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Fish Assemblage Structure and Environmental Correlates in Nepal's West Rapti River, Banke

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Abstract

The spatial and temporal variations of fish assemblages in rivers and streams of Nepal are poorly understood. So, the present study aimed to explore the spatial and temporal variations of fish assemblage structure in Nepal's West Rapti River. The data were collected during autumn, winter and spring seasons, from October 2018 to April 2019. Fish samples were collected using cast net of 12 mm mesh size. A total of 28 species belonging to 7 orders, 10 families and 19 genera were recorded during the study. The analysis of similarity (ANOSIM) showed no significant difference among the stations and seasons. Based on cluster analysis, two major clusters were observed. The similarity percentage (SIMPER) analysis delineated that *Cabdio morar* (C14, 13.63%), *Barilius bendelensis* (C11, 10.32%), *Gogangra viridescens* (C22, 7.85%), *Salmostoma phulo* (C17, 7.74%), *Labeo gonius* (C5, 7.53%), *Gagata cenia* (C23, 6.45%), *Garra gotyla* (C6, 5.87%) and *Labeo dyocelius* (C2, 5.62%) were the most contributing species. The Canonical Correspondence Analysis (CCA) distinctly showed that the environmental variables dissolved oxygen, pH, carbon-dioxide, and water temperature play an essential role in shaping the fish assemblage structure of West Rapti River.

Keywords: Environmental variables, Fish assemblage, Fish diversity, Rapti River, Spatio-temporal

Introduction

Fish assemblage variation is function of the many inter-connecting factors, including hydrol-ogic regime, geo-climatic region, species comp-osition, biotic versus abiotic regulation, channel type, disturbance history and frequency (Gross-mann *et al.,* 1998). It has been widely reported that the distribution and abundance of fish species are strongly regulated by environmental factors (Tejerina *et al.,* 1998; Brown, 2000). These factors include topographical characte-ristics (Platts, 1979), climate (Eaton and Scheller, 1996), hydrological regime (Poff and Allan, 1995), riparian land use (Lammert and Allan, 1999), and water physical-chemical variables like dissolved oxygen and pH (Matthews, 1998). These abiotic parameters have short-term and long-term influences on the structure of fish assemblages (Gasith and Resh, 1999). Beside the abiotic factors, biotic factors like predation and competition also affect fish assemblages via direct and indirect mechanisms (Jackson *et al.,* 2001). Characterizing the factors that affect fish assemblages is beneficial for river management and fish preservation. Similar studies on fish-habitat relationships have

been carried out in South America (Fialho *et al.,* 2008), North America (Feyrer and Healey, 2003), Europe (Gondinho, 2000) and Africa (Ibanez, 2007), but are still lacking for Asia (Shahnawaz *et al.,* 2010).

Rapti River is one of the most important River in Mid- Western part of the country, which provides good habitat for fishes and other aquatic organisms. Despite a number of studies related with aquatic diversity from different parts of Nepal, little study has been conducted on the fish assemblage structure in West Rapti River Banke. Therefore, this study was designed to investigate the spatio-temporal variation in fish assemblage structure of West Rapti River, Banke Nepal.

Materials and method
Study area
The present study was carried out in the West Rapti River, Banke. The West Rapti River is one of

the main drainage of Mid-western region which originates from highland of Rolpa, Pyuthan and some parts of Argakhachi flowing through Mahabharat range to low land of Dang and Banke district and at last discharges into the India. It originates from above the elevation of 3523m near Rangon. The River originates as Madikhola then joins with Lungrikhola and Jhimrukkhola near Airawati and flows to Terai plains known as West Rapti River. Sit khola, Arunkhola, Ransinkhola are major small tributaries of the West Rapti River. Total catchment area is about 6,320Sq.km[15]. The study area starts from Siktaghat at 28°01'48.94"N 81°58'09.19"E to Saipur at 28°02'56.23"N 81°54'09.29"E 12 km along West Rapti River (Fig. 1).The present study was carried out from October 2018 to April 2019.
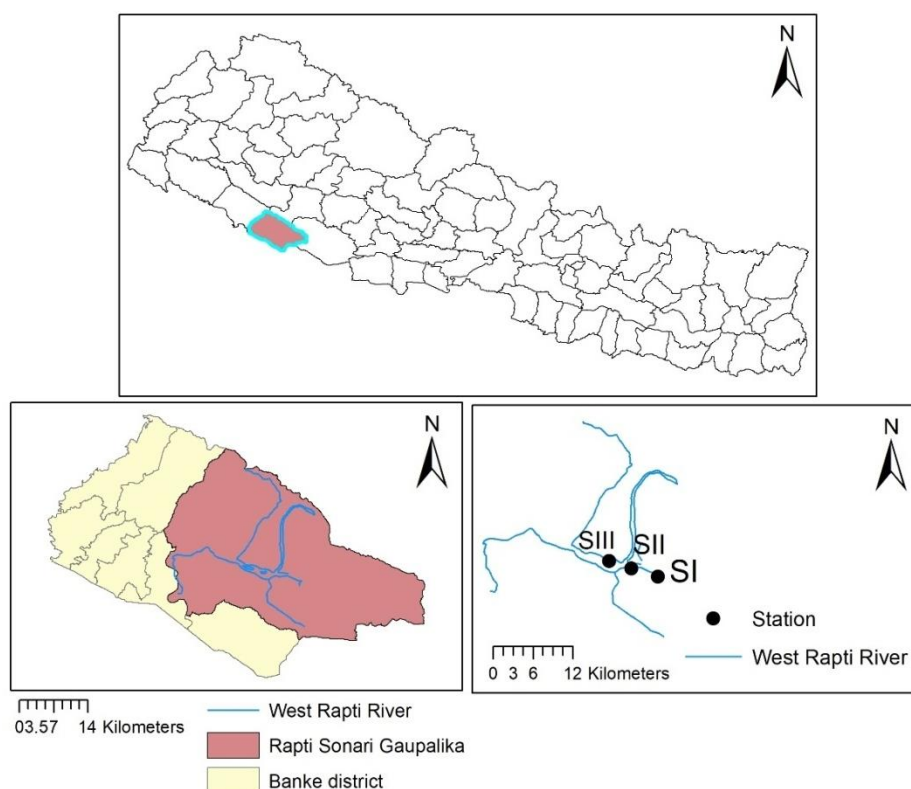
Figure 1. Map of study area

Selection of sampling station
A preliminary survey was done prior to the selection of sampling stations. Three sampling stations were selected below and above the Sikta irrigation dam. Station-I (28°01'48.94"N 81° 58'-09.19"E; 180m asl) is at Siktaghat above the Sikta irrigation dam. This area is also under Banke National Park. So, fishing is restricted to local people except licensed fishermen. Station-II (28°02'41.86"N 81°56'19.18"E; 168m asl) is below

the Sikta irrigation dam and cattle grazing land. This area is under Banke National Park. Station–III (28°03'.06"N 81°54'12.79"E; 159 asl) is near Saipur village and quarrying of stone and sand is done from this area so it is mostly disturbed area.

Fish collection, preservation and identification
The fishes were collected from each sampling station by employing local fishermen in three

different seasons by using cast net of 5 kg weight having 5m length and 20m breadth with 12mm mesh size. Sampling was done from 8 am to 10 am. The collected fish samples were photographed and were preserved in 10% formalin solution and brought to the Central Department of Zoology (CDZ), Tribhuvan Univ-ersity, Nepal for further identification. Identifi-cation of the samples was done by the help of standard references (Talwar and Jhingram, 1991; Jayaram, 2010; Shrestha, 2019).

Analysis of environmental variables
Water samples were collected during morning time (9:00 am to 10:00 am) and analyzed once every three months. Water temperature (ºC) was measured by the help of a mercury thermometer. pH was measured by using a calibrated pH meter (HI 98107, HANNA Instrument). Free CO_2 was determined by titration using 0.05N of NaOH and phenolphthalein as an indicator. Dissolved oxygen (DO) was estimated by Winkler's idiometric method.

Data analysis
Detrended Correspondence Analysis (DCA) was performed to determine whether Redundancy Analysis (RDA) or Canonical Correspondence Analysis (CCA) would be appropriate model to describe the association between fish species and variables. The axis length and eigen value obtained from DCA suggested that the linear model of CCA was more applicable. Therefore, a direct multivariate ordination method (Terbraak, 1986), based on a linear response of species to environmental gradients was applied by using vegan library in R (Oksanenm et al., 2015). One-way analysis of similarity (ANO-SIM) was used to determine the significance of spatial and temporal variation of fish assemblage structure (Clarke, 1993). Similarity percentages analysis (SIMPER) was executed to observe the percentage of similarity in temporal scale (Clarke, 1993).

Results
Fish community composition
A total number of 821 individuals were collected during the study, which belonged to 7 orders, 10 families, 19 genera and 28 species (Table 1, figure 5).The Cyprinidae was the most species–rich family (9 genera and 18 species) (Table 2), which is same to other water bodies in Nepal. he seven most copious fish species comprised (75.88%) of the total catch, i.e., *Cabdio morar* (369 individuals, 59.22%), *Barilius bendelisis* (54 individuals, 8.66%), *Salmostoma phulo* (47 individuals, 7.54%), *Barilius barila* (42 individuals, 6.74%), *Botia lohachata* (42 individuals, 6.74%), *Puntius sophore* (37 individuals, 5.93%), and *Labeo dyocelius* (32 individuals, 5.13%) (Table 1).

Table 1. Spatial and Temporal variation of fish assemblage structure of West Rapti River.

S.N.	Name of species	Autumn			Winter			Spring			Total
		I	II	III	I	II	III	I	II	III	
1.	*Labeo frimbiatus* (C1)	2	2	3	2	1	2	3	-	2	17
2.	*Labeo dyocheilus* (C2)	5	10	-	3	4	1	1	5	3	32
3.	*Labeo bata* (C3)	2	1	1	2	3	2	2	6	1	20
4.	*Labeo boga* (C4)	4	-	2	-	2	1	-	4	2	15
5.	*Labeo gonius* (C5)	-	-	-	-	-	-	5	10	6	21
6.	*Garra gotyla* (C6)	-	-	-	4	2	-	5	4	7	22
7.	*Garra rupecula* (C7)	-	-	-	2	1	-	-	-	-	3
8.	*Puntius sophore* (C8)	6	5	3	3	7	5	3	-	5	37
9.	*Puntius terio* (C9)	-	2	3	1	-	2	-	2	3	13
10.	*Tor putitora* (C10)	-	-	-	1	-	-	-	-	-	1
11.	*Barilius bendelensis (C11)*	12	10	9	8	5	7	2	-	1	54
12.	*Brilius barila* (C12)	4	7	5	5	4	2	5	4	6	42
13.	*Barilius vagra* (C13)	3	3	4	2	1	2	-	2	-	17
14.	*Cabdio morar* (C14)	30	35	42	40	41	39	45	47	50	369
15.	*Raiamas bola* (C15)	-	-	-	-	-	-	3	5	1	9
16.	*Rasbora danionius* (C16)	-	-	-	-	-	-	1	-	-	1
17.	*Salmostoma phulo* (C17)	10	7	5	11	6	3	2	-	3	47
18.	*Salmostoma acinaces* (C18)	5	-	2	-	2	-	1	-	-	10
19.	*Paracanthobotis botia* (C19)	-	-	-	-	-	-	2	-	1	3
20.	*Lepidocephalichthys guntea* (C20)	-	-	-	1	-	-	-	-	-	1
21.	*Botia lohachata* (C21)	5	4	2	6	3	2	8	5	7	42
22.	*Gogangra viridescens* (C22)	-	-	-	-	-	-	5	7	10	22
23.	*Gagata cenia* (C23)	-	-	-	-	-	-	5	6	7	18
24.	*Xenentodon cancila* (C24)	-	-	-	-	-	-	1	-	-	1
25.	*Pseudombassis baculis*(C25)	-	-	-	-	-	-	-	1	-	1
26.	*Macrogonathus armatus* (C26)	-	-	-	-	-	-	1	-	-	1
27.	*Channa punctata* (C27)	-	-	1	-	-	-	-	-	-	1
28.	*Glosso gobiusgiuris* (C28)	-	-	-	-	-	-	-	1	-	1
	Total										821

Table 2. Systematic position of the fish collected from West Rapti River

S.N	Order	Family	Genus	Species
1.	Cypriniformes	Cyprinidae	*Labeo*	*L. frimbiatus*
				L. dyocheilus
				L.bata
				L.boga
				L.gonius
			Garra	*G.gotyla*
				G.rupecula
			Puntius	*P. sophore*
				P.terio
			Tor	*T. putitora*
			Brilius	*B. bendelensis*
				B. barila
				B. vagra
			Cabdio	*C. morar*
			Raiamas	*R. bola*
			Rasbora	*R. danionius*
			Salmostoma	*S. acinaces*
				S. phulo
		Nemacheilidae	*Paracanthobotis*	*P. botia*
		Cobitidae	*Lepidocephalichthys*	*L. guntea*
		Botiidae	*Botia*	*B. lohachata*
2.	Siluriformes	Sisoridae	*Gogangra*	*G. viridescens*
			Gagata	*G. cenia*
3.	Beloniformes	Belonidae	*Xenentodon*	*X. cancila*
4.	Synbranchiformes	Mastacembelidae	*Macrognathus*	*M. aral*
5.	Perciformes	Ambassidae	*Pseudombassis*	*P. baculis*
6.	Anabantiformes	Channidae	*Channa*	*C. punctata*
7.	Gobiiformes	Gobiidae	*Glossogobius*	*G. giuris*

Spatial and temporal relation of fisheries biodiversity

The Canonical Correspondence Analysis (CCA) showed that the species of C12, C2, and C4 were positively correlated to water temperature while species of C11, C17, C18, C13, C27, C1 and C6 were positively related to dissolved oxygen and pH and negatively related to free-carbon dioxide. Fish species of C7, C10 and C20 were not related to any environmental variables. C23, C22, C5, C15, C6, C14, C21, C19, C25, C28, C16, C24, C26, C3, and C9 were positively correlated to free-carbon dioxide and negatively related to dissolved oxygen and pH (Fig. 2).
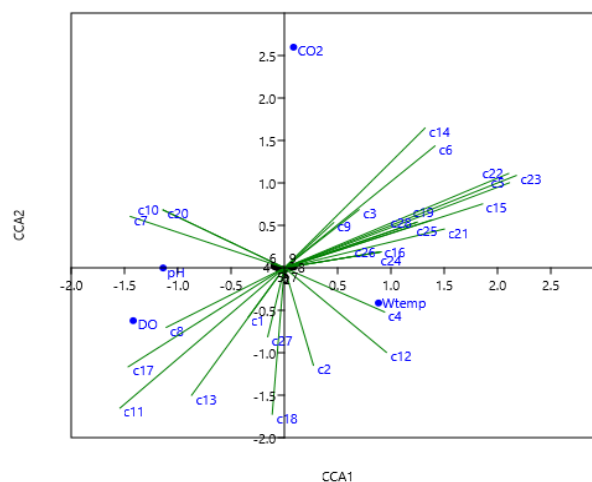
Figure 2. Canonical Correspondence Analysis (CCA) ordination of fish assemblages and environmental variables of West Rapti River (*for species code see table 1*).

Based on similarity percentage (SIMPER) analysis the major contributing species are *Cabdio morar* (13.63%), *Barilius bendelensis* (10.32%), *Gogangra viridescens* (7.851%), *Salmostoma phulo*

(7.749%), *Labeo gonius* (7.537%), *Gagata cenia* (6.453%), *Garra gotyla* (5.874%) and *Labeo dyocheilus* (5.625%) (table 3).

Table3. Average similarity and discriminating fish using SIMPER analysis.

Species	Code	Contribution (%)
Cabdio morar	C14	13.63
Barilius bendelensis	C11	10.32
Gogangra viridescens	C22	7.851
Salmostoma phulo	C17	7.749
Labeo gonius	C5	7.537
Gagata cenia	C23	6.453
Garra gotyla	C6	5.874
Labeo dyocheilus	C2	5.625
Botia lohachata	C21	4.524
Puntius sophore	C8	3.852
Raiamas bola	C15	3.262
Barilius vagra	C13	3.136
Salmostoma acinaces	C18	2.907
Labeo boga	C4	2.885
Brilius ba rila	C12	2.733
Labeobata	C3	2.59
Puntius terio	C9	2.26
Labeo frimbiatus	C1	1.624
Garra rupecula	C7	1.119
Paracanthobotis botia	C19	1.098

Based on cluster analysis, two major clusters were observed. The first cluster contained station II and III with autumn and winter. The Second cluster showed station I with Spring (Fig. 3 and 4).
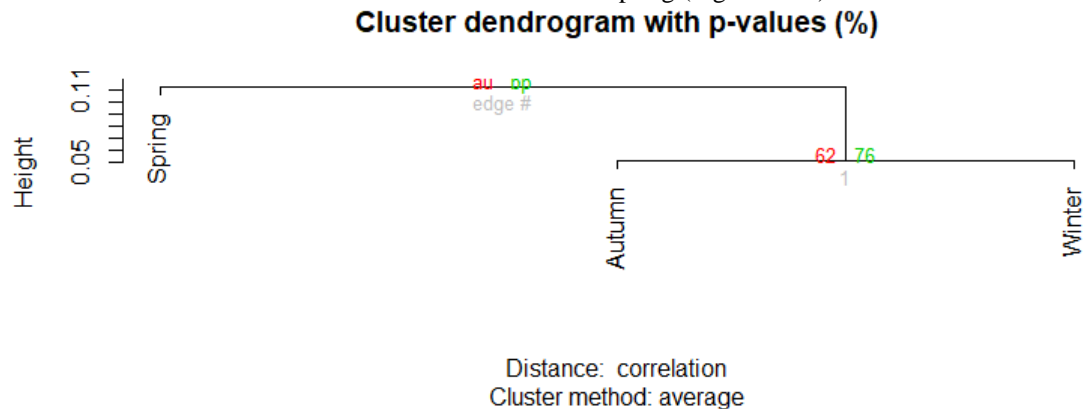
Figure 3. Dendrogram of cluster analysis comparing sampling seasons on the basis of fish assemblage.
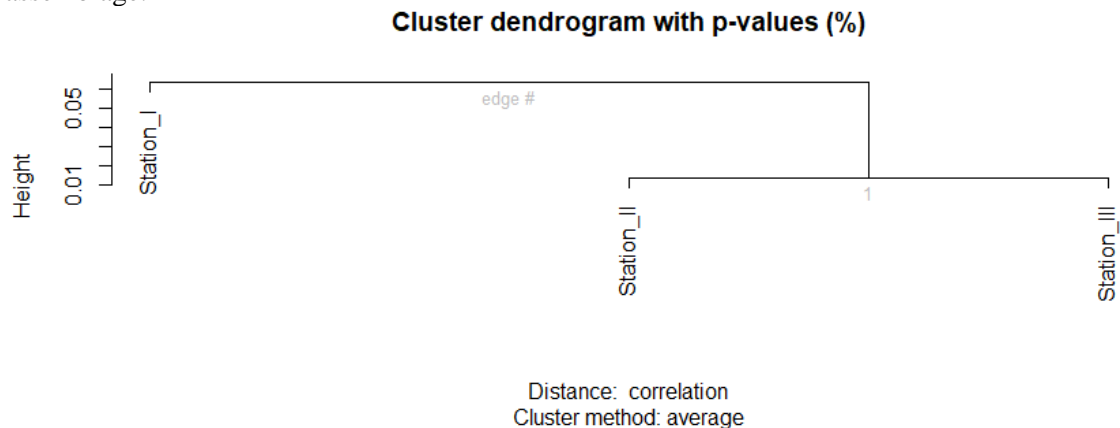
Figure 4. Dendrogram of cluster analysis comparing sampling stations on the basis of fish assemblage

The analysis of similarity (ANOSIM) revealed insignificant spatial variation among the three sampling sites (Table 4). The ANOSIM also showed insignificant seasonal variation in the fish assemblage among the sites (Table 5).

Table 4. Result of one way ANOSIM (significance levels) among different stations.

Stations	I	II	III
I	-	0.8989	0.6984
II	0.8989	-	0.4971
III	0.698	0.4971	-

Table 5. Result of one way ANOSIM (significance levels) among different seasons.

Seasons	Autumn	Winter	Spring
Autumn	-	0.4032	0.0966
Winter	0.4034	-	0.0958
Spring	0.0966	0.0958	-

Discussion

A total number of 28 species were reported during the study period. Among them are *Cabdio morar, Barilius bendelensis, Gogangra virides-cens, Salmostoma phulo, Labeo gonius, Gagata cenia, Garra gotyla, Labeo dyocheilus, Botia lohachata, Puntius sophore, Raiamas bola, Barilius vagra, Salmostoma acinaces, Labeo boga, Brilius barila, Labeo bata, Puntius terio, Labeo fimbriatus, Garra rupecula* and *Paracantho cobotis botia,* each contributing more than 1% based on similarity percentage (SIMPER) analysis. The Cyprinidae was the most numerous family with 18 species which is consistent the findings of Limbu *et al*. (2016) and Yan *et al*. (2010). Limbu *et al*. (2019a), Limbu *et al*. (2019b) and Subba *et al*.(2017) reported 152, 9, 18 and 118 fish species from eastern Nepal, Bakraha River, Ratuwa River and Morang district. Pokharel *et al*. (2018) identified 24 species whereas Oli (2016) found 20 fish species from West Rapti River. In terms of spatial and temporal assemblage structure of fish, two major groups were indicated by Bray-Curtis similarity cluster analysis in the West Rapti River. The first cluster consisted of stations I and II with autumn and winter. Second cluster consisted of station III with spring season. Based on ANOSIM, the fish assemblages in the West Rapti River showed no difference both in temporal and spatial scales. The finding was inconsistent with the finding of Yan *et al*. (2010).

Effects of environmental variable on species distributions were tested by Canonical Correspondence (CCA) analysis. Species located near the origin either do not show a strong relationship to any of the variables or are found at average values of environmental variables Marshall and Elliott (1998). In the present study, water temperature and dissolved oxygen were found to be pivotal variables to shape the fish assemblage structure of West Rapti River. Water temperature Kadye *et al*. (2007) and dissolved oxygen Limbu *et al*. (2019b) have been shown to influence fish assemblages. Besides, current velocity Yu and Lee (2002), depth Kadye *et al*. (2007), width Gerhard *et al*. (2003), substrata Vlach *et al*. (2005), altitude Magalhaes *et al*.(2002), conductivity Yu and Lee (2002) and climate Ferreira *et al*. (2009) have all been also shown to influence fish assemblages structure. Out of 28 fish species, eight species viz; *Tor putitora, Rasbora danionius, Lepidoce-phalichthys guntea, Xenentodon cancila, Pseud-ambassis baculis, Macrogonathus aral, Channa punctata*and *Glossogobius giuris* were recorded of only single individuals of each species. *Tor putitora* has been listed in endangered category (Shrestha, 2019) and was recorded from station I only. This is because this site is restricted area for fishing and is not affected by human activities whereas in station II and III, people have destroyed the habitat of aquatic organisms by extracting boulders, cobbles, pebbles and sand. Furthermore, as mentioned earlier, stations II and III, where local people graze their cattle might have negative impact for aquatic life, including fish. For instance, excreta of cattle and consequences of soil pollution due to grazing near the river bank may have adverse effects. The spatial and temporal variations of fish assemblages in rivers and streams of Nepal are poorly understood. Therefore, to better monitor, manage and conserve the Nepal's fisheries, there is an urgent need to update the information on the spatial and temporal scales of fish diversity, distribution pattern and community structure.

Labeo bata

Labeo frimbiatus

Labeo gonius

Labeo boga

Labeo dyocheilus

Tor putitora

Barilius bendelensis

Raiamas bola

Pseudambassis baculis

Cabdio morar

Glossogobiusgiuris

Salmostomaphulo

Salmostomaacinaces

Garra rupecula

Gogangra viridescens

Gagata cenia

Barilius vagra

Paracanthocobitis botia

Barilius barila

Puntius sophore

Puntius terio

Channa punctata

Xenentodon cancila

Macrogonathus aral

Lepidocephalichthys guntea

Garra gotyla

Botia lohachata

Rasboradanioconius

Figure 5. Fishes of West Rapti River.

Conclusion

The Canonical Correspondence (CCA) analysis hinted that water temperature and dissolved oxygen act as essential variables in shaping the fish assemblage structure of West Rapti River. The populations of *Tor putitora*, *Rasbora danionius, Lepidocephalichthys guntea, Xenentodon cancila, Pseudombassis baculis,Macrogonathus armatus, Channa punctata* and *Glossogobius*

giuris were found to be declining in the West Rapti River. The present study therefore, foresees the need of an immediate conservational initiative to conserve the above mentioned species in the river.

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