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Research Article

WATER QUALITY AND FISH DIVERSITY OF BAGMATI RIVER IN KATHMANDU VALLEY

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ABSTRACT

This study assesses the water quality and aquatic habitat in various sites of the Bagmati River in Kathmandu Valley. This study was carried out between February and June across an urban gradient in the Bagmati River of Kathmandu Valley. We used a D-frame net of 90cm by dipping-net in the benthic zone maintaining a walking distance of 20 m and repeating the same process four times (two times at each bank of the river) on each site on each visit. *Schizothorax labiatus* (Snow Trout), *Schistura beavani (*Ring Loach), *Esomus danrica* (Flying barb), *Glyptosternum maculatum* (Torrent Catfish) and *Channa orientalis* (Asiatic snakehead) were various fish species found during our study. The maximum Biological oxygen demand (BOD) was observed from Teku and the lowest from Shivapuri. The minimum and maximum dissolved Oxygen recorded was at Sundarijal. The pH ranged from 7 to 7.4 in Sundarijal. The minimum conductivity was found in Sundarijal, whereas the maximum was found in Teku. The maximum turbidity was observed at Teku and the lowest at Sundarijal. Maximum alkalinity was observed at Teku and lowest at Shivapuri. The fish diversity and water quality were affected by urbanization. We recommend the study be conducted southwards to determine the impact urbanization has on the lotic ecosystem.

Keywords: Aquatic habitat, aquatic life, Bagmati River, water quality

INTRODUCTION

Aquatic biological diversity is organized from the smallest cell levels up to the complete ecosystem levels, where genetic diversities and species diversities have a vital role in building population and communities (Bunn & Arthington, 2002). The ecological, economic and cultural importance of aquatic ecosystem is infinite and is thus crucial for maintaining proper environmental conditions (Kushwaha et al., 2016).

pH has a vital role in the distribution of aquatic species. Most freshwater fish do best within the range of 6.5 to 8 (Behar, 1996). Likewise, the conductivity of water includes various ions like nitrate, phosphate, and sodium. High conductivity indicates the presence of various ions in water. In general, the conductivity of the distilled water is 0.5 – 3 μS/cm, most streams have 50 - 150 μS/cm. Freshwater streams ideally should have 150 – 500 μS/cm to support diverse aquatic life forms and a significant increase in conductivity may be an indicator that the water contains polluting discharges (Behar 1996). Mance (1987) and Jorgensen (2012) showed that Lead (Pb), Chromium (Cr), Copper (Cu), Zinc (Zn) and Cadmium (Cd) levels in natural waters have ranges of 0.6 – 120 mg/L for Pb, 1 – 10 mg/L for Cr, 0.2 – 30 mg/L for Cu, 0.5 – 10 mg/L for Zn, and <0.1 mg/L for Cd. However, in polluted water, concentrations of these levels are higher than the natural levels, which results from the excess amounts of anthropogenic inputs (Mance, 1987; Jorgensen, 2012). Rainfall results in a significant increase in turbidity and an increased amount of sediments in the water. An increase in turbidity increases water temperature, harms gills and eggs, reduces dissolved oxygen, prevents light from reaching the deep surface, and reduces photosynthesis for plants on the deep surfaces (Behar, 1996). Likewise, Pb and Cd have no known role in biological systems and are toxic to freshwater fishes (Yilmaz et al., 2004). Zn and Cr are necessary elements for organisms in small amounts but in excess, they become toxic and harmful (Wood et al., 2012; Reid et. al., 2012). Cu, Cd, Zn, and Pb are harmful and more sensitive to smaller fishes respectively (Shuhaimi-Othman et al., 2015). Human factors that affect dissolved Oxygen (DO) are introduced through oxygen consuming organic waste like sewage, insertion of nutrients, the addition of chemicals, changing flow of water, raising the temperature, etc. (Behar, 1996). The various DO levels have different roles in particular aquatic species and a higher DO in water is better for the aquatic life.

The aquatic habitat is also used by biotic components of the aquatic ecosystem for food resources, breeding and habitat cover (Hartmann et al., 2007). The Bagmati River is one of the holy rivers in both Hindu and Buddhist cultures and symbolizes civilization. Many cultural and traditional ceremonies are performed by different religions within the periphery of this freshwater river. (Vaidya, 2017). However, unmanaged civilization upstream and along the Bagmati has made the river a water and solid waste disposal site. This has resulted in the deterioration of the water quality of the river. The amount of pollution has the worst impact on Bagmati, turning the river into a toxic blackish type of water by direct mixing of sewage (Kumar, 1994). The river's condition is under intense threat due to various factors.

One of the many activities in Bagmati and its tributaries is the collection of sand for construction activities (Gyawali, 2001).

Various tributaries of the Bagmati River like Bishnumati, Manohara, Tukucha, etc. get mixed at various points during the flow from the origin. These tributaries carry the sewages, pollutants, garbage and trash with them and make the river even dirtier, unhealthy and toxic which can affect the aquatic population highly. Therefore, this research focuses on quantifying the physicochemical parameters of water, assessing fish diversity in the river and quantifying the impact of water quality on the fish diversity in the study area. .

MATERIALS AND METHODS

Study area

The Bagmati River originates from the Shivapuri hills lying inside the Shivapuri-Nagarjun National Park, which is about 15 Kilometers north of Kathmandu. Our study area is located between 27°46'19" and 27°39'25" N latitudes and 85°25'35" and 85°17'37" E longitudes. We observed samples in 50 square meters each month in six sample areas: Sundarijal, Gokarna, Tilganga Bagmati Bridge, Shankhamul, Teku, and Chovar (Fig. 1, Table 1).

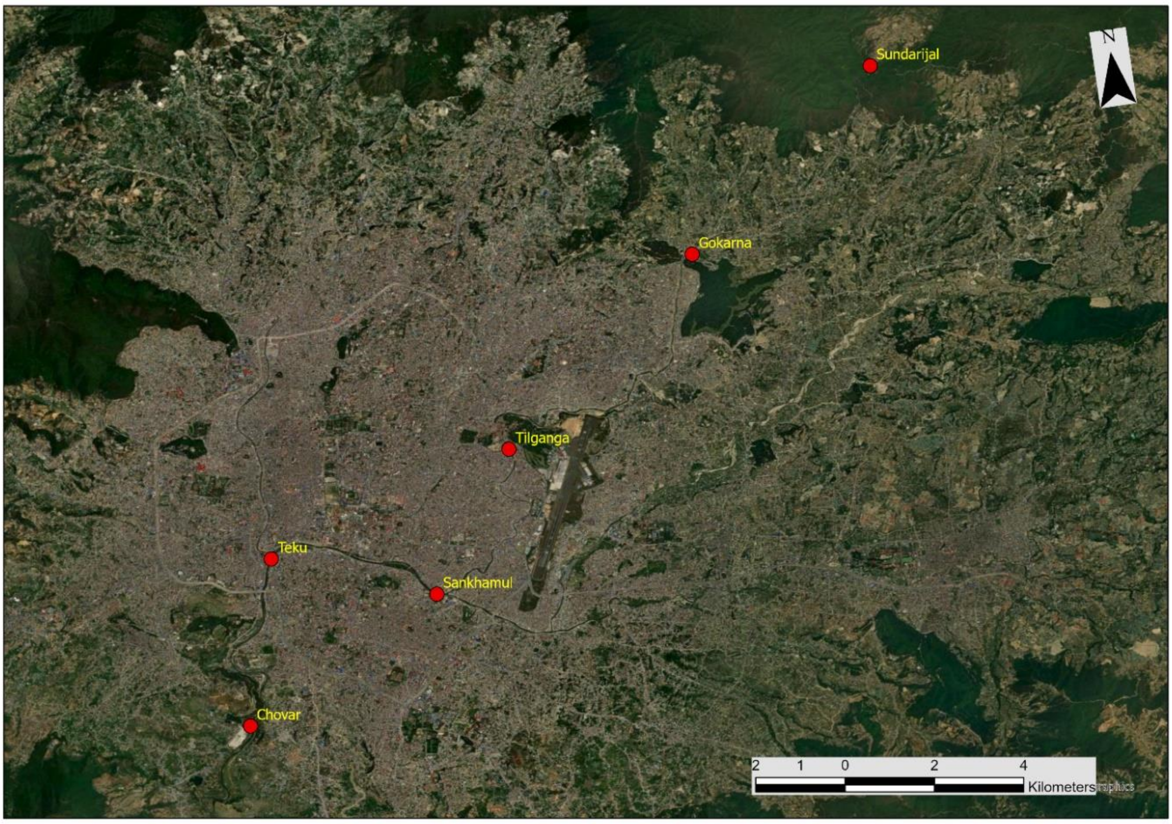

Figure 1. The sampling stations in Bagmati river, Kathmandu to identify the determinants of fish diversity along the urban gradient.

Methods

The samples were gathered from each sampling site and each site was visited on the first week of each month. Purposive sampling was carried out to focus on particular characteristics and qualitative research. The site selection was based on the differences in the substratum, topography, biotic and abiotic factors, the confluence of rivers, and water pollution (Mehta, 2017).

Data Collection

Data was collected from the littoral zone (covering both banks of the river) and the benthic zone. A sweeping net of 90 cm circumference was used to collect aquatic organisms from the littoral zone. The net was swiped into the water at a walking distance of 20 m repeating 4-four times (2-two at each bank of the river) in each site on each visit. D-frame net was used to collect aquatic organisms from the benthic zone. The net was dipped in the benthic zone and a walking distance of 20 m was maintained repeating the same process 4-four times (2-two at each bank of the river) in each site on each visit. To avoid disruption, 10 m of bank spacing was maintained between the littoral zone and the benthic zone. The contents of the net were emptied into the white tray and analyzed.

For dissolved oxygen water samples, adding two milliliters of each manganese sulphate and potassium iodide solutions was partially treated in the field. The water samples were collected in clean plastic bottles to analyze other physiochemical parameters. Sampling bottles included information including sampling location, date and time of collection of samples. Soil sample obtained from the river base was used to analyze soil composition to detect contamination rates. The obtained fish specimens were stored in individual vials with proper labeling of 70 percent ethanol. Likewise, the physicochemical parameters were analyzed following the detailed procedures by Dirica (2015).

We performed a one-way analysis of variance to check if the environmental parameters differ between sites across the sites. All the data obtained were used to fit a multiple regression model to determine the impact of the water quality on the fish richness of Bagmati River. For the purpose, a Karl Pearson Correlation Coefficient between all the variables was calculated to remove the most correlated variables leading to retention of three variables viz. ph, turbidity and bod. The Poisson model was applied for the regression of the species richness with the selected variables using MuMIn package in R. "Dredge" function was used to select the best model among all the candidate models and determine each variable's importance. $\Delta AIC < 2$ was used as the criteria to select the best models.

RESULTS AND DISCUSSION

This study identified *Schizothorax labiatus* (Snow Trout), *Schistura beavani* (Ring Loach), *Esomus danrica* (Flying barb), *Glyptosternum maculatum* (Torrent Catfish) and *Channa orientalis* (Asiatic snake head) fish species.

Table 1. Determination of physical characteristics of water samples in. Sundarijal, Gokarna and Tilganga

Parameters	Sundarijal			Gokarna			Tilganga		
	Year/Month			Year/Month			Year/Month		
	2020/03	2020/05	2020/06	2020/03	2020/05	2020/06	2020/03	2020/05	2020/06
pH	7.2	7	7.4	7.1	6.9	7.3	6.5	6.7	6.8
Conductivity, (μmhos/cm)	47	44	42	119	107	158	874	793	688
Turbidity, (NTU)	4.2	3.7	10.4	27	19	926	72	57	169
Total Hardness as $CaCO_3$ (mg/l)	12	10	12	82	80	76	118	129	135
Total Alkalinity as $CaCO_3$ (mg/l)	31	30	28.7	74.3	77.5	76.5	191.2	183	197
Ammonia, (mg/l)	0.21	0.22	0.9	2	1.65	1.5	12.1	7.9	4.3
Dissolved oxygen (mg/l)	6.4	6.7	6.6	3.1	3.9	5.2	2.31	2.9	5.6
BOD_5, (mg/l)	2.2	1.7	4.5	95	76	68.1	234	197	49
COD, (mg/l)	7.6	6.4	20.5	340	295	210.9	572	410	207

Maximum BOD (864 mg/L) was observed from (Teku in March 2020) and lowest (1.7 mg/L) from Shivapuri in May 2020. Regarding the COD, it was found maximum in Teku in March 2020 which was 1832 mg/L and minimum 6.4 mg/l from Shivapuri in May 2020 (Table 2 & 3).

The minimum and maximum dissolved Oxygen recorded were 6.4 mg/L and 6.7 mg/L at Sundarijal, 3.1 mg/L and 5.24 mg/L at Gokarna, 2.31 mg/L and 5.6 mg/L at Tilganga, 0 mg/L and 4.6 mg/L at Sankhamul, 0 mg/L and 4.2 mg/L at Teku and 1.9 mg/L and 5.9 mg/L at Chovar. The lower oxygen level means lower chances of survivability for water organisms (Table 3). Low DO may be the function of higher water temperature and the decomposition of organic matter (Verma, 2013). The pH ranges are 7 to 7.4 for Sundarijal, 6.9 to 7.3 for Gokarna,6.5 to 6.8 for Tilganga, 7.1 to 7.3 for Sankhamul, 7.1 to 7.2 for Teku and 7.0 to 7.3 for Chovar.

We found that the seasonal average value for pH ($F = 5.41$, $p = 0.008$), conductivity ($F = 37$, $p < 0.05$), turbidity ($F = 3.977$, $p = 0.02$), hardness ($F = 316.4$, $p < 0.05$), alkalinity ($F = 364.8$, $p < 0.05$), ammonia ($F = 5.55$, $p = 0.008$), BOD ($F = 7.98$, $p = 0.002$), and COD ($F = 7.76$, $p = 0.002$) differed significantly in the sites, while we did not find any difference in DO ($F = 2.86$, $p = 0.06$).

A total of eight models were run which identified two top models under our criteria (Table 4). The model estimate indicated that the species richness is negatively related to BOD and positively with pH. But only BOD has a significant impact on the fish species richness (Table 5).

Table 3. Determination of physical characteristics of water samples in Sankhamul, Teku and Chovar

Parameter	Sankhamul			Teku			Chovar		
	Year/Month			Year/Month			Year/Month		
	020/03	020/05	020/05	020/03	020/05	020/05	020/03	020/05	020/05
pH	7.2	7.3	7.1	7.2	7.2	7.1	7	7.3	7.1
Conductivity (μmhos/cm)	1279	1160	870	1304	1182	868	643	583	622
Turbidity (NTU)	1805	430	1241	1845	447	1035	879	975	1045
Total Hardness as $CaCO_3$ (mg/L)	198	200	184	198	200	184	126	116	114
Total Alkalinity as $CaCO_3$ (mg/L)	205.5	202	188	212.5	198.4	192.6	210	200.8	197
Ammonia (mg/L)	1.32	2.5	2.2	1.76	2.12	2.32	21.2	20.97	4.2
Dissolved oxygen (mg/L)	Nil	1.2	4.6	Nil	1.02	4.2	1.9	2.81	5.9
BOD_5 (mg/L)	824	612	314	864	634	342	261	234.2	71
COD (mg/L)	1764	1097	734	1832	1104	812	612	560	536

Table 4. Total candidate models run to determine the relationship between the fish diversity and physico-chemical parameters in Bagmati River, Kathmandu Valley.

Model	df	logLik	AICc	delta	Weight
BOD	2	-21.47	47.74	0	0.42
BOD + pH	3	-20.10	47.92	0.18	0.39
BOD + Turbidity	3	-21.35	50.42	2.68	0.11
BOD + pH + Turbidity	4	-20.10	51.28	3.54	0.07
pH + Turbidity	3	-24.77	57.26	9.52	0.004
Turbidity	2	-27.26	59.31	11.57	0.001
Null	1	-29.50	61.25	13.51	0.0005
pH	2	-28.29	61.38	13.64	0.0005

All six sites show suitability for organism growth based on pH as Nepal water has a guideline that a pH range between 6.5 – 8.5 is best suitable for aquaculture. The research by Milner et. al. (2015) recorded the minimum and maximum pH of the Bagmati River as 7.39 and 9.37, respectively. The slight seasonal fluctuation of pH can be attributed to the combined effect of temperature, CO_2 balance, and buffering capacity of water. Generally, water with low levels of carbonates, bicarbonates, and phosphates has a low buffering capacity (Agrawal, 1999). The present value (7 to 7.4) was similar to the result of ENPHO (1997), Pokhrel (1997), Ghimire (1999) and Paudyal (2001) in the Sundarijal area. This value was also similar to the range of 6.6-7.5 found by Lohman *et al.* (1988) in Begnas and Rupa Tal.

Table 5. Model averaged estimates (ΔAIC < 2) for the fish diversity and physio-chemical parameters in Bagmati River, Kathmandu Valley.

Variables	Estimates	Std. error	Adjusted se	Z value	p
Intercept	-4.32	7.52	7.81	0.55	0.58
BOD	-0.004	0.001	0.001	2.67	**0.007**
pH	0.76	0.99	1.08	1.46	0.14

The minimum conductivity was found in Sundarijal (42 μmhos/cm) in June 2020 whereas the maximum was found in Teku (1304 μmhos/cm) in March 2076. The minimum and maximum conductivity were found to be 42 μmhos/cm and 47 μmhos/cm for Sundarijal, 107 μmhos/cm and 119 μmhos/cm for Gokarna, 688 μmhos/cm and 874 μmhos/cm for Tilganga, 870 μmhos/cm and 1279 μmhos/cm for Sankhamul, 868 μmhos/cm and 1304 μmhos/cm for Teku and 583 μmhos/cm and 643 μmhos/cm for Chovar. A high conductivity indicates a significant amount of dissolved salts in water (DOFW, 1994), as well as a relatively higher trophic status of the system. The minimum and maximum levels of ammonia recorded were 0.21 mg/L and 0.85 mg/L at Shivapuri, 1.48 mg/L and 2 mg/L at Gokarna, 4.3 mg/L and 12.1 mg/L at Tilganga, 1.32

mg/L and 2.5 mg/L at Sankhamul, 1.76 mg/L and 2.32 mg/L at Teku, 4.2 mg/L and 21.2 mg/L at Chovar, respectively. WHO (2011) states that to be at a normal natural level it should be below 0.2 mg/L for both underground and surface sources. High ammonia is an indication of more municipal waste and sewage (Milner et al., 2015). The minimum hardness was observed at Sundarijal in March 2020, and it was 10 mg/L whereas the maximum hardness was observed from Sankhamul and Teku in May 2020 and that was 200 mg/ L. Total hardness affects the toxicity of metals such as zinc, lead, copper and cadmium to the aquatic environment (Milner et al., 2015). A similar trend was recorded by (Bhatta *et al.*, 1999) in Taundaha Lake, Nepal as well as ENPHO (1997) and Paudyal (2001) in Sundarijal. The water of these rivers and the reservoir can be regarded as soft water as described by ENPHO (1996) and the value was far below the WHO standard of 500 mg/L. The maximum turbidity was observed at Teku, it was 1845 NTU in March 2020, and the lowest was at Sundarijal and that was 3.7 in May 2020. Maximum alkalinity of 212.5 mg/L was observed at Teku in March 2020 and lowest at Shivapuri 30 mg/L in May 2020. These values were far less than in the Tinau River as reported by Sharma and Shrestha (2001). The present values were similar to Paudyal (2001) in Sundarijal.

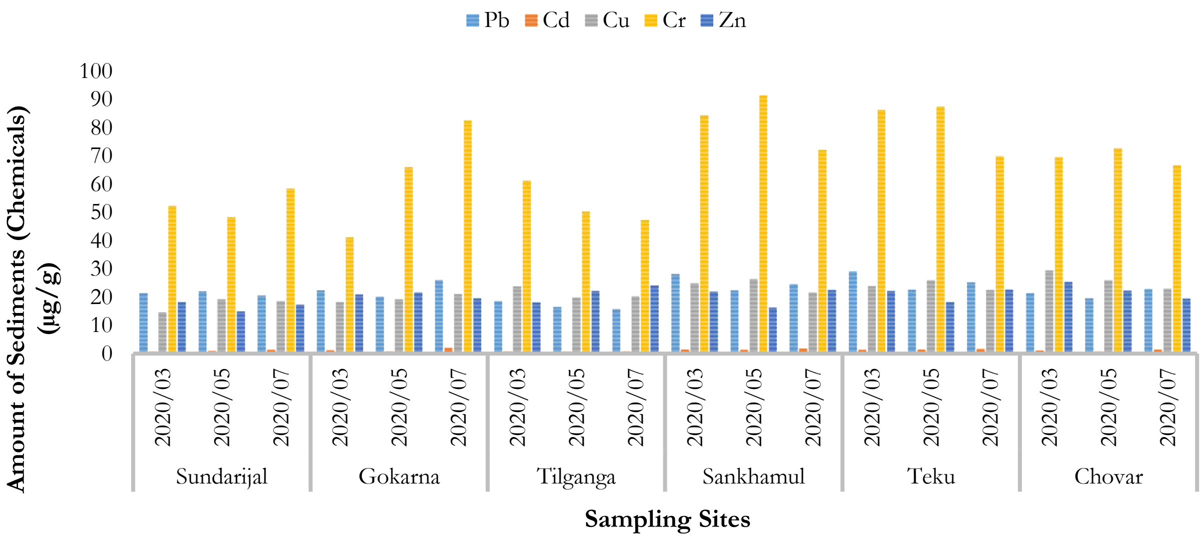

Figure 3. Graphical representation of the Sediments levels in water of Bagmati at the sample collection sites in three different months

Maximum Lead content, i.e., 29.02 µg/g was recorded from Teku from the sample of March 2020 whereas the minimum was observed from Tilganga, i.e., 15.66 µg/g from the sample of June 2020. Maximum Cadmium content, i.e., 1.9 µg/g was recorded from Gokarna from the sample of June 2020 whereas the minimum was observed from Tilganga, i.e., 0.6 µg/g from the sample of May 2020 (Fig. 3). Metals such as Pb, Cd, Ni, As, and Hg enhance the overall toxic effect on organisms even at very low concentrations (Mehta et al., 2016). Cadmium (Cd) is known to be one of the most harmful heavy metals and has a significant effect on fish (Paudyal, 2001).

The maximum copper of 29.4 µg/g was observed from Chovar in March 2020, and the minimum was observed at Sundarijal from the sample in March 2020 and it was 14.5 µg/g. Copper is an important trace nutrient that humans, other mammals, fish, and shellfish need in small quantities. Heavy metal contamination due to natural and anthropogenic sources is a global environmental concern. The release of heavy metals without proper treatment poses a significant threat to public health because of their persistence, biomagnification, and accumulation in the food chain (Rajendran *et al.,* 2003). The high value of Cu and Zn may be due to chemical fertilizers and pesticides (Yilmaz *et al.,* 2004) used in agricultural land of the upstream region and the value of Cr may be due to animal wastes (Best, 1982) from the catchments area. The increasing Pb concentration may be caused by atmospheric pollution because of vehicular emission or bullet firing by security personnel, whose concentration was found highest in winter in Bagmati because in winter the pollution problem becomes high. Lead (Pb) emission originating from traffic causes a distinct increase in the lead content in the soil (Brady, 1995). Kathmandu Valley is getting heavily polluted mainly by vehicular emissions. Whatever, the amount of toxic metals emitted or released into the environment finally gets into the river system, which drains this valley.

Table 4. List of Fishes recorded on the sites in Bagmati River

Location	Month	Fish species				
Sundarijal	February	*Schizothorax labiatus*	*Schistura beavani*	*Esomus danrica*	*Glyptosternum maculatum*	*Channa orientalis*
	March	*Schizothorax labiatus*	*Schistura beavani*	*Esomus danrica*	-	*Channa orientalis*
	April	*Schizothorax labiatus*	*Schistura beavani*	*Esomus danrica*	-	*Channa orientalis*
	May	*Schizothorax labiatus*	*Schistura beavani*	*Esomus danrica*	-	-
	June	*Schizothorax labiatus*	*Schistura beavani*	*Esomus danrica*	*Glyptosternum maculatum*	-
Gokarna	February	-	-	*Esomus danrica*	-	*Channa orientalis*
	March	-	-	*Esomus danrica*	*Glyptosternum maculatum*	*Channa orientalis*
	April	-	-	*Esomus danrica*	*Glyptosternum maculatum*	*Channa orientalis*
	May	-	-	*Esomus danrica*	*Glyptosternum maculatum*	*Channa orientalis*
	June	-	-	-	-	*Channa orientalis*
Tilganga	February	-	-	-	-	-
	March	-	-	-	-	-
	April	-	-	-	-	-
	May	-	-	-	-	-
	June	-	-	-	-	-
Sankhamul	February	-	-	-	-	-
	March	-	-	-	-	-
	April	-	-	-	-	-
	May	-	-	-	-	-
	June	-	-	-	-	*Channa orientalis*
Teku	February	-	-	-	-	-
	March	-	-	-	-	-
	April	-	-	-	-	-
	May	-	-	-	-	-
	June	-	-	*Esomus danrica*	-	-
Chovar	February	-	-	*Esomus danrica*	-	-
	March	-	-	*Esomus danrica*	*Glyptosternum maculatum*	-
	April	-	-	-	*Glyptosternum maculatum*	-
	May	-	-	-	*Glyptosternum maculatum*	*Channa orientalis*
	June	-	-	-	*Glyptosternum maculatum*	*Channa orientalis*

CONCLUSIONS

We concluded that the water quality was good at Sundarijal and fair at Gokarna. However, the other four sites had worsening water quality. The sites other than Sundarijal and Gokarna were ecologically poor and very few species could survive on these sites. Direct mixing of sewage, wastewater from households and industries, and plastics has highly affected the quality of the Bagmati River. All the mixing of the waste has made the Bagmati River highly polluted. There was a direct mixing of pollutants, i.e., from the Gokarna to Chovar there was an increase in chemical elements, plastics, sewage, municipal waste, kitchen, and industries. The contamination of heavy metals Pb, Cd, Cu, and Cr, and the presence of ammonia is affecting aquatic life. There was a scarcity of food resources and imbalance in the food chain and food web as the presence of aquatic fauna is low in the food chain. Apart from these, chemical contaminants were in adverse quantities that have affected the water quality and remaining aquatic fauna of Bagmati River.

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AUTHOR CONTRIBUTIONS
B. Rijal: Conceptualization, data curation, data analysis, investigation, methodology, writing original draft, review & editing; T.R. Adhikari: Conducted field surveys, wrote the manuscript, and reviewed the manuscript; S. Adhikari: Field surveys, data analysis, review; S Lamichhane: data collection and field report assistance; S. Baral: Data analysis, wrote the manuscript, reviewed.

CONFLICT OF INTEREST
The authors declare no conflict of interests.

DATA AVAILABILITY STATEMENT
The data that supports the findings of this study are available from the corresponding author, upon reasonable request.

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