rono stream (Rono Hills), Senki River, Kalma River, Hati nallah, Poma River, Moing drainage, Buka nallah (Sopo), Tumru nallah, and Nyorch drainage of Arunachal Pradesh were randomly visited to explore the distribution of *A. uniobarensis*. Among these sites, River Poma (Fig. 1, Supplementary Fig. 2(a,b,c)) was selected to evaluate the water quality parameters as the indicator of habitat study due to frequent catch of the species during random visits. The abundant fish species were also identified, matching the voucher specimens maintained in the Rajiv Gandhi University Museum of Fishes (RGUMF) and Zoological Survey of India, Itanagar.

Sampling of water parameters

Ten physicochemical parameters viz., water temperature (WT), pH, dissolved oxygen (DO), biological oxygen demand (BOD), free carbon dioxide (FCO$_2$), alkalinity, total hardness, electrical conductivity (EC), total dissolved solid (TDS), and salinity were selected for the sequential study. Water samples were randomly collected in the midstream of each 3 selected sites: Site-I (27^{0}3$^/$47.31$^{//}$N and 93^{0}31$^/$43.12$^{//}$E), Site-II (27^{0}3$^/$47.22$^{//}$N and 93^{0}31$^/$43.29$^{//}$E), and Site-III (27^{0}3$^/$58.57$^{//}$N and 93^{0}32$^/$9.97$^{//}$E) of Poma River in the morning between 6 a.m to 10 a.m. Three replicas of water samples of each site (for each parameter) were taken and the average values were calculated. Though sample collection was every month, to perform statistical analysis, values were pooled seasonally into four distinct seasons: pre-monsoon (March to May), monsoon (Jun to August), post-monsoon (September to November), and winter (December to February). pH, WT, DO, EC, TDS were measured at collection sites with the help of Portable Field Multiparameter Water Quality Meter (Hanna Instruments, HI98194). For BOD estimation water samples were taken in BOD (approximately 300 mL each) bottles and for estimation of other parameters were collected in triplicate using sterile 500 mL universal sample bottles and bought to the laboratory for further analysis. After filatration (used Whatman filter paper to avoid suspended solids) FCO$_2$, alkalinity, total hardness and salinity were analysed within 2 days, but BOD samples were kept in BOD incubator (maintaining 20°C) for 5 days and then analysed. Samples were analysed by adopting the standard methodology (APHA, 2012), and calculated values were compared with the standard values set for aquaculture (Bhatnagar and Devi, 2013).

Statistical analysis

Since the dataset did not follow a normal distribution, the non-parametric tests used in IBM-SPSS-23 included Simpson correlation, Kruskal-Walli's, Mann-Whitney

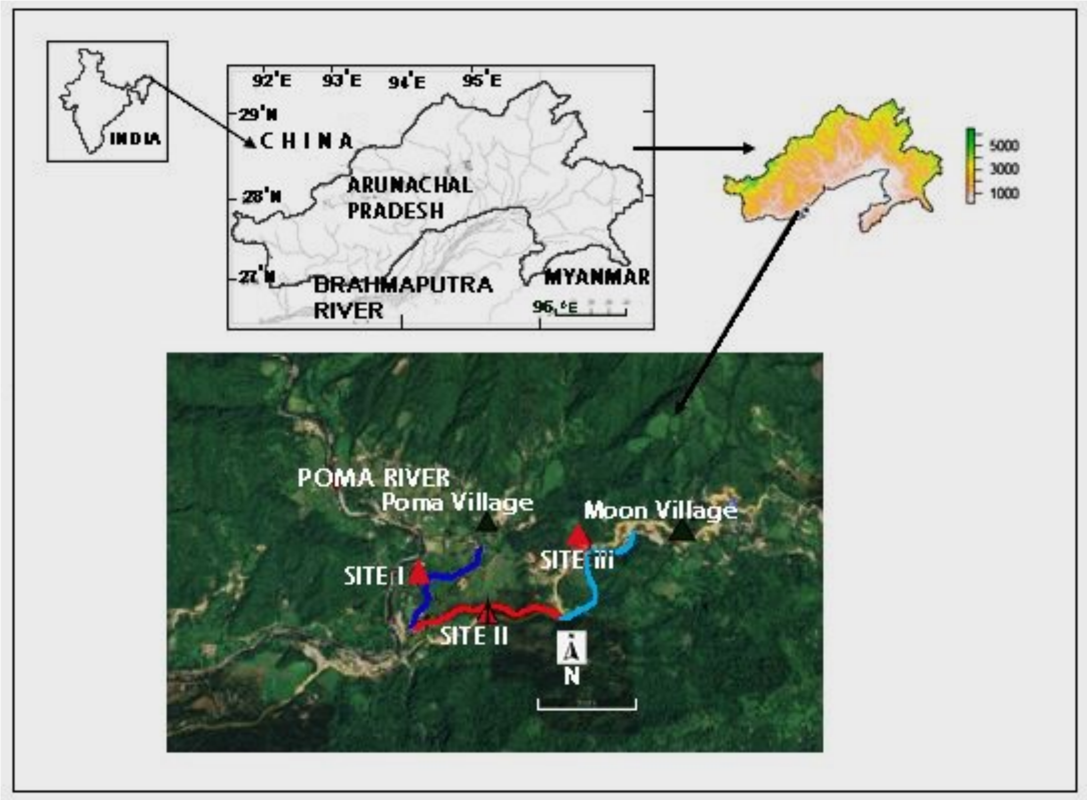

Fig. 1. *Map of Arunachal Pradesh showing sampling sites of the river Poma*

tests and Principal component analysis. Site mapping utilized R software version 4.3.0 and Google Earth, while MS Excel 2019 was employed for graphing purposes.

RESULTS AND DISCUSSION

During the study period, *A. uniobarensis* was encountered in cool rock-bedded water that flowed either fast or moderately in the Poma River of Arunachal Pradesh. The river Poma, which has generous diversity, is a preferred habitat for this fish species, thus making *A. uniobarensis* abundantly available. The other fish species dwelling with *A. uniobarensis* in Poma River were: *Barilius barna, Opsarius bendelisis, Danio dangila, Devario devario, D. equipinnatus, Olyra longicaudata. Tor putitora, Osteobrama cotio, Chagunius chagunio, Puntius conchonius, Puntius ticto, Puntius sarana, Garra birostris, Paracanthocobits botia, Pseudolaguvia vespa, Badis badis, Nandus nandus, Channa pomanensis, Amblyceps arunachalensis, Glyptothorax sp., Schizothorax sp., Devario aequippinatus,* and *Crossocheilus latius* (Gurumayum, 2021). The presence of fish species makes the River Poma valuable for *in-situ* autecological research on *A. uniobarensis,* indicating prestine aquatic environment.

The analysis of the water quality of Poma River revealed that the water parameters exhibited significant year-wise seasonal variations between different seasons and within the same season across two years (Table 1 and Supplementary Table ST1). For example, the DO concentration in the pre-monsoon period of the first year differed from that of the second year. Similarly, the total hardness values during the monsoon season and the alkalinity levels during winter showed significant ($P < 0.005$) differences between the first and second years (Supplementary Table ST1). The data for each parameter from the three sampling stations were analyzed separately using an initial Kruskal-Wallis test, and no significant differences were observed among the stations, except for salinity values between site 1 and site 3, which were found to be significant using the Mann-Whitney test (p= 0.02) (Supplementary Table ST 2 and 3).

pH

pH is a crucial factor in aquatic ecology, influencing water's physical and chemical properties (Adamou *et al.,* 2020). A higher pH concentration causes corrosion in aquatic organisms (Narasimha *et al.,* 2011) and can serve as an indicator for assessing the pollution level (Kumar *et al.,* 2011; Singh, 2014) and is often used as a parameter to ascertain the level of acidity or alkalinity (Ahmed *et al.,* 2024) of a water body. During the present study period, the minimum 6.29±0.30 and the maximum pH value of 7.42±0.34 were observed during post-monsoon and monsoon periods, respectively (Table 1). According to Bhatnagar and Devi (2013), a pH range of 6.5-9 is desirable for freshwater fish, and the current pH value, which is slightly acidic to neutral, falls within this acceptable range. The acidic pH of the Poma River is due to the effect of the soil quality in the hilly terrain through which it flows. This finding aligns with Bagra *et al.* (2014), who noted similar effects of river water on hilly regions. While most aquatic organisms can tolerate a pH range of 0-14 (Matta *et al.,* 2017), our findings align with those of Ering *et al.* (2018), which noted *A. kempi* inhabits water bodies in the hilly regions of Arunachal Pradesh, where the pH is nearly neutral to slightly alkaline.

Water temperature (WT)

The River Poma flows moderately at a low altitude with a discontinuous light canopy. Low-altitude rivers with smaller canopies are prone to higher water temperatures (Novikmec *et al.,* 2013). The temperature of an aquatic ecosystem is an important factor that influences the characteristics of abiotic factors and regulates the biotic activity (Ganie *et al.,* 2018), physiological activities of aquatic biota, including survival activities of fishes (Fry, 1971). During the study period, the WT of Poma river varied from 15.9℃ to 26.00℃. The average minimum (18.62℃) and maximum (25.43℃) water temperatures were recorded during winter and post-monsoon, respectively (Table 1). Kachari *et al.,* 2013 and Bui and Lodhi, 2020, recorded water temperature ranges of 16.60℃-26.50℃ and 19.00℃ - 25.60℃ from Dengka stream and spring water from Upper Subansiri respectively, which aligns with the present findings, and noted it to be in favourable condition for aquatic diversity. There was a significant difference (p<0.001) (Supplementary Table ST1) among the seasonal temperature. The seasonal variations of the River Poma, being the running water, were probably caused by climate, elevation, extent of streamside vegetation, and the relative importance of the groundwater inputs (Kachari *et al.,* 2013).

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is one of the crucial ecological factors for the survival of aquatic biota and is useful for assessing aquatic quality (Laluraj *et al.,* 2002; Geetha *et al.,* 2008; Islam *et al.,* 2017;). DO serves as a regulatory factor for maintaining diversity in aquatic environments and the discharge of waste can be assessed by the oxygen balance of the aquatic body (Matta *et al.,* 2017; Lone *et al*., 2021). The recorded DO concentration range in the present study was 5.00 mgL^{-1} to 8.66 mgL$^{-1,}$ respectively (Fig. 1, Table 1). The DO values varied with the time of day, season, and location. The minimum and maximum values of DO record throughout the investigation were 6.55±0.46 mgL^{-1} and 7.80±0.56 mgL^{-1} during monsoon and pre-monsoon, respectively (Table 1). According to Bhatnagar and Devi (2013), a DO concentration of 3-5 mgL^{-1} is suitable for aquatic organisms, indicating that the present DO values are higher than the desirable range. The variation of DO concentration is influenced by factors such as turbulence, elevation and temperature, primary production and the breakdown of organic waste (Kunal *et al*., 2021; Mir *et al*., 2023). Bhatnagar and Devi (2013) also noted that the concentration of DO is related to water temperature, with cold water supporting desirable DO levels for aquatic organism evident in the present study also (WT showed positive correlation with DO, p<0.001) (Table 2). Thus, the topography of the Poma river (Supplementary Fig. 2(a, b, c)) and the WT variation from 15.9˚C to 26.00˚C supports desirable oxygen levels for *A. uniobarensis* (Table 3).

Biological oxygen demand (BOD)

Biological oxygen demand (BOD) defines the amount of oxygen the microorganisms need to oxidize the organic matter in the water (Effendi and Wardiatno, 2015; Sarkar *et al.,* 2016; Singh *et al*., 2023). Lower BOD concentration is beneficial for aquatic organisms, as low BOD indicates lower organic pollution of the water (Hasan *et al.,* 2020). The BOD values ranged from 2.40 mgL^{-1} to 7.36 mgL^{-1} during the study period. The average minimum and maximum BOD values were 3.85±1.01 mgL^{-1} and 5.42±0.63 mgL^{-1} during pre-monsoon and post-monsoon, respectively (Table 1). The recommended BOD values for fisheries and other aquatic life are 3.0-6.0 mgL^{-1} (Chapman and Hall, 1996)). Higher BOD values result from the rapid utilization of oxygen at higher temperatures (Chetana and Somasekhar, 1997). The average maximum temperature (25.43±0.66℃) and its negative correlation with DO (p= 0.000 at 95 % confidence interval) suggest that microorganisms have a higher oxygen demand to oxidize organic matter. According to Rahman *et al.* (2021) BOD values are high at 20°C due to the high utlilization of oxygen by microorganisms. The direct discharge of untreated domestic waste into the Poma River could be the reason for the high BOD, as a similar observation was noted in Ganga Canal of Haridwar, Uttarakhand by Matta *et al.* (2017).

Free carbon dioxide (FCO_2)

Free carbon dioxide (FCO_2) is found in water in the dissolved state or bound form of earth's crust, particularly in limestone and coral reefs (Bhatnagar and Devi, 2013; Mir *et al.,* 2023). The concentration of FCO_2 in the Poma River ranged from 2.00 mgL^{-1} to 9.99 mgL^{-1}. The minimum and maximum mean FCO_2 values, recorded during the pre-monsoon and post-monsoon, were 3.89±1.31 mgL^{-1} and 6.48±1.55 mgL^{-1}, respectively (Table 1). According to Bhatnagar and Devi (2013) 5-8 mgL^{-1} FCO_2 is desirable for fish and aquaculture. The higher FCO_2 values observed in the present study may be attributed to the decay and decomposition of organic matter from the discharge of domestic waste and sewage into the water. This is supported by the negative correlation between FCO_2 and DO (p<0.001), and the positive correlation between FCO_2 and BOD (p=0.002). Additionally, elevated levels of free carbon dioxide could result from acceleration of organic matter decomposition and aquatic organisms respiratory activities (Mir *et al*., 2023)

Alkalinity

Alkalinity is a measure of the total concentration of bases like carbonates, bicarbonates, hydroxides, phosphates, calcium, magnesium, and the ability to resist changes in pH in water (Bhatnagar and Devi ,2013; Barakat *et al*., 2018). Alkalinity in hilly areas depends on the weathering of rocks over which the water flows Kunal *et al.* (2021). The values of alkalinity ranged from 31.80 mgL^{-1} to 64.00 mgL^{-1} and the lowest average alkalinity value, 37.25±4.70 mgL^{-1} was recorded during the post-monsoon period, and the highest value, 59.34±3.85 mgL^{-1} was recorded during the monsoon (Table 1). According to Bhatnagar and Devi (2013), the alkalinity range (Table 1) of Poma river was within the desirable limit. Kunal *et al.,* 2021, reported an alkalinity range of 23.00±3 mgL^{-1} to 83.00±15 mgL^{-1} in the spring water of Upper Subansiri, identifying it as the favourable range for growth of phytoplankton and an indicator of good primary productivity. This alkalinity range is consistent with that observed in the Poma river. It is proved that photosynthesis, denitrification and sulphate reduction increase the alkalinity concentration, whereas respiration, nitrification decrease its value (Stumm and Morgan, 1981; Cook *et al.,* 1986; Wolf-Gladrow, 2007; Hu and Cai, 2011). It is assumed that the phenomenon of evaporation and decomposing organic matter established a negative correlation ($r=-0.360^{**}$) between alkalinity and BOD (p= 0.002) (Table 1 and Table 2).

Total hardness

Total hardness measures the concentration of cations like calcium, magnesium and other ions such as aluminium, manganese, zinc, iron, hydrogen, etc., present in water (Singh *et al*., 2023). These cations are crucial for fish growth; calcium and magnesium are needed for bone and scale formation (Bhatnagar and Devi, 2013; Kunal *et al*., 2021). The presence of hydrogen ions might have influenced the total hardness of water. The slightly acidic to neutral pH values (pH= 6.00-7.87) also support the observed ranges of total hardness 16.40 to 70.60 mgL^{-1}, as indicated in Table 1. The average minimum and maximum total hardness were 23.71±5.28 mgL^{-1} and 45.62±17.78 mgL^{-1}, recorded during the winter and pre-monsoon, respectively (Table 1). The higher value of total hardness during pre-monsoon could be due to salts or cations (calcium, magnesium) leaching from soil due to pre-monsoon shower. According to Bhatnagar and Devi (2013), the total hardness of water within 12 mgL^{-1} and 300 mgL^{-1} is considered acceptable for freshwater fisheries and ranges from 75-150 mgL^{-1} is considered optimum for fish health (Bhatnagar and Devi, 2013).

Total dissolved solids

Total dissolved solids (TDS) measure the inorganic salts and selective organic matter in water (Kumar *et al*., 2020; Kunal *et al.,* 2021). The values of TDS ranged from 22.00 to 81.00 ppm. The minimum TDS value of 29.78±4.60 ppm was observed during winter, and the maximum TDS value of 71.12±6.47 ppm was observed during the monsoon (Table 1). Kunal *et al.* (2021) observed higher values of TDS during monsoon, which is attributed due to the mixing of allochthonous components in Kameng River from the surrounding soil as the outcome of surface runoff by rainwater. Similar observation was noted during the study, suggesting that mixing domestic waste in the Poma River may cause fluctuations in TDS values.

Electrical conductivity (EC)

Calculating Electrical conductivity (EC) is a way to measure the total ionic concentration (Ca^{2+}, Mg^{2+}, $HCO3^-$, CO_3^-, NO_3^- and PO_4^-) of a water body Bhatnagar and Devi (2013). The conductivity values varied from 49. 00 to 165.00 μs/cm. The minimum and maximum conductivity was 57.22±3.89 μs/cm and 117.33±35.36 μs/cm recorded during winter and pre-monsoon, respectively (Table 1). Freshwater ecosystem usually possesses 50 μs/cm to 1500 μs/cm conductivity (Boyd, 1979) and 300 μs/cm is a drinking water standard (ICMR, 1975). Therefore, the EC of Poma River is congruent with the desirable range for freshwater and found to be significantly correlated with TDS (p<0.001) (Table 2), indicating an increase in EC with the start of rainfall, which resulted in the accumulation of domestic waste to the river water.

Salinity

Salinity of water is the total concentration of electrically charged ions such as Ca^{2+}, Mg^{2+}, K^+, Na^+, CO_3^-, HCO_3^-, SO_4^-, Cl^-, and it also includes NO_3^-, NH_4^+ and PO_4^- concentrations (Bhatnagar and Devi, 2013). It is a crucial parameter that affects the density and growth of aquatic populations, including fish (Jamabo, 2008; Bhatnagar and Devi, 2013). The salinity range recorded during the study period was from 0.02 ppt to 0.16 ppt (Table 1). According to Likongwe *et al.* (1996), 0-8 gL^{-1} salinity is good for the growth of fish *Oreochromis niloticus* at 28-32 ˚ C. The continuous flowing fresh water with less dissolved ions in the river Poma menifested limited and lower values of salinity range as a characteristics of fresh water. However, salinity values differed signifi-

Table 1. Showing physicochemical parameters of Poma River water during the study period 2018 and 2019 (January-December) (Mean±SD values, n=3)

Parameters	1st year Pre-monsoon ean±SD),	2nd year Pre-monsoon (Mean±SD)	1st year Mon-soon (Mean±SD)	2nd year Mon-soon (Mean±SD)	1st year Post-monsoon (Mean±SD)	2nd year Post-monsoon (Mean±SD)	1st year Win-ter (Mean±SD)	2nd year Win-ter (Mean±SD)	*Standard values (Min-Max)
pH	7.42±0.34 (6.85-7.82)	7.33±0.35 (6.85-7.82)	6.91±0.19 (6.51-7.17)	7.15±0.38 (6.70-7.87)	6.29±0.30 (6.00-6.88)	6.47±0.38 (6.00-6.89)	7.34±0.19 (7.14-7.68)	7.41±0.29 (6.87-7.86)	(6.25-8.87)
WT (°C)	19.60±2.71 (16.2-23.00)	19.80±2.56 (16.8-23.1)	24.36±1.06 (23.0-25.8)	24.35±0.86 (23.1-25.2)	25.17±0.67 (24.0-26.0)	25.43±0.66 (24.4-26.0)	18.62±2.86 (16.0-22.5)	18.73±2.78 (15.9-22.6)	(15-35)
DO (mgL^{-1})	7.80±0.56 (6.84-8.66)	7.32±0.29 (6.92-7.86)	6.55±0.46 (5.64-7.26)	6.86±0.48 (6.30-7.64)	6.58±0.56 (5.60-7.36)	6.59±0.79 (5.00-7.36)	7.64±0.57 (7.00-8.46)	7.60±0.71 (6.40-8.66)	(3-5)
BOD (mgL^{-1})	3.85±1.01 (2.80-6.00)	4.40±1.43 (2.86-7.36)	4.79±1.02 (3.00-6.00)	4.74±0.57 (4.00-5.60)	5.42±0.63 (4.40-6.22)	5.22±0.38 (4.64-5.96)	4.06±1.08 (2.40-6.20)	4.07±1.08 (2.62-6.20)	(3-6)
FCO_2 (mgL^{-1})	4.13±1.41 (2.00-5.99)	3.89±1.31 (2.00-5.49)	5.95±0.89 (4.99-8.09)	5.43±2.11 (2.80-9.99)	6.31±1.23 (4.00-7.99)	6.48±1.55 (4.00-9.49)	4.05±1.71 (2.60-7.99)	4.21±1.61 (2.60-7.99)	(0-10)
TDS (ppm)	52.00±21.73 (22.0-74.0)	46.78±16.40 (22.0-63.0)	67.67±9.39 (54.0-81.0)	71.12±6.47 (63.0-81.0)	61.23±9.83 (46.0-71.0)	62.11±8.08 (49.0-71.0)	30.12±3.95 (24.0-37.0)	29.78±4.60 (24.0-37.0)	(<500)
Alk (mgL^{-1})	57.36±7.20 (46.5-63.5)	55.10±5.62 (48.2-62.50)	59.34±3.85 (54.0-63.90)	55.21±5.29 (49.30-63.5)	43.58±8.19 (32.20-55.2)	37.25±4.70 (31.80-44.1)	56.58±4.49 (49.8-64.0)	50.15±6.78 (42.0-61.10)	(50-200)
Har (mgL^{-1})	45.62±17.78 (26.00-70.6)	35.46±3.34 (30.0-40.00)	31.34±5.67 (25.9-41.10)	38.38±7.41 (25.30-46.8)	30.77±3.02 (26.1-34.30)	30.14±3.97 (23.4-34.50)	23.71±5.28 (16.4-32.00)	24.78±4.61 (16.4-32.00)	(>20)
EC (µs/cm)	117.33±35.36 (79.0-165.0)	108.66±44.56 (49.0-157.0)	99.88±19.23 (78.0-126.0)	116.88±28.57 (78.0-149.0)	86.44±12.50 (68.0-98.0)	93.55±6.61 (85.0-104.0)	57.22±3.89 (51.0-62.0)	60.44±4.95 (54.0-68.0)	(20-1500)
Sal(ppt)	0.07±0.04 (0.02-0.16)	0.05±0.03 (0.02-0.12)	0.06±0.02 (0.02-0.09)	0.06±0.02 (0.03-0.08)	0.07±0.03 (0.04-0.14)	0.06±0.02 (0.04-0.10)	0.06±0.04 (0.02-0.13)	0.06±0.03 (0.02-0.12)	(2-10)

WT: Water temperature, DO: Dissolved oxygen, BOD: Biological oxygen demand, FCO_2: Free Carbon dioxide, TDS: Total dissolved solids, EC: electrical conductivity, Sal: Salinity, Alk: Alkalinity, Har: Total Hardness; *Source: Bhatnagar and Devi (2013)

Table 2. Pearson's correlation values of water quality parameters of Poma River

Parameters		pH	WT	DO	BOD	FCO_2	TDS	Alk	Har	EC	Sal
pH	Co-coef	1.000	-.732**	.485**	-.528**	-.428**	-.330**	.384**	-.172	-.182	-.149
	Sig.	.	.000	.000	.000	.000	.005	.001	.148	.125	.212
WT	Co-coef	-.732**	1.000	-.688**	.638**	.627**	.643**	-.335**	.337**	.516**	.117
	Sig	.000	.	.000	.000	.000	.000	.004	.004	.000	.330
DO	Co-coef	.485**	-.688**	1.000	-.507**	-.357**	-.475**	.230	-.125	-.292*	-.035
	Sig.	.000	.000	.	.000	.002	.000	.052	.295	.013	.771
BOD	Co-coef	-.528**	.638**	-.507**	1.000	.473**	.191	-.360**	.133	.112	.207
	Sig.	.000	.000	.000	.	.000	.108	.002	.267	.348	.082
FCO_2	Co-coef	-.428**	.627**	-.357**	.473**	1.000	.318**	-.261*	.036	.125	-.146
	Sig.	.000	.000	.002	.000	.	.007	.027	.764	.297	.220
TDS	Co-coef	-.330**	.643**	-.475**	.191	.318**	1.000	.197	.505**	.659**	.175
	Sig.	.005	.000	.000	.108	.007	.	.098	.000	.000	.141
Alk	Co-coef	.384**	-.335**	.230	-.360**	-.261*	.197	1.000	.248*	.082	-.117
	Sig.	.001	.004	.052	.002	.027	.098	.	.035	.492	.329
Har	Co-coef	-.172	.337**	-.125	.133	.036	.505**	.248*	1.000	.616**	-.063
	Sig.	.148	.004	.295	.267	.764	.000	.035	.	.000	.600
EC	Co-coef	-.182	.516**	-.292*	.112	.125	.659**	.082	.616**	1.000	.154
	Sig.	.125	.000	.013	.348	.297	.000	.492	.000	.	.196
Sal	Co-coef	-.149	.117	-.035	.207	-.146	.175	-.117	-.063	.154	1.000
	Sig.	.212	.330	.771	.082	.220	.141	.329	.600	.196	.

Abbr. WT: Water temperature, DO: Dissolved oxygen, BOD: Biological oxygen demand, FCO_2: Free Carbon dioxide, TDS: Total dissolved solids, EC: Electrical conductivity, Sal: Salinity, Alk: Alkalinity, Har: Total Hardness.

cantly between site 1 and site 3 ($p<0.05$, according to the Mann-Whitney test). The average salinity range recorded was 0.02-0.10 for site 1 and 0.02-0.13 for site 3. The relatively higher salinity at site 3 may be due to drier conditions. Topographical observations suggest that site 3, with its wide, gravel-filled area, often has less water than the other sites. Berger *et al*. (2019) also found that dryness increases water salinity in river ecosystems by reviewing salinity studies in various rivers worldwide.

The range of physical and chemical water parameters in the Poma River indicates that the water quality is suitable for supporting aquatic biodiversity, including the abundance of *A. uniobarensis*. Maintaining these water conditions is crucial for preserving the species in its natural habitat and can also contribute to future research on captive breeding, which is an effective conservation strategy for such species having restricted in situ habitat. Being ornamentally lucrative for the aquarium fish trade, its conservation and artificial propagation may also positively impact the country's economy. However, the fluctuating values (for example, BOD, FCO_2, Table 1) observed for the physicochemical parameters suggest that the river water may be slightly impacted at present and is at risk of pollution due to the dumping of domestic waste by residents and tourists, as well as unplanned setting up of stone and pebble removers and stone crushing machines.

Simpson's correlation analysis, supplemented with an analysis of regulating factors using water quality parameters from the river, might have revealed the gradual process of habitat degradation through the vulnerability of certain parameters and regulating factors.The Simpson's correlation coefficient was used to show the interrelationship and coherence pattern among the river water quality parameters. The analyzed correlation coefficient values are given in Table 2. pH showed a significant positive correlation with DO and alkalinity and exhibited a negative correlation with water temperature, BOD, FCO_2 and TDS. Kumar *et al.* (2011) stated that temperature influences pH, alkalinity and DO concentration. The pH of water is also influenced by the concentration of FCO_2 (Boyd, 1979). Water temperature showed a positive correlation with BOD, FCO_2, TDS, total hardness, and electrical conductivity. The concentration of DO, as it depends on various factors, showed a positive correlation with pH and a negative correlation with water temperature, BOD, FCO_2 and TDS. BOD also showed a negative correlation with alkalinity and a positive correlation with FCO_2. According to Boyd and Pillai (1985), FCO_2 is related to phytoplankton growth and depends on alkalinity concentration. However, alkalinity also exhibited positive correlation with total hardness. The TDS also showed a positive correlation with total hardness and conductivity. A study revealed that TDS might influence taste, total hardness, and corrosion properties and regulate various other factors (Seth *et al.,* 2016). Total hardness is also positively

Table 3. PCA analysis: loading values, eigenvalues, component loading and percentage and cumulative percentage

Component	Eigen values	Percentage of variance	Cumulative percentage of variance
PCA1	3.785	37.848	37.848
PCA2	2.121	21.206	59.055
PCA3	1.157	11.573	70.628

Table 4. Results of the Principal component analysis (PCA) of different physicochemical parameters of study sites

Parameters	Components		
	PCA1	PCA2	PCA3
Water temperature (^{0}C)	0.955		
DO (mgL^{-1})	-0.732		
pH	-0.729		
TDS (ppm)	0.715	0.587	
BOD (mgL^{-1})	0.686		
Free CO_2 (mgL^{-1})	0.636		
Hardness (mgL^{-1})		0.775	
Electrical conductivity (µs/cm)		0.718	
Alkalinity (mgL^{-1})		0.631	
Salinity (ppt)			0.947

correlated with conductivity and the other water parameters (Table 2).

The study indicated that the water parameters are correlated with each other, with certain parameters functioning cumulatively, and they have effect on both water quality and the aquatic organisms present. The PCA analysis comprises loading values, eigenvalues, component loading and percentage and cumulative percentage (Table 3, 4, Supplementary Fig. 1). the four Principal components account for 70.63 % of the total variance in the study. The first Principal component (Factor 1) defined 37.85 % of the variance, including water temperature, BOD, total hardness, TDS, and electrical conductivity, in the form of the highest weightage parameter. The second Principal component (Factor 2) comprised 59.06 % of the total variance and 59.06 % of total variance and includes pH, free carbon dioxide and alkalinity. Whereas the third Principal component (Factor 3) defined 70.63 % of the total variance and according to this Principal component analysis. WT, TDS (showed high positive loading), BOD and FCO_2 showed positive loading against pH and DO (showed negative loading) on the same factor (PCA 1 or Factor 1). The findings indicated that with an increase of WT, TDS, BOD, and FCO_2, pH and DO values decrease (Table 4), as exhibited by the correlation matrix (Table 2). pH, water temperature and DO are highly responsible (with high positive loading) for water quality variations. TDS, total hardness, EC and alkalinity showed positive loading on the second factor (PCA 2 or Factor 2). At the same time, salinity showed positive loading on PCA3 (Factor 3) with no correlation with any water parameters (Table 4), supported by Table 2. Hence, the analysis revealed that the water quality of Poma River and its biodiversity, including the abundance of *A. uniobarensis* was greatly influenced by physical variables such as pH, WT, FCO_2, TDS, alkalinity, total hardness, and EC, and chemical factors such as DO and BOD. Mineral-like salinity also affected the variation of water quality in River Poma (Table 3, 4). According to some studies, physical and chemical variables result from the biological activities of aquatic biota or anthropogenic inputs (Ram *et al.,* 2007; Taboada-Castro *et al.,* 2007; Sarwar *et al.,* 2010; Hazarika, 2013).

Conclusion

The present study showed the Poma River's habitat characteristics (physiochemical characteristics), where *A. uniobarensis*, an ornamental fish, coexisted with various other fish species. The recorded values of these parameters fell within an acceptable range (according to the standard values set for aquaculture by Bhatnagar and Devi (2013), with a higher DO level and a lower salinity level. The Kruskal-Walli's, and Mann-Whitney tests indicated significant seasonal variations in the water parameters, with some changes noted during the study period. These variations can be attributed to the mixing of domestic waste, waste accumulation at tourist spots along the river, and unplanned activities. These findings were supported by the correlation coefficient analysis among the parameters and by the Principal component analysis. All analyses suggest that the water in the Poma River is suitable for supporting *A. uniobarensis* and other aquatic organisms. These findings also clearly revealed the preferred habitat for this sought-after wild ornamental fish. The findings will be beneficial in conducting captive research using the species under simulated conditions to explore reproductive biology and artificial propagation.

Supplementary Information

The author(s) is responsible for the content or functionality of any supplementary information. Any queries regarding this should be directed to the corresponding author. The supplementary information is downloadable from the article's webpage and will not be printed in the print copy.

ACKNOWLEDGEMENTS

The authors are grateful to the Ministry of Tribal Affairs (MOTA), Government of India, for providing financial assistance. Authors are also indebted to Rajiv Gandhi University Museum of Fishes (RGUMF) and the Department of Zoology, Rajiv Gandhi University, for their unstinted help in every aspect of this research.

REFERENCES

1. Abujam, S., Tamang, L., Nimasow, G. & Das, D. N. (2021). Trade Potential of Indigenous Ornamental Fishes of Arunachal Pradesh, India. *Asian Fisheries Science*, 34 (4), 312-325. doi.org/10.33997/j.afs.2021.34.4.004.
2. Adamou, H., Ibrahim, B., Salack, S., Adamou, R., Sanfo, S. & Liersch, S. (2020). Physico-chemical and bacteriological quality of groundwater in a rural area of Western Niger: a case study of Bonkoukou. *Journal of Water and Health,* 18(1), 77-90. doi.org/10.2166/wh.2020.082.
3. Ahmed, W., Ahmed, I., Dar, N.A. & Farah, M.A., (2024). Spatio-temporal evaluation of physic-chemical parameters of snow-fed River Poonch in Northwest Himalayan region of India. *Applied Water Science* 14(91). https://doi.org/10.1007/s13201-024-02146-x.
4. APHA (American Public Health Association). (2012). Standard Methods for the Examination of Water and Wastewater, 22nd ed. American Public Health Association, Washington, DC.
5. Bagra, K., Dutta, R. & Das, D. N. (2014). Portraying in-situ habitat features of Assamese king fish Semiplotus semiplotus (McClelland, 1839) from Sipu River in West Siang district of Arunachal Pradesh, India. *International Journal of Fish Aquaculture,* 4(1), 47-57.
6. Barakat, A., Meddah, R., Afdali, M., & Touhami, F., (2018). Physicochemical and microbial assessment of spring water quality for drinking supply in Piedmont of Beni-Mellal Atlas (morocco). *Physics and Chemistry of the Earth Partsa/b/c,* 3(2), 276-280.
7. Berger, E., Frör, O., & Schäfer, R. B. (2019). Salinity impacts on river ecosystem processes: a critical mini-review. *Philosophical Transactions of the Royal Society B*, 374 (1764), 20180010.
8. Bhatnagar, A. & Devi, P. (2013). Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences,* 3(6), 1980-2009. doi.org/10.6088/ijes.2013030600019.
9. Boyd, C. B. (1979). *Water quality in Warm water Fish Ponds*. Agricultural Experiment. Station. Auburn: Auburn University.
10. Boyd, C. E. & Pillai, V. K. (1985). Water quality management in aquaculture. *CMFRI special Publication,* 22, 1-44.
11. Bui, Y. & Lodhi, M. S. (2020). Assessment of spring water quality using water quality index method: study from upper Subansiri district, Arunachal Pradesh, India. *International Journal of Science Environment,* 9, 898-908.
12. Chapman, D. (1996). *Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, 2nd ed; London, UK. https://doi.org/10.1201/9781003062103.
13. Chetana, S. & Somasekhar, R. (1997). Ecological study on the riverine ecosystem of Karnataka. I. Physico-chemical characteristics of river Cauvery. *Jornal of Environment Pollution,* 4(1), 57-63.
14. Cook, R. B., Kelly, C. A., Schindler, D. W., & Turner, M. A. (1986). Mechanisms of hydrogen ion neutralization in an experimentally acidified lake. *Limnology and Oceanography,* 31(1), 134-148.
15. Das, B. K., Boruah, P. & Kar, D. (2014). Fish diversity and drainage analysis of River Siang, East Siang district of Arunachal Pradesh. *Bioscience Discovery,* 6, 16-20.
16. Effendi, H. & Wardiatno, Y. (2015). Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. *Procedia Environmental Sciences,* 24, 228-237. https://doi.org/10.1016/j.proenv.2015.03.030.
17. Ering, O., Machahary, K. Q., Abujam, S., Das, R. K. & Narayan, D. (2018). Habitat features of loach Aborichthys kempi (chaudhuri, 1913) from Rono Hills, Arunachal Pradesh, India. *Trends in Fisheries Research,* 7(2), 46-52.
18. Fry, F. (1971). The effect of environmental factors on the physiology of fish. In *Fish physiology* (Vol. 6, pp. 1-98): Elsevier.
19. Ganie, P. A., Baruah, D., Kunal, K., Posti, R. & Garima, D. S. (2018). Phytoplankton diversity and abundance in upland streams of Kameng drainage, Arunachal Pradesh. *Journal of Entomology and Zoology Studies,* 6(6), 1166-1173. www.entomoljournal.com.
20. Gaur, N., Sarkar, A., Dutta, D., Gogoi, B. J., Dubey, R. & Dwivedi, S. K. (2022). Evaluation of water quality index and geochemical characteristics of surfacewater from Tawang India. *Scientific Reports,* 12(1), 11698. https://doi.org/10.1038/s41598-022-14760-3.
21. Geetha, A., Palanisamy, P., Sivakumar, P., Kumar, P. G. & Sujatha, M. (2008). Assessment of underground water contamination and effect of textile effluents on Noyyal River basin in and around Tiruppur Town, Tamilnadu. *E-journal of Chemistry,* 5(4), 696-705. https://doi.org/10.1155/2008/394052.
22. Gurumayum, S. D. (2021). A preliminary report on fish diversity of Poma river and its tributaries, Arunachal Pradesh, India. *International Journal of Fisheries and Aquatic Studies,* 9(2), 158-162. https://doi.org/10.22271/fish.2021.v9.i2c.2437.
23. Hasan, M. M., Ahmed, M. S. & Adnan, R. (2020). Assessment of physico-chemical characteristics of river water emphasizing tannery industrial park: a case study of Dhaleshwari River, Bangladesh. *Environmental Monitoring and Assessment,* 192, 1-24. https://doi.org/10.1007/s10661-020-08750-z.

24. Hazarika, L. P. (2013). A study of certain physico-chemical characteristics of Satajan wetland with special reference to fish diversity indices, Assam, India. *European Journal of Experimental Biology,* 3(4), 173-180.
25. Hu, X. & Cai, W-J. (2011). An assessment of ocean margin anaerobic processes on oceanic alkalinity budget. *Global Biogeochemical Cycles*, 25, 1-11. Doi:1029/2010GB003859.
26. ICMR. (1975). *Manuals of standards of quality for drinking water supplies*. New Delhi: I. C. M. R.
27. Islam, M. S., Akbar, A., Akhtar, A., Kibria, M. M. & Bhuyan, M. S. (2017). Water quality assessment along with pollution sources of the Halda River. *Journal of the Asiatic Society of Bangladesh, Science,* 43(1), 61-70.
28. Jamabo, N. A. (2008). *Ecology of Tympanotonusfuscatus (Linnaeus, 1758) in the Mangrove Swamps of the Upper Bonny River, Niger Delta, Nigeria.* Rivers State University of Science and Technology, Port Harcourt, Nigeria.
29. Kachari, A. (2021). Habitat predilection of Amblyceps apangi from the streams of Arunachal Pradesh, India. *Dera Natung Government College Research Journal,* 6(1), 66-78. https://doi.org/10.56405/dngcrj.2021.06.01.07.
30. Kachari, A., Gogoi, B., Dutta, R., Aran, K., Ghosh, P., Maitra, S. & Das, D. N. (2014). Habitat preference of an endangered hill stream catfish Olyra longicaudata (McClelland) From Arunachal Pradesh, India. *International Journal of Fisheries and Aquatic Studies,* 1, 86-93. https://www.researchgate.net/publication/344043063.
31. 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. *Reviews in Fish Biology and Fisheries,* 19, 465-480. https://doi.org/10.1007/s11160-009-9114-5.Kiron, B., Basack, S. & Goswami, G. (2022). Assessment of Water Quality Parameters in Kamle District, Arunachal Pradesh, India. *Enveronmental Monitoring,* 1(1), 23-26. https://doi.org/10.55571/em.2022.04005.
32. Kiron, B., Basack, S., Goswami, G. & Bida, H. (2021). Hydrological and environmental study on surface water characterization in a locality in north eastern India. *WSEAS Transactions on Environment and Development,* 17, 1228-1233. 10.37394/232015.2021.17.112.
33. Kumar, R., Kumari, R., Prasad, C., Tiwari, V., Sinhg, N, Mohapatra, S., Merugu, R., Namtak, S. & Deep, A. (2020). Phytoplankton diversity in relation to physicochemical attributes and water quality of Mandakini River, Garhwal Himalaya. Environmental Monitaring and Assessment, 192(799). https://doi.org/10.1007/s10661-020-08768-3.
34. Kumar, V., Arya, S. & Dhaka, A. (2011). A study on physico-chemical charactersitics of Yamuna River around Hamirpur (UP), bundelkhand region central India. *International Multidisciplinary Research Journal,* 1(5).
35. Kunal, K., Ganie, P. A., Baruah, D., Jaiswar, A. K., Garima, Shukla, S. P. & Thungon, P. K. (2021). Spatiotemporal variations in surface water quality parameters of Kameng drainage, Eastern Himalaya, Arunachal Pradesh, India. *Journal of Entomology and Zoology Studies,* 9(1), 781-787. https://dx.doi.org/10.22271/j.ento.
36. Laffaille, P., Briand, C., Fatin, D., Lafage, D. & Lasne, E. (2004). Point sampling the abundance of European eel (Anguilla anguilla) in freshwater areas. *Archiv fur Hydrobiologie,* 162(1), 91-98.
37. Laluraj, C., Padma, P., Sujatha, C., Nair, S., Kumar, N. & Chacko, J. (2002). Base-line studeis on the chemical constituents of Kayamkulam estuary near to the newly commissioned NTPC power station. *Indian Journal of Environmental Protection,* 22(7), 721-731.
38. Likongwe, J. S., Stecko, T. D., Stauffer Jr, J. R. & Carline, R. F. (1996). Combined effects of water temperature and salinity on growth and feed utilization of juvenile Nile tilapia Oreochromis niloticus (Linneaus). *Aquaculture,* 146(1-2), 37-46. https://doi.org/10.1016/S0044-8486(96)01360-9.
39. Lone, S.A, Bhat, S.U., Hamid, A., Bhhat, F.A. & Kumar, A. (2021). Quality assessment of springs for drinking water in the Himalaya of South Kashmir, India. *Environmental Science and Pollution Research International*, 28, 2279-2300.https://doi.org/10.1007/s11356-020-10513-9.
40. Loyi, R., Bam, G. & Das, D. N. (2018). Fish Diversity and Physico-chemical Parameters of Hillem River, Arunachal Pradesh, India. *International Journal of Research and Analytical Reviews,* 5(3), 204-210.
41. Matta, G., Srivastava, S., Pandey, R. & Saini, K. (2017). Assessment of physicochemical characteristics of Ganga Canal water quality in Uttarakhand. *Environment, Development and Sustainability,* 19, 419-431. https://doi.org/10.1007/s10668-015-9735-x.
42. Mir, Z.A, Bakhtiyar, Y., Arafat, M.Y., Khan, N.A. & Parveen, M. (2023). Spatiotemporal variation of physico-chemical parameters in Aripal and Watalara streams of Kashmir Himalaya using multivariate statistical techniques. *Environmental Monitoring and Assessment*, 195 (6):743. https://doi.org/ 10.1007/s10661-023-11261-2
43. Nanda, P., Machahary, K. Q., Tamang, L. & Das, D. N. (2021). Aborichthys uniobarensis, a new species of river loach (Cypriniformes: Nemacheilidae) from Arunachal Pradesh, India. *Asian Journal of Conservation Biology,* 10 (1), 3-9. https://doi.org/10.53562/ajcb.ASHI9566 R.
44. Narasimha, R., Dorairaju, S., Bujagendra, R. & Chalapathi, P. (2011). Statistical analysis of drinking water quality and its impact on human health in Chandragiri, near Tirupati, India. *Reterived September*, 27, 2024.
45. Nikolsky, G. V. (1980). Theory of fish population dynamics. In B. Singh and M. P. Singh (Eds.), (pp. 317). West Germany: India and Ottokoeltz Science Publishers. https://connectjournals.com/03895.2022.25.2529.
46. Novikmec, M., Svitok, M., Kočický, D., Šporka, F. & Bitušík, P. (2013). Surface water temperature and ice cover of Tatra Mountains lakes depend on altitude, topographic shading, and bathymetry. *Arctic, Antarctic, and Alpine Research,* 45(1), 77-87. https://doi.org/10.1657/1938-4246-45.1.77.
47. Rahman, A., Jahanara, I. & Jolly, Y. N. (2021). Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh. *Water Science and Engineering*, 14(2), 139-148. doi.org/10.1016/j.wse.2021.06.006
48. Ram, H. K., Ramachandra, M. M. & Vishalakshi, Y. (2007). Limnological studies on Kolaramma Lake Kolar, Karnataka. *Enveronment and Ecology,* 52, 364-367.
49. Sarkar, M., Islam, J. & Akter, S. (2016). Pollution and ecological risk assessment for the environmentally impacted Turag River, Bangladesh. *Journal of Materials and Environmental Science,* 7(7), 2295-2304. http://www.jmaterenvironsci.com/.

50. Sarkar, U., Pathak, A. & Lakra, W. (2008). Conservation of freshwater fish resources of India: new approaches, assessment and challenges. *Biodiversity and Conservation,* 17, 2495-2511. https://doi.org/10.1007/s10531-008-9396-2.
51. Sarwar, M. I., Majumder, A. K. & Islam, M. N. (2010). Water quality parameters: A case study of Karnafully River Chittagong, Bangladesh. *Bangladesh Journal of Scientific and Industrial Research,* 45(2), 177-181. 10.3329/bjsir.v45i2.5722.
52. Seth, R., Mohan, M., Singh, P., Singh, R., Dobhal, R., Singh, K. P. & Gupta, S. (2016). Water quality evaluation of Himalayan rivers of Kumaun region, Uttarakhand, India. *Applied Water Science,* 6(2), 137-147. https://doi.org/10.1007/s13201-014-0213-7.
53. Shangningam, B., Kosygin, L., Sinha, B. & Gurumayum, S. D. (2019). *Aborichthys kailashi and A. pangensis (Cypriniformes: Nemacheilidae), two new species from Arunachal Pradesh, India*. *Ichthyological Exploration of Freshwaters* . http://doi.org/10.23788/IEF-1123.
54. Singh, A. D., Abujam, S., & Das, D. N. (2018). Biodiversity of fishes in Arunachal Himalaya: systematics, classification, and taxonomic identification. Academic Press.
55. Singh, K., Dhiman, S. & Kishor, B. (2023). Spatio-Temporal Variations in Physico-Chemical Parameters of River Tawi. In: IOP Conference Series: *Earth and Environmental Science*. 1110, 012050. https:// doi.org/10.1088/1755-1315/1110/1/012050
56. Singh, P. (2014). Studies on seasonal variations in physico-chemical parameters of the river Gomti (UP) India. *International Journal of Advanced Research,* 2(2), 82-86. http://www.journalijar.com.
57. Singh, P. & Kosygin, L. (2022). Aborichthys bajpaii, a New Species of Loach (Nemacheilidae) from Eastern Himalaya, India. *Journal of Ichthyology*, 1-8. https://doi.org/10.1134/S0032945222050162.
58. Stumm, W. & Morgan, J. J. (1981). An introduction emphasizing chemical equilibria in natural waters, aquatic chemistry. In (Vol. 2nd ED, pp. 780). New York: John Wiley and Sons, New York.
59. Taboada-Castro, M. M., Rodríguez-Blanco, M. L. & Taboada-Castro, M. T. (2007). Assessment of seasonal variations in stream water by principal component analysis. *WIT Transactions on Ecology and the Environment,* 106. 10.2495/ECO070511.
60. Wolf-Gladrow, D. A., Zeebe, R. E., Klaas, C., Kortzinger, A. & Dickson, A. G. (2007). Total alkalinity: The explicit conservative expression and its application to biogeochemical processes. *Marine Chemistry*, 106, 287-300.