Annals of Agri-Bio Research **30** (1): 1-9, 2025

Impact Score: 0.3 (Scopus)

Physicochemical Parameters of Water and Their Effects in Temporal Variation of Fish Composition in Lower Reaches of Mahakali River, Nepal

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(Received: September 3, 2024; Accepted: November 29, 2024)

ABSTRACT

Water quality shapes aquatic fauna. However, no information is available about water quality and its effect on fish diversity of Mahakali River. This study was conducted to measure the temporal variation of physicochemical parameters of water and their effects on fish composition in the lower reaches of Mahakali River, Nepal in between September 2022 to August 2023. Measurements of water quality parameters and fish collection were carried out on a monthly basis. Shannon–Weiner diversity index was calculated to measure fish diversity and multiple regression analysis was computed to analyze the effects of physicochemical parameters of water in fish composition. This study revealed that physicochemical parameters of water at lower reaches of the river were in the range of fish tolerance and support good fish diversity (H = 3.06). Changing physicochemical parameters of water, instead of affecting the overall species, affected the species-specific manner and had significant effect on the species composition of *Anguilla, Schizothorax, Mystus, Amblyceps, Bagarius, Ompok, Garra, Acanthocobitis, Schistura, Lepidocephalichthys, Xenentodon, Mastacembelus, Glossogobius* and *Channa* fish species but had no effect on the species composition of *Salmophasia, Barilius, Raimas, Puntius, Tor, Chagunius, Labeo* and *Botia*. This study suggests that in snow fed perennial river high fish diversity, dominated by cyprinids, is found in autumn followed by winter season associated with clear river water, moderate temperature and more hardness in water containing more total dissolved solids.

Key words: water quality, fish diversity, Mahakali River, species composition, cyprinid fish

INTRODUCTION

Water is essential component for survival of any organism (Westall and Brack, 2018). The physical and chemical properties (temperature, pH, turbidity, dissolved oxygen, free carbon dioxide, total dissolved solids and total hardness) of water bodies are gradually degrading due to both natural processes and anthropological activities (Oude Essink, 2001; Herbert et al., 2015; Keilholz et al., 2015; Khatri and Tyagi, 2015). This in turn affects morphology and physiology of aquatic organisms and their distribution including fishes (Reynolds, 2014; Shetty et al., 2015).

Mahakali River, where the present study was conducted, is one the major river basin in Nepal. It harbours rich fish diversity nearly three decades ago (Shrestha, 1990) but later, regional studies suggest gradual decline in the fish diversity (Saund et al., 2013). Although the river is snow fed, it receives many rivulets in the middle and lower reaches encroached by human settlements (*Sharda River*, n.d.). Their activities directly or indirectly affect water quality of the river. Information is lacking regarding variation of water quality and fish composition in lower reaches of the river. The present study was conducted to document temporal variation of the physicochemical parameters of the water and their effects in fish composition in lower reaches of Mahakali River, Nepal.

MATERIALS AND METHODS

The water samples and fish samples were collected from Sarada barrage (28º58''45.44'N 80º69''48.96'E) to Mahakali Suspension bridge (28º55''35.11'N 80º65''25.8'E) of the Mahakali River, Nepal on monthly basis in between September 2022 to August 2023.

Water sample was collected at 8:00 am about 25 cm below surface water in 1 L white Polyethylene bottle. Temperature was measured in situ using mercury thermometer. Water sample was transported at 4 °C to the laboratory of Central Department of General Science, Far Western University, Mahendranagar, Nepal for analysis. pH and turbidity were measured using digital pH meter (model number: Jainco 1901) and digital turbidity meter (model number: MARS ME-105A) respectively. Total dissolved solids were measured with the help of digital TDS meter- Hanna Instruments (model: HI 96107, Italy). Dissolved oxygen was measured by Winkler test, free carbon dioxide, total hardness and calcium hardness of water were measured by titration method outlined in Standard Methods for the Examination of Water and Wastewater (APHA et al., 2017) and ecology and environment (Sharma, 2005) in the departmental laboratory of the university.

The fish specimens were collected randomly with the help of Cast net and drag nets of mesh sized 12 × 12 cm^2 and 25 × 25 cm^2 respectively. The collected fish specimens were also transported to the laboratory of Central Department of General Science, Far Western University, Mahendranagar, Nepal for identification. Fish species were identified using keys outlined in Jayaram (2010).

The fish diversity was calculated by Shannon–Weiner diversity index (Shannon and Weaver, 1949). The effects of physicochemical parameters of water in fish composition were statistically analyzed by multiple regression analysis computed using IBM SPSS Statistics Version 25.0 (IBM Corp, 2017) at 5% significance level.

RESULTS AND DISCUSSION

The physicochemical parameters of water in the lower reaches of Mahakali River were varied temporally and seasonally. Minimum temperature (14 °C) was recorded in the month of January and maximum (26 °C) in the months of July to August. pH was found slightly alkaline (7.82–8.35). Turbidity was lowest in the month of April (6 NTU) and highest in July (252 NTU). Concentration of dissolved oxygen ranged from 6.03–9.25 mg/L. Free carbon dioxide concentration ranged from 4.4–8.8 mg/L. Total dissolved solids varied between 112–159 mg/L. Total hardness of water ranged in between 142–220 mg/L and calcium hardness ranged in between 28.85–46.49 mg/L (Table 1). The physicochemical parameters of water in the lower reaches of Mahakali River were, thus, found in fish tolerance range (Boyd and Pillai, 1984; Bhatnagar and Devi, 2013; Pandey and Shukla, 2019; Mariu et al., 2023). Mahamood et al. (2021) and Mehmood et al. (2023) also reported nearly similar value of dissolved oxygen, carbon dioxide, pH and total hardness from the snow fed Yamuna and Sip rivers respectively. This study finding contradict with Karim et al. (2022) who reported low oxygen level and higher water temperature in polluted river water. In the present study, the fluctuations in temperature might be due to effect of changing surrounding environmental temperature correlated with climate change (Caissie, 2006; Winslow et al., 2017). The alkaline pH of the river water throughout year might be due to higher concentration of minerals (especially calcium salts) leached from rocks and river bed (Kaushal et al., 2013). The lower reaches of the river had slightly elevated pH than the middle and upper reaches (Kunwar et al., 2015) possibly due to nutrient enrichment draining from associated tributaries. Increasing alkalization in fresh water river is also reported by Jiang et al. (2022). The higher turbidity from July to September was due to surface runoff discharged into the river during monsoon (Chen et al., 2020). The value of dissolved oxygen and free carbon dioxide were found not drastically changed due to fast flow and snow fed nature of the river (Mahakali River System, n. d.). Kunwar et al. (2015) reported slightly higher concentration dissolved oxygen in the middle and upper reaches of the Mahakali River due to the presence of planktons and other aquatic vegetations that utilize carbon dioxide from the water and produce oxygen during photosynthesis and also due to fast flow of the river in steeper regions. The higher levels of total dissolved solids and total hardness in river water in autumn and winter seasons than summer season might be due to higher concentration of minerals leached from rocks and river bed during chemical weathering (Kaushal et al., 2013) in comparatively low discharge of water in the river during these seasons (Mahakali River System, n. d.).

Table 1. Physicochemical parameters of water in lower reaches of Mahakali River

Physicochemical Parameters of Water	Seasons, Months and year											
	Autumn			Winter			Spring			Summer		
	Sept. 2022	Oct. 2022	Nov. 2022	Dec. 2022	Jan. 2023	Feb. 2023	Mar. 2023	Apr. 2023	May 2023	June 2023	July 2023	Aug. 2023
Temperature (°C)	23	20	18	18	14	19	21	24	27	25	26	26
pH	8.20	8.23	8.30	7.82	8.16	8.15	8.34	8.32	8.33	8.27	8.25	8.35
Turbidity (NTU)	180	13.2	10	8.8	9.2	9.6	6.4	6	35.2	56	252	132
Dissolved oxygen (mg/L)	6.43	6.43	7.64	8.44	7.24	6.43	9.25	7.24	6.43	6.83	7.24	6.03
Carbon dioxide (mg/L)	8.8	6.6	6.6	6.6	6,6	4.4	4.4	4.4	6.6	4.4	6.6	6.6
Total dissolved solids (mg/L)	167	127	112	145	152	159	159	135	119	132	112	109
Total hardness (mg/L)	188	170	198	204	210	206	220	186	162	142	154	142
Calcium hardness (mg/L)	28.85	33.66	40.08	42.48	46.49	44.08	44.88	40.88	36.07	32.86	30.46	30.46

Altogether, 27 fish species belonging to 6 orders (viz., Anguilliformes, Cypriniformes, Siluriformes, Beloniformes, Synbranchiformes and Perciformes), 12 families (viz., Anguillidae, Cyprinidae, Balitoridae, Cobitidae, Bagridae. Siluridae, Amblycipitidae, Sisoridae, Belonidae, Mastacembelidae, Gobiidae and Channidae) and 23 genera (viz., *Anguilla, Salmophasia, Barilius, Raiamas, Puntius, Tor, Chagunius, Labeo, Schizothorax, Garra, Acanthocobitis, Schistura, Botia, Lepidocephalichthys, Mystus, Ompok, Amblyceps, Bagarius, Glyptothorax, Xenentodon, Mastacembelus, Glossogobius and Channa*) were recorded from the lower reaches of Mahakali River (Table 2). The highest fish diversity (25 fish species) was recorded in autumn season and the lowest diversity (14 fish species) in the summer season (Table 2). The Shannon– Weiner diversity index showed high fish species diversity (H = 3.06). Cyprinidae was found dominant family (represented by 13 species). The higher fish species diversity in autumn followed by winter season might be due to uniform water quality, sufficient food availability in the river and migration of the most of the fishes to the river from adjoining streams to protect from predators in these seasons (Chapman et al., 2011; Brönmark et al., 2014). Andrabi et al. (2022) and Mehmood et al. (2023) also reported the dominance of cyprinidae family with maximum diversity in winter and minimum diversity in summer in Manasbal Lake, Kashmir and from Sip River with changing water quality parameters. These similarities could be due to perennial nature of the rivers. But, Ding et al. (2018) has reported higher fish diversity in summer than other seasons in Lijiang River, China due to its ephemeral nature.

Table 2. Season and Month-wise fish composition in lower reaches of Mahakali River.

Fish species	Seasons, Months and Year											
	Autumn			Winter			Spring			Summer		
	Sept. 2022	Oct. 2022	Nov. 2022	Dec. 2022	Jan. 2023	Feb. 2023	Mar. 2023	Apr. 2023	May 2023	June 2023	July 2023	Aug. 2023
Order: Anguilliformes Family: Anguillidae Genus: *Anguilla* Schrank, 1798 *Anguilla bengalensis* (Gray & Hardwicke)	+	+	+	+	+	+	–	–	–	–	–	–
Order: Cypriniformes Family: Cyprinidae Genus: S*almophasia* Swainson, 1839 *Salmophasia bacaila* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Barilius* Hamilton-Buchanan, 1822 *Barilius bendelisis* Hamilton-Buchanan	+	+	+	+	+	+	+	+	+	+	+	+
Barilius vagra Hamilton-Buchanan	+	+	+	+	+	+	+	+	+	+	+	+
Raiamas guttatus (Day)	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Puntius* Hamilton-Buchanan, 1822 *Puntius ticto (*Hamilton-Buchanan	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Tor* Gray, 1834 *Tor putitora* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Chagunius* H.M. Smith, 1938 *Chagunius chagunio* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Labeo Cuvier, 1816 *Labeo dero* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Labeo dyocheilus (Mc Clelland)	+	+	+	+	+	+	+	+	+	+	+	+

Labeo calbasu (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Schizothorax* Heckel, 1838 *Schizothorax richardsoni* (Gray)	+	+	+	+	+	+	–	–	–	–	–	–
Genus: *Garra* Hamilton-Buchanan, 1822 *Garra gotyla gotyla* (Gray)	+	+	+	+	+	+	+	+	+	–	–	–
Garra annandalei Hora	+	+	+	+	+	+	+	+	+	–	–	–
Family: Balitoridae Genus: *Acanthocobitis* Peters, 1861 *Acanthocobitis botia* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	–	–	–
Genus: *Schistura* Mc Clelland, 1839 *Schistura beavani* (Gunther)	+	+	+	+	+	+	+	+	+	–	–	–
Family: Cobitidae Genus: *Botia* Gray, 1831 *Botia lohachata* Chaudhuri-India	+	+	+	+	+	+	+	+	+	+	+	+
Genus: *Lepidocephalichthys* Bleeker, 1858 *Lepidocephalichthys guntea* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	–	–	–
Order: Siluriformes Family: Bagridae Genus: *Mystus* Russell, 1756 *Mystus seenghala* (Sykes, 1839)	+	+	+	+	+	+	–	–	–	–	–	–
Family: Siluridae Genus: *Ompok* Lacepede, 1803 *Ompok bimaculatus* (Bloch)	–	–	–	–	–	–	+	+	+	+	+	+
Family: Amblycipitidae Genus: *Amblyceps* Blyth, 1858 *Amblyceps mangois* (Hamilton-Buchanan)	+	+	+	+	+	+	–	–	–	–	–	–
Family: Sisoridae Genus: *Bagarius* Bleeker, 1853 *Bagarius bagarius* (Hamilton-Buchanan)	+	+	+	+	+	+	–	–	–	–	–	–
Genus: *Glyptothorax* Blyth 1860 *Glyptothorax cavia* (Hamilton-Buchanan)	+	+	+	+	+	+	+	+	+	+	+	+
Order: Beloniformes Family: Belonidae Genus: *Xenentodon* Regan, 1911 *Xenentodon cancila* Hamilton-Buchanan	+	+	+	+	+	+	+	+	+	–	–	–
Order: Synbranchiformes Family: Mastacembelidae	+	+	+	–	–	–	–	–	–	+	+	+

Genus: *Mastacembelus* Scopoli, 1777 *Mastacembelus armatus* (Lacepede)												
Order: Perciformes Family: Gobiidae Genus: *Glossogobius* Gill, 1859 *Glossogobius giuris* (Hamilton-Buchanan)	–	–	–	–	–	–	+	+	+	–	–	–
Family: Channidae Genus: *Channa* Scopoli, 1777 *Channa gachua* (Hamilton-Buchanan)	+	+	+	+	+	+	–	–	–	–	–	–

(+) represent present and (–) represent absent.

The results of regression analysis (Table 3) indicated that the physicochemical parameters of water (temperature, pH, turbidity, dissolved oxygen, free carbon dioxide, total dissolved solids, total hardness and calcium) had significant effects on the species composition ($F = 11.687_{(8,\ 3)}$, $p < 0.05$, adjusted R square = .886). Nearly 89% fish species diversity was influenced by changing water quality parameters and remaining 11% fish species diversity was influenced by other factors which might be food availability, spawning period, migratory behaviour and presence of predators. This needs further investigation. Fuchs (2013) also reported the relationship of water quality parameters with other physical variables contributes fish richness. Contrary to this, Duque et al. (2020) reported water quality parameters, especially, lower concentration of nitrate and phosphate and moderate temperature have significant impact on fish diversity. These differences might be due to deteriorating water bodies resulting from anthropogenic influences.

Table 2. Regression output for water quality parameters effect on fish diversity

	Fish Species											
	Overall		*Anguilla, Schizothorax, Mystus, Amblyceps, Bagarius, Channa*		*Garra, Acanthocobitis, Schistura, Lepidocephalichthys, Xenentodon*		*Ompok*		*Mastacembelus*		*Glossogobius*	
Variables	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Constant	69.387	0.178	15.455	0.015	-1.261	0.831	-14.455	0.018	3.390	0.462	-16.716	0.065
Temperature (°C)	-0.080	0.757	-0.092	0.015	0.060	0.161	0.092	0.015	-0.130	0.012	0.152	0.022
p^H	-5.619	0.288	-1.251	0.035	-0.194	0.765	1.251	0.035	0.747	0.190	1.057	0.200
Turbidity (NTU)	-0.033	0.040	-0.001	0.169	-0.004	0.055	0.001	0.169	0.000	0.768	-0.003	0.157
Dissolved oxygen (mg/L)	-1.970	0.084	-0.262	0.023	-0.144	0.268	0.262	0.023	0.084	0.363	0.119	0.376
Carbon dioxide (mg/L)	0.451	0.541	-0.043	0.457	0.113	0.297	0.043	0.457	-0.165	0.089	0.156	0.206
Total dissolved solids (mg/L)	-0.052	0.298	-0.007	0.138	-0.003	0.674	0.007	0.138	-0.008	0.165	0.004	0.574
Total hardness (mg/L)	0.245	0.033	0.020	0.029	0.023	0.083	-0.020	0.029	0.005	0.503	0.003	0.806
Calcium hardness (mg/L)	-0.662	0.084	-0.086	0.024	-0.024	0.552	0.086	0.024	-0.151	0.011	0.062	0.204
Sample size	11		11		11		11		11		11	
F value	11.687	0.034	26.115	0.011	6.097	0.082	26.115	0.011	15.256	0.023	5.135	0.103
R	0.984		0.993		0.971		0.993		0.988		0.965	
R Square	0.969		0.986		0.942		0.986		0.976		0.932	
Adjusted R Square	0.886		0.948		0.788		0.948		0.912		0.750	

In the present study, the effect water quality parameters varied according to the fish species and seasons. Changes in temperature, pH, dissolved oxygen and calcium hardness had negative significant effect but total hardness of water had positive significant effect on the proportion of *Anguilla, Schizothorax, Mystus, Amblyceps, Bagarius* and *Channa* at 5% significance level indicating that a unit increase in temperature, pH, dissolved Oxygen, and calcium hardness decreases the assemblage proportion of these fishes by 0.092, 1.251, 0.262 and 0.086 respectively but a unit increase in total hardness increases the proportion these fishes by 0.020 (Table 3). It might be due to, being cold water fishes, their increased feeding efficiency and best growth in lower water temperature (7 to 19 °C) (Hinshaw, 1999) associated with slightly acidic or alkaline water (pH = 6.5-9.0) and dissolved oxygen (> 6 mg/L) (Mariu et al., 2023). George et al. (2016) and Jiang et al. (2021) revealed higher temperatures are stressful and negatively influence growth and survival of many cold-water fishes. It affects food intake, digestion, absorption, overall metabolisms and reproduction (Volkoff and Rønnestad, 2020) and impairment in the functioning of kidney and liver (Karim et al., 2022). Romano et al. (2020) reported that increasing total hardness of water increases survival rate of fish by improving stress resistance and thus, have significant role in fish biology (Swain et al., 2020), thereby on fish composition (Viadero, 2019). Karnatak et al. (2018) reported temperature and seasonal precipitation has significant effect on the breeding of *Channa*. Similarly, water turbidity had negative significant effect on the proportion of *Garra, Acanthocobitis, Schistura, Lepidocephalichthys* and *Xenentodon* at 5% significance level indicating that a unit increase in turbidity decreases the assemblage proportion of these fishes by 0.004 (Table 3). This study finding is comparable to the findings of Seehausen et al. (1997) and Lunt and Smee (2020) who also revealed low species diversity in turbid area. Researches have shown that turbidity affects the fish diversity by influencing the mobility of fish (Rodrigues et al., 2023), blocking the fish gills and reducing the productivity of water (Ibrahim, 2017). Further, temperature, pH, dissolved oxygen and calcium hardness had positive significant effect but total hardness had negative significant effect on the proportion of the *Ompok* at 5% significance level indicating that a unit increase in temperature, pH, dissolved oxygen and calcium hardness increases the assemblage proportion of *Ompok* by 0.092, 1.251, 0.262 and 0.086 respectively but a unit increase in total hardness decreases the proportion this fish by 0.020 (Table 3). It might be due to its well adaptation in tropical climates and species–specific decreasing feeding efficiency with increasing hardness of water (Romano et al., 2020). Islam et al. (2022) also reported better growth of *Ompok* at 30 °C. Temperature and calcium hardness had negative significant effect on the proportion of *Mastacembelus* at 5% significance level indicating that a unit increase in temperature and calcium hardness decreases the assemblage proportion *Mastacembelus* fish by 0.130 and 0.151 (Table 3). It might be due to species–specific adaptation with water quality parameters. Fabian (2023) reported a temperature range of 22 °C to 28 °C for its better growth. Serajuddin et al. (2012) reported their gonadal ripening during summer and spring stimulated by increased riverine temperature. Temperature had positive significant effect on the proportion of *Glossogobius* at 5% significance level indicating that a unit increase in temperature increases the proportion *Glossogobius* fish by 0.152 (Table 3). Jabbar et al. (2020) observed its breeding season in spring governed by increased riverine temperature.

In this study, the water quality parameters had also important roles in the seasonal variations of some species of fishes. As a result, *Anguilla bengalensis* were found during autumn and winter seasons due to low water temperature and their migration from cooler upstream to midstream and downstream areas in these seasons (Arai and Abdul Kadir, 2017; Arai et al., 2020); *Schizothorax* in autumn and winter seasons due to their breeding behaviour in these seasons (Joshi et al., 2016); most of the cat fish (*Mystus, Bagarius, Amblyceps*) in autumn and winter season due to favourable temperature and turbidity (Odoemenam, n.d.; Paul et al., 2019); *Channa* in the autumn and winter seasons due to their migration in the river from adjoining rivulets and streams breeding sites (Ferdausi et al., 2016); *Garra* species from autumn to spring seasons due to sufficient availability of foods in the river and ripening of gonads in these seasons (Gaur et al., 2013; Bhatt et al., 2021); *Acanthocobitis* from autumn to spring seasons due to their preference in fast flowing clean water with sandy and pebbly bottoms (Rahman, 1989); *Schistura* and *Lepidocephalichthys* during autumn, winter and spring seasons due to their returning into the river for feeding from breeding sites of adjoining rivulets after monsoon and inhabiting throughout these seasons (Mandal and Mandal, 2022; Dvořák et al., 2023); *Xenentodon cancila* during autumn, winter and spring seasons due to abundant food availability in these seasons in the rivers (Parihar et al., 2016); *Ompok* fish in spring and summer seasons due to their migration to flooded area in these seasons for spawning and feeding (*Ompok bimaculatus*, n. d.); *Mastacembelus* during summer and spring due to their gonadal ripening stimulated by temperature (Serajuddin et al., 2012); *Glossogobius giuris* in spring due to their breeding season governed by increased water temperature (Jabbar et al., 2020). But the species of *Salmophasia, Barilius, Raimas, Puntius, Tor, Chagunius, Labeo* and *Botia* were found in all seasons indicating slight variations in water quality parameters had little or no effect in composition of these species. It might be due to their wide range of ecological adaptability, diverse distribution in nutrient rich water and ability to tolerate changes in water quality (Mahamood et al., 2021) and prolific breeding habit.

CONCLUSIONS

The present study documented the physicochemical parameters of water in the lower reaches of the Mahakali River, Nepal in the tolerance range of fish and higher fish diversity with dominance of cyprinids in autumn followed by winter, spring and summer seasons. This study reveals that the physicochemical parameters of the water in snow fed Perennial River are nearly uniform throughout year except summer season and are in the fish tolerance range. The physicochemical properties of water along with species–specific traits had significant effect on fish diversity and shape the fish composition in the snow fed river. Fish species having wide range of adaptability, diverse diet and prolific breeding habit are not affected by slight change in physicochemical properties of water.

ACKNOWLEDGEMENTS

We acknowledge the Central Department of General Science, Faculty of Science and Technology, Far Western University, Mahendranagar, Nepal for laboratory facility.

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