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Spatial and temporal variation of ichthyo-faunal diversity with relation to environmental variables in the Lohandra River, Eastern, Nepal

Jamuna Rajbanshi[1], Prakash Kumar[1], Dipak Rajbanshi[1] and Dil kumar Limbu*[2]

[1]*Department of Zoology, Post Graduate Campus, Tribhuvan University, Biratnagar*
[2]*Department of Botany, Central Campus of Technology, Tribhuvan University, Hattisar, Dharan, Nepal*

**E-mail: dilklimbu@gmail.com*

Abstract

The present study aimed to examine space and time variation in fish community structure with relation to environmental variables in the Lohandra River. Fish samples were collected based on different habitat representations from March 2020 to February 2021, covering 12 months. Fish sampling took place from 6 am to 9 am. For the fish sampling, two cast nets of different sizes were used, one having a large mesh size of having a mesh size of 1 cm, 5 m diameter, and 5 kg weight and another having 0.5 cm, 3 m diameter, and 2 kg weight, covering 200 to 250m across each station to cover all possible areas. In addition, monofilament gill nets with mesh sizes of 6, 8, and 10 cm were used to capture the fish. In each station, 9-gill nets were left late in the evening (5 pm – 6 pm) and taken out early in the morning (6 am – 7 am) in a sampling distance of 200 - 250m. A total of 1178 specimens representing 72 species belonging to 10 orders and 25 families were documented. An analysis of similarity (ANOSIM) testing for both time (R=-0.25, P>0.05) and space (R=-0.28, P>0.05) showed no significant dissimilarity in fish assemblage structure. Results from the similarity percentage analysis (SIMPER) indicated that the fish species: *Cirrhinus reba, Labeo bata, Cirrhinus mrigala, Labeo boga, Puntius sophore, Salmostoma bacaila, Channa orientalis, Chagunius chagunio, Glossogobius giuris, Labeo caeruleus, Barilius bendelisis, Colisa faciatus, Esomus danricus, Salmostoma acinaces,* and *Chitala chitala.* The CCA revealed that of the selected environmental variables, three parameters namely, transparency, water temperature, and water velocity (p<0.05) were found to be influencing factors to determine the fish assemblage structure of the Lohandra River.

Keywords: Assemblage structure, freshwater, fish diversity, stream

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Introduction

Fish account for about half of all vertebrates on the planet. There are 35890 fish species in the globe, living in both fresh and saltwater (Nelson *et al*., 2016). Freshwater environments make up a small percentage of the world's surface water, but they house a disproportionately large number of the world's fish species, totaling over 15000 (Reid *et al*., 2013; Nelson *et al*., 2016). Of these, 11952 are freshwater residents, while 3048 roam between the sea and freshwater or live in estuaries and coastal wetlands (Reid *et al*., 2013). Despite the difference in size and volume of freshwater and marine realms, both have a startlingly similar number of fish species (15150) and marine realm (14740) (Arthington *et al*., 2016). Nepal's water bodies harbor more than 220 indigenous freshwater fish species (Khatri *et al*., 2020). Freshwater fish are an imperative element in aquatic biodiversity which have been used for aquatic ecosystem assessment

(Yan *et al*., 2011; Guo *et al*., 2018). Environmental factors may influence a population's spatial distribution and temporal dynamics at the same time, resulting in changes in the functional structure of populations (Frelat *et al*., 2018). Freshwater physical and chemical parameters are important factors of the health of fish assemblages. (Li *et al*., 2012; Limbu *et al*., 2021a). Any modification of the riverine habitat and ecosystem may greatly influence the river ecology and fish dispersal (Tumbahangfe *et al.*, 2021; Limbu *et al*., 2021b). Ecological parameters, such as water velocity (Yu and Lee, 2002; Limbu and Prasad, 2020), dissolved oxygen (Guo *et al*., 2018; Vieira *et al*., 2020), water temperature (Hossain *et al*., 2012), pH (Vieira and Garro, 2020), substrate (Limbu and Prasad, 2020), altitude (Limbu *et al*., 2021b) have all been shown to affect the fish community structure.

The Lohandra River has been pre-eminently altered due to several human encroachments such as human settlement, factories, embankment, sand mining, electrofishing, damming, agriculture, and so on. To date, the space and time pattern of the low-land, Terai region remains relatively unknown. Moreover, the details on fish community structure relating to their anthropogenic activities is also scanty. Facts about the relationship between fish community structure and environmental conditions can help us protect and manage aquatic biodiversity away from human-caused challenges like pollution and global climate (Li *et al*., 2012). Here, we studied the Spatio-temporal spectrum by relating environmental variables including anthropogenic activities.

Materials and Methods

Study area

The Lohandra river, one of the major river systems i.e. Koshi river system surges from the Bhogateni village development committee which lies just above the Churia hills, in between Mahabharat hills and Churia hills. The Lohandra River (Figure 1) is one of the Morang district's most important sources of water for irrigation and agriculture which originates from the Bhogateni village development committee of Morang district. The geographical location is between latitude 26.6799° and longitude 87.4603°. Sahai to the North, Biratnagar to the West, South to India, and Rangeli to the East surrounds the study area. The Lohandra River has a sunny, occasionally occurring cloud with an average yearly temperature of 30.9 °C (Khanal, 2015). The river's vegetation is diverse, with bamboo forests and bushes predominating. Dominated substrata consist of sand, gravel, cobble, pebble, and a little boulder.

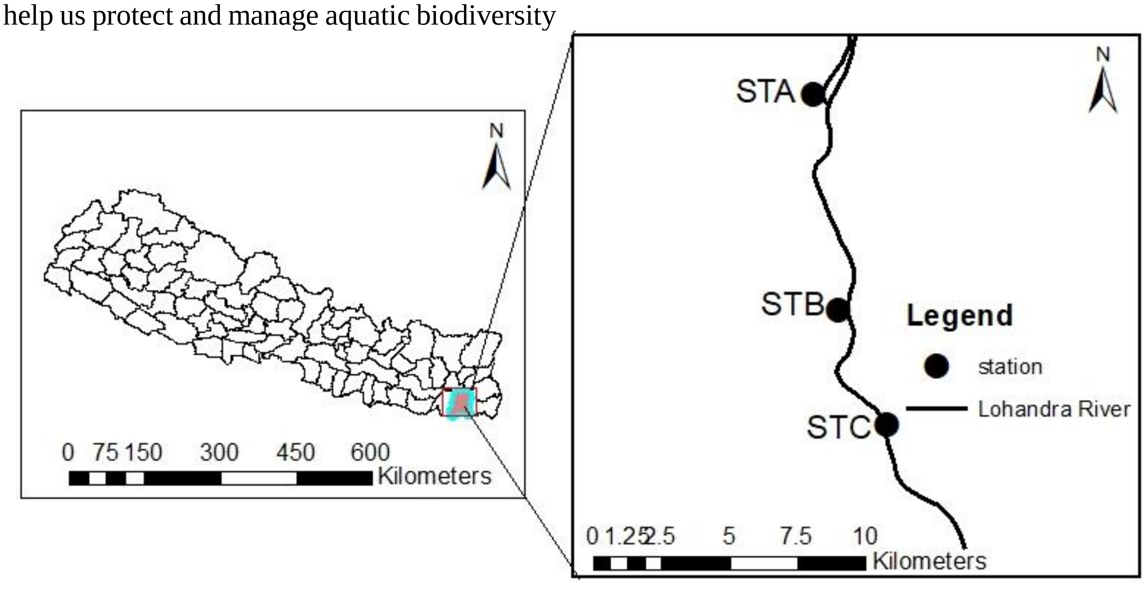

Figure 1. Map of study area showing sampling stations.

Sampling method

The study area was divided into three sampling stations (Figure 1): Ramchowk (station A), Beria (station B), and Sisiriya (station C) for measuring hydrological parameters and collection of fish. Fish samples were collected based on different habitat representation from March 2020 to February 2021, covering 12 months. Fish sampling took place from 6 a.m. to 9 a.m. For the fish sampling, two cast nets of different sizes were used, one having large mesh size of having a mesh size of 1 cm, 5 m diameter, and 5 kg weight and another having 0.5 cm, 3 m diameter, and 2 kg weight, covering 200 to 250 m (Limbu *et al*., 2021c) across each station to cover all possible areas. However, sampling was restricted in some areas due to difficulties of access. In addition, monofilament gill nets with mesh sizes of 6, 8, and 10 cm were used to capture the fish. In each station, 9-gill nets were left late in the evening (5 pm – 6 pm) and taken out early in the morning (6 am – 7 am) in a sampling distance of 200 – 250 m. The collected fish were photographed in fresh condition and identified in the field and if not, the voucher specimens were preserved in 10 % formalin. After the photography, the remaining samples were returned to their natural habitat from where they were captured. Fishes were identified with the help of standard literature (Talwar and Jhingran, 1991; Jayaram, 2010; Fricke *et al.,* 2021) and other available standard literature. The environmental variables were examined during field visits following the standard methods of the American Public Health Association (APHA, 1998). During the study period, all the selected water parameters such as water temperature, dissolved oxygen (DO), pH, total hardness, water velocity, conductivity, alkalinity, and free carbon dioxide (CO2) were measured *in situ*. Water temperature (^{0}C) was measured with a digital thermometer by placing it in the water at a depth of 1 foot within one minute and the observed value was recorded. The Winkler titra-metric method was used to measure the dissolved oxygen. Each sampling site's water sample was taken in a 300 mL BOD bottle with no bubbling. Then, from the side of the bottle, 2 ml of MnSO4 and 2 ml of KI were gently poured, the mixture was shaken thoroughly to complete the reaction, and the sample was left for half an hour for the precipitates to settle. To dissolve the brown precipitate at the bottom of the solution, 2 mL concentrated H2SO4 was added. In the burette washed by the solution, sodium thiosulphate (0.025 N) was taken for titration. One or two drops of starch solution were added as an indication to about 50ml of the mixture in the conical flask. The solution was then titrated against sodium thiosulphate solution until it became colorless. pH was measured by using a pH meter (HI 98107, HANNA Instrument). Total hardness (mg/l) was determined by using EDTA titrimetric method. Water velocity was measured by the float method with the help of a stopwatch, small ball, and measuring tape. To assess alkalinity, a 10 ml water sample was placed in a conical flask with one drop of phenolphthalein added and thoroughly stirred. Bromocresol Green-methyl Red (1 packet) was added and thoroughly mixed into it. After that, it was titrated using sulfuric acid, and the endpoint was noted. A Secchi disk was used to measure the water transparency. Free carbon dioxide was measured in mg/l by titrimetric method using phenolphthalein as an indicator.

Data analysis

One-way analysis of variance (ANOVA) was used for temperature, pH, dissolved oxygen, hardness, and water velocity to calculate the existence of any differences between space and time spectrum. A post-hoc Tukey HSD test was used to test which means were significantly different at a 0.05 level of probability (Spjøtvoll and Stoline, 1973).

Shannon Weiner diversity index (Shannon and Weaier, 1963) considers both the number of species and the distribution of individuals among species. The Shannon-Weiner diversity was calculated by the following formula:

$$H = \sum_{i=1}^{S} Pi * logPi$$

Where S is the total number of species and Pi is the relative cover of i_{th} of species.

The Simpson dominance index (Harper, 1999) was calculated by using the following formula:

$$D = \sum_{i} \left(\frac{ni}{n}\right)^2$$

Where n_i is a number of individuals of species i.

The evenness index (Pielou, 1966) was determined by the following equation:

$$E = H' / \log S$$

Where H' = Shannon- Weiner diversity index

S = Total number of species in the sample.

One-way analysis of similarity (ANOSIM) (Clarke, 1993) was used to test the significant difference among the spatial and temporal scales. To visualize the major contributing species both to space and time, similarity percentage (SIMPER) (Clarke, 1993) analysis was performed. Of 72 fish species, 36 species occurred <1% frequency of the samples and were eliminated from the present analysis. Rare species were excluded in the analysis as they tend to affect multivariate analyses (Gauch, 1982). Samples by species and environmental variables were analyzed through a multivariate analysis tool. Detrended correspondence analysis (DCA) (Hill and Gouch, 1983) was performed to determine whether redundancy correspondence analysis (RDA) or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species and environmental variables. The value of axis length and eigenvalues obtained from DCA suggested that the uni-model associated with CCA was more applicable. Therefore, a direct multivariate ordination method (Legendre and Legendrem, 1998) based on a linear response of species to environmental gradients was applied.

Results

Species abundance and distribution

In this study, a total of 1178 specimens representing 72 species belonging to 10 orders and 27 families were documented (Table 1). Of these, 9 species fall under the IUCN red list (Table 2). The order Cypriniformes was documented to be most dominated order which comprised 54.16% followed by Siluriformes 19.44%, Perciformes 6.94%, Anabantiformes 6.94%, Synbranchiformes 4.16%, Osteoglossiformes 2.77%, Clupeiformes 1.38%, Beloniformes 1.38%, Cyprinodontiformes 1.38% and Gobiiformes 1.38%. At the species level, ~63.7% of catches were dominated by 20 fish species, namely, *Chagunius chagunio* (5.2%), *Cirrhinus reba* (5.2%), *Barilius bendelisis* (4%), *Labeo- bata* (4.9%), *Channa punctatus* (3.8%), *Salmostoma acinaces* (3.6%), *Channa orientalis* (3.5%), *Puntius sophore* (3.3%), *Cirrhinus mrigala* (3.1%), *Labeo boga* (2.8%), *Salmostoma bacaila (2.7%)*, *Glossogobius giuris* (2.5%), *Labeo fimbriatus* (2.4%), *Labeo gonius* (2.4%), *Pseudambassis ranga* (2.2%), *Lepidocephalus Guntea* (2.1%), *Pseudambassis baculis* (2%), *Esomus danricus* (1.8%), *Aspidoparia jaya* (1.7%) and *Aspidoparia morar* (1.4%).

Table 1. Fish species of Lohandra River.

Order	Family	Species	Local name
Clupeiformes	Engraulidae	*Setipinna phasa* (Hamilton 1822)	Phasi
Osteoglossiformes	Notopteridae	*Chitala chitala* (Hamilton 1822)	Vuna
	Notopteridae	*Notopterus Notopterus* (Pallas 1769)	Lepsi
Cypriniformes	Cyprinidae	*Labeo catla* (Hamilton 1822)	Vakur
	Cyprinidae	*Chagunius chagunio* (Hamilton 1822)	Patharchatti
	Cyprinidae	*Cirrhinus mrigala* (Hamilton 1822)	Naini
	Cyprinidae	*Cirrhinus reba* (Hamilton 1822)	Mrigal
	Xenocyprididae	*Ctenopharyngodon idella* (Valenciennes 1844)	Ghase macha
	Cyprinidae	*Cyprinus carpio communis* (Linnaeus 1758)	Common carp
	Cyprinidae	*Labeo bata* (Hamilton 1822)	Rohu
	Cyprinidae	*Labeo boga* (Hamilton 1822)	Tikauli Boga
	Cyprinidae	*Labeo caeruleus* Day 1877	Bishari
	Cyprinidae	*Labeo fimbriatus* (Bloch 1795)	Boi
	Cyprinidae	*Labeo gonius* (Hamilton 1822)	Karsa
	Cyprinidae	*Labeo pangusia* (Hamilton 1822)	Lalpuchhya
	Cyprinidae	*Pethia conchonius* (Hamilton 1822)	Sidhre
	Cyprinidae	*Barbonymus gonionotus* (Bleeker 1849)	Pothiya,sidhre
	Cyprinidae	*Puntius sophore* (Hamilton 1822)	Pothi
	Cyprinidae	*Pethia ticto* (Hamilton 1822)	Tite pothi
	Danionidae	*Laubuka laubuca* (Hamilton 1822)	Glass-barb
	Danionidae	*Salmostoma acinaces* (Valenciennes 1844)	Chilwa
	Danionidae	*Salmostoma bacaila* (Hamilton 1822)	Galphulani
	Danionidae	*Amblypharyngodon microlepis* (Bleeker 1853)	Mada, Dhawai
	Danionidae	*Amblypharyngodon mola* (Hamilton 1822)	Mada, Dhawai
	Danionidae	*Cabdio jaya* (Hamilton 1822)	Bhenga, Mara
	Danionidae	*Cabdio morar* (Hamilton 1822)	Karangi, Chakale
	Danionidae	*Opsarius barna* (Hamilton 1822)	Titerkane faketa

	Danionidae	*Opsarius bendelisis* (Hamilton 1807)	Chiple faketa
	Danionidae	*Opsarius shacra* (Hamilton 1822)	Fakete
	Danionidae	*Barilius vagra* (Hamilton 1822)	Lam faketa
	Danionidae	*Devario devario* (Hamilton 1822)	Chitharipothi
	Danionidae	*Esomus danrica* (Hamilton 1822)	Dedhawa
	Danionidae	*Raiamas bola* (Hamilton 1822)	Butte chala
	Danionidae	*Raiamas guttatus* (Day 1870)	Thople bola
	Cyprinidae	*Tariqilabeo latius* (Hamilton 1822)	Lohari
	Cyprinidae	*Garra mullya* (Sykes 1839)	Khurpe buduna
	Psilorhynchidae	*Psilorhynchus balitora* (Hamilton 1822)	Balotora Minow
	Nemacheilidae	*Paracanthocobitis botia* (Hamilton 1822)	Baghe
	Nemacheilidae	*Schistura scaturigina* McClelland 1839	Gadela
	Cobitidae	*Lepidocephalichthys guntea* (Hamilton 1822)	Lata
	Cobitidae	*Canthophrys gongota* (Hamilton 1822)	Baluwari
	Botidae	*Botia lohachata* Chaudhuri 1912	Baghi
Siluriformes	Bagridae	*Sperata aor* (Hamilton 1822)	Kanti
	Bagridae	*Mystus cavasius* (Hamilton 1822)	Tenger
	Bagridae	*Mystus vittatus* (Bloch 1794)	Kanti
	Siluridae	*Ompok bimaculatus* (Bloch 1794)	Papta
	Siluridae	*Ompok pabda* (Hamilton 1822)	Pabdah, Catfish
	Siluridae	*Wallago attu* (Bloch & Schneider 1801)	Buhari
	Ailiidae	*Ailia coila* (Hamilton 1822)	Patsi
	Horabagridae	*Pachypterus atherinoides* (Bloch 1794)	Patasi
	Sisoridae	*Gagata cenia* (Hamilton 1822)	Ganfak
	Sisoridae	*Pseudolaguvia kapuri* (Tilak and Husain 1975)	Kirkire
	Sisoridae	*Sisor rabdophorus* Hamilton 1822	Puchhare Machho
	Sisoridae	*Glyptothorax pectinopterus* (McClelland)	Capre
	Clariidae	*Clarias batrachus* (Linnaeus 1758)	Mangur
	Heteropneustidae	*Heteropneustes fossilis* (Bloch 1794)	Singhi
Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton 1822)	Kabali
Cyprinodontiformes	Aplocheilidae	*Aplocheilus panchax* (Hamilton 1822)	Tikuli
Synbranchiformes	Synbranchidae	*Ophichthys cuchia* (Hamilton 1822)	Andho bam
	Mastacembelidae	*Macrognathus aral* (Bloch & Schneider 1801)	Gainchi
	Mastacembelidae	*Mastacembelus armatus* (Lacepède 1800)	Chuche bam
Perciformes	Ambassidae	*Chanda nama* Hamilton 1822	Chanerbijuwa
	Ambassidae	*Parambassis baculis* (Hamilton 1822)	Chanari
	Ambassidae	*Parambassis ranga* (Hamilton 1822)	Chanerbijuwa
	Nandidae	*Nandus nandus* (Hamilton 1822)	Dalahi,Dhoke
	Badidae	*Badis badis* (Hamilton 1822)	Pasari
Gobiformes	Gobidae	*Glossogobius giuris* (Hamilton 1822)	Bulle, vulvule
Anabantiformes	Anabantidae	*Anabas testudineus* (Bloch 1792)	-
	Osphronemidae	*Trichogaster fasciata* Bloch & Schneider 1801	Kotari
	Osphronemidae	*Trichogaster lalius* (Hamilton 1822)	Lal kotari
	Channidae	*Channa orientalis* Bloch & Schneider 1801	Garahi
	Channidae	*Channa punctata* (Bloch 1793)	Garahi

Table 2. IUCN (2020) category of fish species in the Lohandra River.

Fish species	IUCN red list category
Labeo pangusia	Near threatened
Chitala chitala	Near threatened
Ailia coila	Near threatened
Ompok bimaculatus	Near threatened
Ompok pabda	Near threatened
Wallago attu	Near threatened
Laubuka laubuca	Near threatened

Cyprinus carpio communis	Vulnerable
Channa orientalis	Critically endangered

Diversity status

The value of Shannon Weiner diversity index (H), Simpson dominance index (D), Evenness index (E), and Species richness (S) were calculated according to seasons and stations (Table 3 and 4). The highest Shannon diversity index (3.89) was recorded at station C and the lowest (3.8) was found at station B. Highest Shannon Weiner diversity index (3.69) was found in Spring while low during Autumn (3.1). There was no significant difference (*P*>0.05) was found among the seasons and stations. The Highest Simpson dominance index was (0.97) found at station C where the minimum was at station A (0.96). The maximum dominance index (0.963) was recorded in Spring where the minimum index value was in Autumn (0.94). There is also no significant difference (*P*>0.05) was observed. The highest value of the evenness index (0.51) was observed in Spring where the minimum was in Summer and Autumn which contribute equal values (0.5). Likewise, the highest evenness index (0.54) was found at station B and the lowest value (0.52) was observed at station C. No significant difference (*P*>0.05) was found in the mean value of evenness value among the seasons and stations. Similarly, the highest value of species richness (69) was found at station C and the lowest (62) was observed at station B. On the contrary, the highest species richness value (71.72) was observed in Autumn where the lowest value (51.67) was in Winter. No significant difference (*P*>0.05) was found in the mean value of species richness value among the stations but a significant difference (*P*<0.05) was observed among the seasons.

Spatio-temporal relation of fisheries biodiversity

An analysis of similarity (ANOSIM) testing for both time (*R*=-0.25, *P*>0.05) and space (*R*=-0.28, *P*>0.05) showed no significant dissimilarity in assemblage structure. According to similarity percentage (SIMPER) analysis (Table 5), 49.62% similarities were found among the stations and major contributing species are C7, C10, C6, C11, C18, C22, C72, C71, C5, C67, C12, C28, C69, C32, C21, and C2. On the contrary, 51.1% similarities were observed among the seasons and major donating species are C7, C10, C6, C11, C18, C22, C72, C71, C67, C5, C12, C28, C32, C69, C2, and C21 (Table 4).

Table 3. Value of diversity indices according to seasons.

Season	Shannon-Weiner index	Simpson Index	Evenness Index	Species Richness
Winter	3.54	0.95	0.51	51.67
Spring	3.69	0.96	0.51	66.72
Summer	3.32	0.95	0.5	70.42
Autumn	3.1	0.94	0.5	71.72

Table 4. Value of diversity indices according to stations.

Station	Shannon-Weiner index	Simpson Index	Evenness Index	Species Richness
A	3.80	0.96	0.53	67
B	3.80	0.97	0.54	62
C	3.89	0.97	0.52	69

Table 5. Average similarity and discriminating fish in each station and season using SIMPER analysis.

Code	Species	Contribution % (Stations)	Code	Species	Contribution % (51.1Seasons)
C7	*Cirrhinus reba*	6.54	C7	*Cirrhinus reba*	6.62
C10	*Labeo bata*	4.61	C10	*Labeo- bata*	4.77
C6	*Cirrhinus mrigala*	3.86	C6	*Cirrhinus mrigala*	4.00

C11	*Labeo boga*	3.57	C11	*Labeo boga*	3.72
C18	*Puntius sophore*	2.85	C18	*Puntius sophore*	2.86
C22	*Salmostoma bacaila*	2.71	C22	*Salmostoma bacaila*	2.73
C72	*Channa punctatus*	2.70	C72	*Channa punctatus*	2.54
C71	*Channa orientalis*	2.43	C71	*Channa orientalis*	2.39
C5	*Chagunius chagunio*	2.34	C67	*Glossogobius giuris*	2.37
C67	*Glossogobius giuris*	2.32	C5	*Chagunius chagunio*	2.35
C12	*Labeo caeruleus*	2.29	C12	*Labeo caeruleus*	2.34
C28	*Opsarius bendelisis*	2.28	C28	*Opsarius bendelisis*	2.33
C69	*Colisa faciatus*	2.09	C32	*Esomus danricus*	2.11
C32	*Esomus danricus*	2.08	C69	*Colisa faciatus*	2.11
C21	*Salmostoma acinaces*	2.06	C2	*Salmostoma acinaces*	2.07
C2	*Chitala chitala*	2.04	C21	*Chitala chitala*	2.02

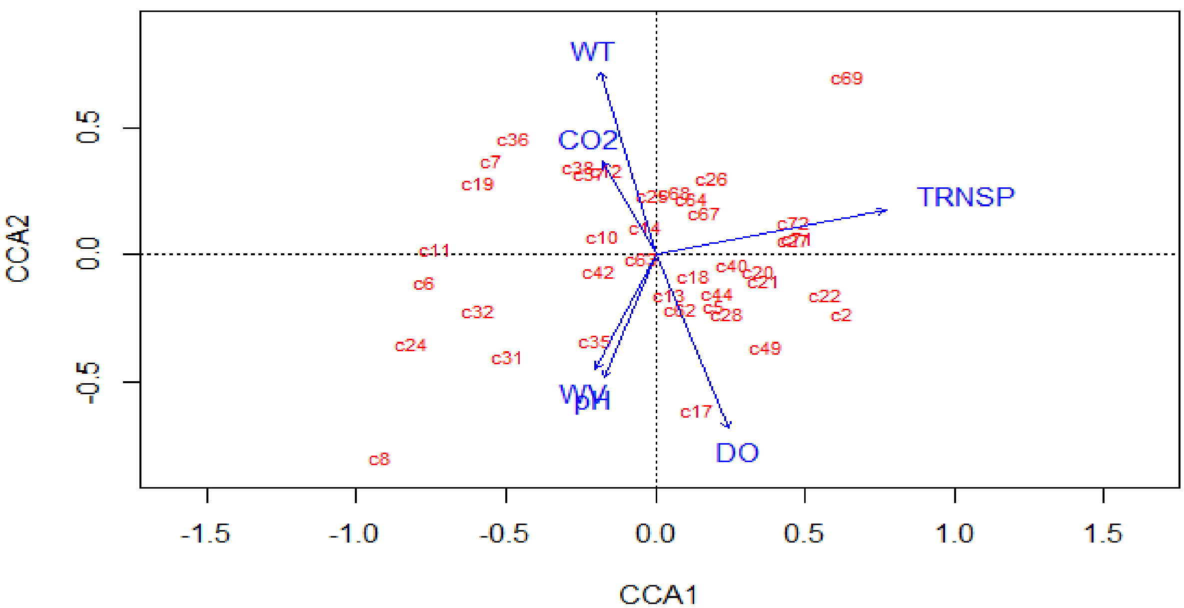

Figure 2. Canonical correspondence analysis (CCA) of species abundance and environmental variables (WT = water temperature, WV = water velocity, DO = dissolved oxygen, TRNSP = transparency, for species code see appendix I)

Driving factors of fisheries distribution

The CCA ordination demonstrated a significant relationship (analysis of variance permutation tests, n=999, $p<0.05$) between species and environmental parameters based on species data matrix (Figure 2). The first and second axis of the CCA accounted for 49% of the total variance (35% on the first axis and 14% on the second). The CCA revealed that of the selected environmental variables, three parameters namely, transparency, water temperature, and water velocity ($p<0.05$) were found to be influencing factors to determine the fish assemblage structure of the Lohandra River. C17, C49, C2, C22, C28, C21, C20, C40, C44, C5, C62, C13, and C18 were positively related to dissolved oxygen and negatively related to water temperature and free carbon dioxide. C8, C24, C6, C32, C31, C35, C42, and C63 were positively related to water velocity and pH and negatively related to transparency. C11, C7, C36, C38, C62, C10, C37, and C14 were positively related to water temperature and free carbon dioxide whereas negatively related to dissolved oxygen. Similarly, C69, C72, C71, C67, C64, C68, and C26 were positively related to transparency and negatively related to water velocity and pH.

Discussion

In this study, 72 fish species were subjected to examination, among which C7, C10, C6, C11, C18, C22, C72, C71, C5, C67, C12, C28, C69, C32, C21, and C2 were the contributing species, each contributing more than 1% of the total composition. In terms of total fish species number, medium-size river like the Lohandra River is considered to be the richest in the ichthyofaunal diversity. This is maybe due to the availability of plenty of food, continuous flow of water, sufficient amount of oxygen, large water volume, and capability to tolerate water temperature above 30 ℃ of all the captured fishes. The results showed that Cypriniformes were the most abundant order comprising 54.166% and Clupeiformes, Beloniformes, Cyprinodontiformes, and Gobiiformes were the least abundant order each comprising 1.388%. The outcomes of this study are congruous with the findings of Adhikari *et al*. (2021), Chaudhary and Limbu (2021), Limbu *et al*. (2021c), and Nelson (2016) also indicated that the majority of the freshwater fish falls under the order Cypriniformes and Family Cyprinidae. The representation of Cypriniformes found in this study is also consistent with the information reported in different Asian freshwater rivers (for example., Hossain *et al*., 2012; Guo *et al*., 2018; Ngor *et al*., 2018; Mia *et al*., 2019; Prasad *et al*., 2020) of Meghna River, Ganjian River, Tropical flood system of southeast Asia, Atrai River and Seti Gandaki River.

The diversity indices like the Shannon-Weiner index examine the richness and proportion of each species. On the other hand, Simpson dominance and Evenness index accounts for the sample's relative size (Hossain *et al*., 2012). The diversity indices observed from the present study are not so high according to Shannon-Weiner diversity index values and they do not exactly reflect the significant differences occurring among the seasons and stations except species richness. The probable reason for showing lower diversity is that fishing gears used have a high selectivity effect (Keskin and Unsel, 1998; Hossain *et al*., 2012). There could be another reason showing lower or higher diversity indices values is that seasonal fish migration, atmospheric air currents, environmental conditions, elevations, characteristic features of rivers and streams, and availability of food contents (Vieira and Garro, 2020; Limbu *et al*., 2021).

Different environmental factors influence fish health as well as the diversity and distribution of fishes in the water bodies like rivers, streams, lakes, creeks, canals, and reservoirs (Radinger *et al*., 2019; Prasad *et al*., 2020; Limbu *et al*., 2021). Water temperature and dissolved oxygen (DO) are mostly in charge of observed changes in species diversity and are also accountable to change the fish community structure according to seasons and elevations (Adhikari *et al*., 2021). In the present study, environmental variables like transparency, water temperature, and water velocity ($p<0.05$) were found to be influencing factors to determine the fish assemblage structure of the Lohandra River. The dissolved oxygen (DO) (Yan *et al*., 2010; Hossain *et al*., 2012; Li *et al*., 2012; Frelat *et al*., 2018; Mia *et al*., 2019; Limbu *et al*., 2020a; 2020b; Vieira and Garro, 2020; Chaudhary *et al*., 2021; Limbu *et al*., 2021a, 2021b), water velocity (Yu and Lee, 2002; Limbu and Prasad, 2020), depth (Kadye *et al*., 2008) have already been shown to influence the fish community structure.

The Lohandra River exhibits a good fish diversity even though the quality of the river is imperiled by different human encroachments like sand mining, disposal of non-degradable things (e.g., water bottles, plastic bags), and industrial pollution which directly or indirectly affects the fish. According to recent studies, humans have altered almost 83 percent of the land area surrounding freshwater systems (Arthington *et al*., 2016). Moreover, catchment disturbance, deforestation, riparian loss and fragmentation, water pollution, river corridor engineering, dams and water diversions, groundwater depletion, aquatic habitat loss and fragmentation, invasive species, and overfishing are considered as the main factors to threats the native fish species by numerous freshwater habitats (Dudgeon *et al.*, 2006; Arthington *et al*., 2016; Vieira and Garro, 2020; Limbu *et al*., 2021). The present study reported 9 fish species to fall under the IUCN red list and their categories are near threatened, vulnerable, and critically endangered. The medium river like Lohandra itself has such several red list fish species hinted that the water bodies scattered throughout the country are greatly affected by human footprint, deforestation, habitat loss, haphazard ongoing road development, etc. which in turn to contribute the fish species loss.

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Appendix I: Checklist of fish species from Lohandra River.

Code	Name of species	Spring			Summer			Autumn			Winter			Grand	% frequency
		March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.		
C1	*Setipinna phasa*	1	0	0	0	1	1	0	0	0	0	0	0	3	0.3
C2	*Chitala chitala*	0	0	1	2	1	2	2	3	5	0	0	0	16	1.4
C3	*Notopterus notopterus*	2	1	2	0	0	2	0	0	0	0	0	3	10	0.8
C4	*Catla catla*	0	0	1	1	0	1	0	0	0	0	0	0	3	0.3
C5	*Chagunius chagunio*	4	5	5	4	7	9	7	6	4	5	3	2	61	5.2
C6	*Cirrhinus mrigala*	2	5	3	7	10	9	0	0	0	0	0	0	36	3.1
C7	*Cirrhinus reba*	6	12	15	5	11	10	0	0	0	0	0	2	61	5.2
C8	*Ctenopharyngodon idellus*	0	0	0	3	7	2	0	0	0	1	0	0	13	1.1
C9	*Cyprinus carpiocommunis*	0	0	0	1	0	1	0	0	0	0	0	0	2	0.2
C10	*Labeo- bata*	3	7	9	6	9	10	8	3	0	0	1	2	58	4.9
C11	*Labeo boga*	2	4	6	7	9	5	0	0	0	0	0	0	33	2.8
C12	*Labeo caeruleus*	4	5	3	3	2	5	3	0	0	0	1	2	28	2.4
C13	*Labeo fimbriatus*	3	1	2	3	4	4	3	2	1	1	3	1	28	2.4
C14	*Labeo gonius*	2	3	1	1	3	3	2	2	0	0	1	1	19	1.6
C15	*Labeo pangusia*	1	1	0	1	0	2	1	0	0	0	1	1	8	0.7
C16	*Puntius conchonius*	0	0	0	0	0	1	1	0	0	0	0	0	2	0.2
C17	*Puntius gonionotus*	0	1	2	2	1	3	1	1	0	3	2	1	17	1.4
C18	*Puntius sophore*	2	4	3	2	5	8	7	4	2	1	1	0	39	3.3
C19	*Puntius ticto*	3	1	2	2	2	4	0	0	0	0	0	0	14	1.2
C20	*Chela labuca*	0	0	1	0	1	0	1	1	0	0	0	0	4	0.3
C21	*Salmostoma acinaces*	4	3	2	3	3	6	7	4	4	3	1	2	42	3.6
C22	*Salmostoma bacaila*	2	1	0	1	3	5	7	5	4	0	2	2	32	2.7
C23	*Amblypharyngoddonmicrolepis*	1	0	2	0	0	1	0	0	0	0	0	0	4	0.3
C24	*Amblypharyngodon mola*	0	1	1	2	3	5	0	0	0	0	0	0	12	1.0
C25	*Aspidoparia jaya*	3	2	4	1	4	3	3	2	2	0	0	0	24	2.0
C26	*Aspidoparia morar*	3	2	2	2	1	3	4	1	2	0	0	0	20	1.7
C27	*Barilius barna*	2	1	2	1	0	2	3	2	1	1	1	0	16	1.4
C28	*Barilius bendelisis*	1	3	5	5	5	6	6	6	3	3	1	3	47	4.0
C29	*Barilius shacra*	1	0	0	0	1	1	1	2	0	0	0	0	6	0.5
C30	*Barilius vagra*	1	1	0	0	1	2	1	0	0	1	1	0	8	0.7

C31	*Danio devario*	1	0	1	2	2	5	0	0	0	1	0	1	13	1.1
C32	*Esomus danricus*	1	2	3	4	5	4	0	0	0	1	1	0	21	1.8
C33	*Raiamas bola*	1	1	0	1	0	2	2	4	0	0	0	0	11	0.9
C34	*Raiamas guttatus*	1	0	0	0	1	2	2	1	1	0	0	0	8	0.7
C35	*Crossocheilus latius*	0	1	0	1	3	4	2	1	0	0	0	1	13	1.1
C36	*Garra mullya*	1	2	0	1	0	2	0	0	0	0	0	0	6	0.5
C37	*Psilorhynchus balitora*	1	0	1	1	0	1	0	0	0	0	0	1	5	0.4
C38	*Acanthocoboitis botia*	4	3	2	2	2	3	1	0	0	1	0	1	19	1.6
C39	*Schistura Scaturigina*	1	0	1	0	0	1	1	1	0	0	0	1	6	0.5
C40	*Lepidocephalus Guntea*	3	2	1	1	3	4	3	4	2	1	1	0	25	2.1
C41	*Somileptes gongota*	1	1	0	0	1	2	1	0	0	1	1	0	8	0.7
C42	*Botia lohachata*	2	2	0	1	3	3	1	1	0	1	0	1	15	1.3
C43	*Aorichthy aor*	0	0	0	0	1	1	2	1	0	0	0	0	5	0.4
C44	*Mystus cavasius*	1	1	0	1	2	4	3	3	0	0	0	1	16	1.4
C45	*Mystus vitttatus*	1	0	1	0	1	1	1	2	1	0	1	1	10	0.8
C46	*Ompok bimaculatus*	1	0	0	0	1	1	2	2	4	0	0	0	11	0.9
C47	*Ompok pabda*	0	0	0	0	1	1	1	0	0	0	0	0	3	0.3
C48	*Wallago attu*	1	0	1	1	2	2	1	0	0	0	0	1	9	0.8
C49	*AiliaCoila*	0	0	0	1	2	3	3	2	2	0	0	0	13	1.1
C50	*Pseudeutropins atherinoides*	0	0	0	0	1	1	0	0	0	0	0	0	2	0.2
C51	*Gagata Cenia*	1	1	0	0	1	2	2	1	0	1	0	0	9	0.8
C52	*Pseudolsguvia kapuri*	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1
C53	*Sisor rhabdophorus*	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1
C54	*Glyptothorax pectinopterus*	0	1	0	0	0	0	0	1	0	0	0	0	2	0.2
C55	*Clarias batrachus*	1	0	0	0	0	0	0	0	0	0	0	0	3	0.3
C56	*Heteropneustes fossilis*	2	1	0	0	0	0	0	0	0	1	1	0	5	0.4
C57	*Xenetodo ncancilla*	1	0	1	1	0	2	0	0	0	0	0	1	6	0.5
C58	*Aplocheilus Panchax*	1	1	0	0	2	2	2	1	0	0	0	0	9	0.8
C59	*Monopterus cuchia*	0	0	0	1	0	0	0	0	0	0	1	1	3	0.3
C60	*Macrognathus aral*	3	1	1	0	0	1	1	0	0	0	0	2	9	0.8
C61	*Mastacembelus armatus*	0	1	1	0	0	0	0	0	0	0	0	1	3	0.3
C62	*Chanda nama*	2	3	1	2	5	5	4	3	1	2	1	1	30	2.5
C63	*Pseudambassis baculis*	3	3	1	1	4	4	3	1	0	1	2	1	24	2.0
C64	*Pseudambassis ranga*	5	3	1	2	3	3	3	3	1	1	0	1	26	2.2
C65	*Nandus nadus*	1	1	0	0	0	1	1	1	0	0	0	0	5	0.4
C66	*Badis Badis*	1	0	0	0	0	1	1	0	0	0	0	0	3	0.3

C67	*Glossogobius giuris*	4	3	2	2	4	4	4	5	2	0	0	0	30	2.5
C68	*Anabas cobojius*	3	2	1	0	2	2	2	1	0	1	0	1	15	1.3
C69	*Colisa faciatus*	4	4	1	0	0	0	4	3	2	0	0	0	18	1.5
C70	*Colisa lalius*	1	1	0	0	1	2	0	0	0	0	0	0	5	0.4
C71	*Channa orientalis*	6	4	2	1	2	4	7	5	3	3	2	1	41	3.5
C72	*Channa punctatus*	8	5	3	2	1	3	6	6	2	4	3	2	45	3.8
Grand total														**1178**	**100.0**