Study of substrate and physico-chemical base classification of the rivers of Nepal

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Patterns of diversity and conservation status of freshwater fishes in the glacial fed and rain fed rivers of Eastern Nepal

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Abstract Assessment of headwater biodiversity is essential for maintaining upstream downstream ecosystem services of rivers. Fish biodiversity assessment was conducted in the headwater tributaries of the glacial-fed Tamor River and rain-fed Kamala River in eastern Nepal. A total of eight sites were sampled. pH, dissolved oxygen, conductivity and temperature were estimated using multi-meter field probe. Standard electrofishing was conducted for fish sampling with two rounds of fishing for 20 min each at site. Catch per Unit Effort (CPUE) was calculated for each sample and the samples were identified in the field itself following standard literature. Unidentified samples were brought to the laboratory for further identification. Descriptive statistics was performed; Species richness, Shannon Weiner Diversity and Simpson's Diversity Index were estimated. One way ANOVA and an independent t test were performed respectively to look at the variation in fish abundance between seasons and between the tributaries of the Tamor River and the Kamala River. Threat status categories of the fish species was compared with those of IUCN. pH was neutral to alkaline in both the types of streams. Significant variation ($p = 0.01$) in seasons as well as between two types of headwater tributaries were observed in pH, temperature and conductivity. Temperature and conductivity were significantly higher in the rain-fed tributaries. These parameters were significantly higher during the pre-monsoon and lowest during the winter in both types of streams. A total of 8940 fishes belonging to four orders, 10 families, 26 genera and 34 species were enumerated. Significant variation in Shannon-Weiner Diversity Index ($p = 0.015$) and Species Richness ($p = 0.005$) between the glacial fed and rain fed streams with higher values of these indices in the rain fed tributaries. Fish abundance also varied significantly ($p = 0.02$) between seasons in the Tamor's tributaries with higher abundance in the pre-monsoon and lowest during the winter. Cypriniformes was the most dominant taxa with *Schistura beavani* (26.14), *Barilius vagra* (8.46) and *Garra gotyla gotyla* (7.63). *Schizothorax richardsonii* (10.31) and *Schistura beavani* (47.19) were the most dominant species in the Kamala's and the Tamor's tributaries. These findings

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indicate that fish assemblages reflect the different ecological regimes of the glacial-fed and rain-fed headwaters. The findings of this study contribute to the knowledge of fish diversity and also compliment the threat status of the IUCN fish data. Replication of similar studies encompassing temporal and spatial scales is necessary for the development pf effective conservation strategies.

Keywords Headwater streams · Glacial-fed rivers · Rain-fed rivers · Fish diversity · CPUE

Introduction

Headwater streams are defined as "the first and second-order stream segments of a river basin which are closely associated with hillslope and other adjacent terrestrial processes" (Barmuta et al. 2009). These freshwater bodies are characterized by cool, fast-flowing and highly oxygenated water (Day 2006; Snyder et al. 2013). They contribute around three quarters of the stream channel of a drainage basin (Leopold et al. 1964; Hansen 2001; Benda et al. 2005; Clarke et al. 2008) and form a strong terrestrial-aquatic linkage due to their small catchment size (Lowe and Likens 2005) providing inputs of nutrients (Peterson et al. 2001; Bernhardt et al. 2005) and energy from the watershed to the streams (Naiman et al. 2005; Craig et al. 2008). These ecosystems often act as spawning sites for a variety of organisms, migration corridors and refuge during flood events and food scarcity (Meyer et al. 2007; Wipfli et al. 2007; Clarke et al. 2008; White and Crisman 2014); unique biodiversity repositories harbouring rare, threatened and specialist species (Morse et al. 1993; Meyer and Wallace 2001; Meyer et al. 2007; Callanan et al. 2014). Due to their small size, they are sensitive to disturbances and climate change may exacerbate the impacts on these mountain streams thereby threatening their biodiversity and overall integrity of these ecosystems (Jacobsen et al. 2012). However, despite their significant ecological functions and susceptibility to disturbances these streams have received very little attention from researchers for protection and management (Barmuta et al. 2009; Jacobsen et al. 2012).

Nepal is rich in freshwater water resources with around 6000 rivers and rivulets draining an estimated area of 145,724 km^2 (WECS 2005). The rivers range from glacial fed rivers originating from the Himalayan glaciers to rain-fed and spring originating from the Mahabharata and the Siwalik ranges (WECS 2011). These rivers serve a multitude of ecosystem services and support a rich aquatic biodiversity. The country is known to have a rich fish biodiversity with 232 fish species (Shrestha 2008). Although, fish studies in Nepal dates back to as far as early 1800s (Hamilton 1822), knowledge on fish diversity of the country is still lacking (Rajbanshi 2002) particularly those of headwater streams due to rough topography and huge water resource of the country (Jha et al. 2015). Most of the country's fish diversity studies have focussed on fish inventories and are sporadic (Shrestha 2008; Shrestha et al. 2009; Shrestha and Edds 2012). Recent studies have focussed in lowland streams and rivers (Shah 2016; Yadav 2017). Considering the ecological importance of fish and headwaters and their role as environmental indicators including those of climate change, there is a need to study the biotic assemblages of headwater streams. Therefore, this study is an attempt to understand the fish assemblages in headwater streams of glacial-fed and rain-fed rivers in eastern Nepal.

Materials and methods

Study area

The study was conducted in the eastern region of Nepal on the tributaries of two major rivers i.e. Tamor River and the Kamala River. Tamor River is a perennial and glacial-fed river which originates from the Kanchenjunga range (Shrestha et al. 2009) whereas then Kamala River originates from the Siwalik region and is classified as a rain/spring fed river with low flow during dry season (Khanal 2001). Three headwater streams of Tamor River viz. the Mewa *Khola* and the Maiwa *Khola* in Taplejung district and the Hewa *Khola* in Panchthar district; and two headwater streams of the Kamala River viz. the Tawa *Khola* and the Lalleri *Khola* in Udayapur district of Nepal were selected. Eight different sites were chosen for the sampling of the study (Table 1 and Fig. 1). Site selection was based on the accessibility of the location. The sampling was conducted during March 2015 (Spring), November 2015 (Autumn/post-

Table 1 Study site showing geographical coordinates and elevation: 1.a Tributaries of Tamor River: Maiwa Khola (M1) and Maiwa Khola (M2), 2.a Tributaries of Kamala River: Hewa Khola 1 (H1) and Hewa Khola 2 (H2), 1.c Tributaries of Kamala River: Tawa Khola 1 (T1) and Lalleri Khola (L1), 1.d Tributaries of Kamala River: Tawa Khola 2 (T2) and Tawa Khola 3 (T3)

Site name	Site code	Geographical co-ordinates	Elevation (m)	Site & district
Maiwa	M1	N 27°22.064′ E 087°37.098’	664	Khamlung, Taplejung
Mewa	M2	N 27°22.675′ E 087°37.617’	666	Handrung, Taplejung
Hewa	H1	N 27°10.061′ E 087°47.321’	629	Phidim, Panchthar
Hewa	H2	N 27°09.802′ E 087°45.560’	550	Phidim, Panchthar
Tawa	T1	N 26°59.211′ E 086° 27.743’	330	Bahunetar, Udaypur
Lalleri	L1	N 26°59.347′ E 086°27.430’	327	Bahunetar, Udaypur
Tawa	T2	N 26°57.512′ E 086°23.361’	258	Rukse, Udaypur
Tawa	T3	N 26°56.925′ E 086°17.291’	167	Khoksa, Udaypaur

monsoon), January 2016 (Winter) and May 2016 (Summer/pre-monsoon).

Field work

Selected physico-chemical parameters such as temperature, pH, Dissolved Oxygen (DO) and Conductivity were also measured on site using multi-parametric probes (Orion multimeter). Three replicates were taken at each site. Standard electrofishing by wading method (Jha 2009; Sharma and Jha 2012) where the fishes were stunned, was used for the fish sampling. Although authorized animal care or ethical committees do not exist in Nepal; however, mandatory permission from the Department of the National Park and Wildlife Sanctuary, Nepal was taken prior to sampling. Self-restraint was practised and care was taken by the researchers to maintain minimum mortality of the fishes. The captured fishes were then released back to their natural habitat. In each site, fish sampling was done in two runs each consisting of 20 min encompassing approximately 100 m stretch of the river. Fish abundance was measured in temporal unit called catch per unit effort (CPUE), which is expressed as the number of fishes collected per 20 min of electrofishing (Jha 2009). The sum of the CPUE for the individuals of a site gives the relative abundance of each fish species. The fish samples were identified up to the species level in the field following standard literatures (Shrestha 2008; Shrestha et al. 2009; Shrestha and Edds 2012). The samples which could not be identified in the field were preserved in 70% Ethanol and brought to the laboratory at the Department of Environmental Science and Engineering, Kathmandu University (Accession Number: KU/DESE/Tamor 2015–2016) and identified following other standard literatures (Talwar and Jhingran 1991; Fishbase 2017). Moreover, the assemblages were compared with the assemblages of the previous study (Shrestha et al. 2009) conducted in the same area and fish experts associated with the same study were also consulted for verification of the identified fish species. Descriptive statistical analyses were performed for the selected physico-chemical parameters. The fish samples were enumerated and the Shannon-Weiner Diversity (H′) and Simpson's Index of Diversity (1-D) were calculated. An independent t-test was performed to look at significant variation in the diversity indices. The statistical software IBM SPSS Statistic 23 was used for statistical analyses. The threat status of the fishes was listed following Jha et al. (2006), Jha (2009) and was compared with those of IUCN. In this approach, the species with an average yearly abundance of 10.1 or above were categorizes as "common"; abundance of 5.1–10 as "fairly common"; abundance between 1 and 5 and with less than one but more than three in any one of the sampled sites were labelled as vulnerable. The species with an average yearly abundance of less than one but not exceeding three in any one of the streams were categorized as endangered (Fig. 2).

Results

The results of the estimated selected on-site physico-chemical parameters are presented in Table 2. Mean pH in both the types of streams was neutral and slightly alkaline. Significant variation ($p < 0.01$) in pH, temperature and conductivity were observed between the

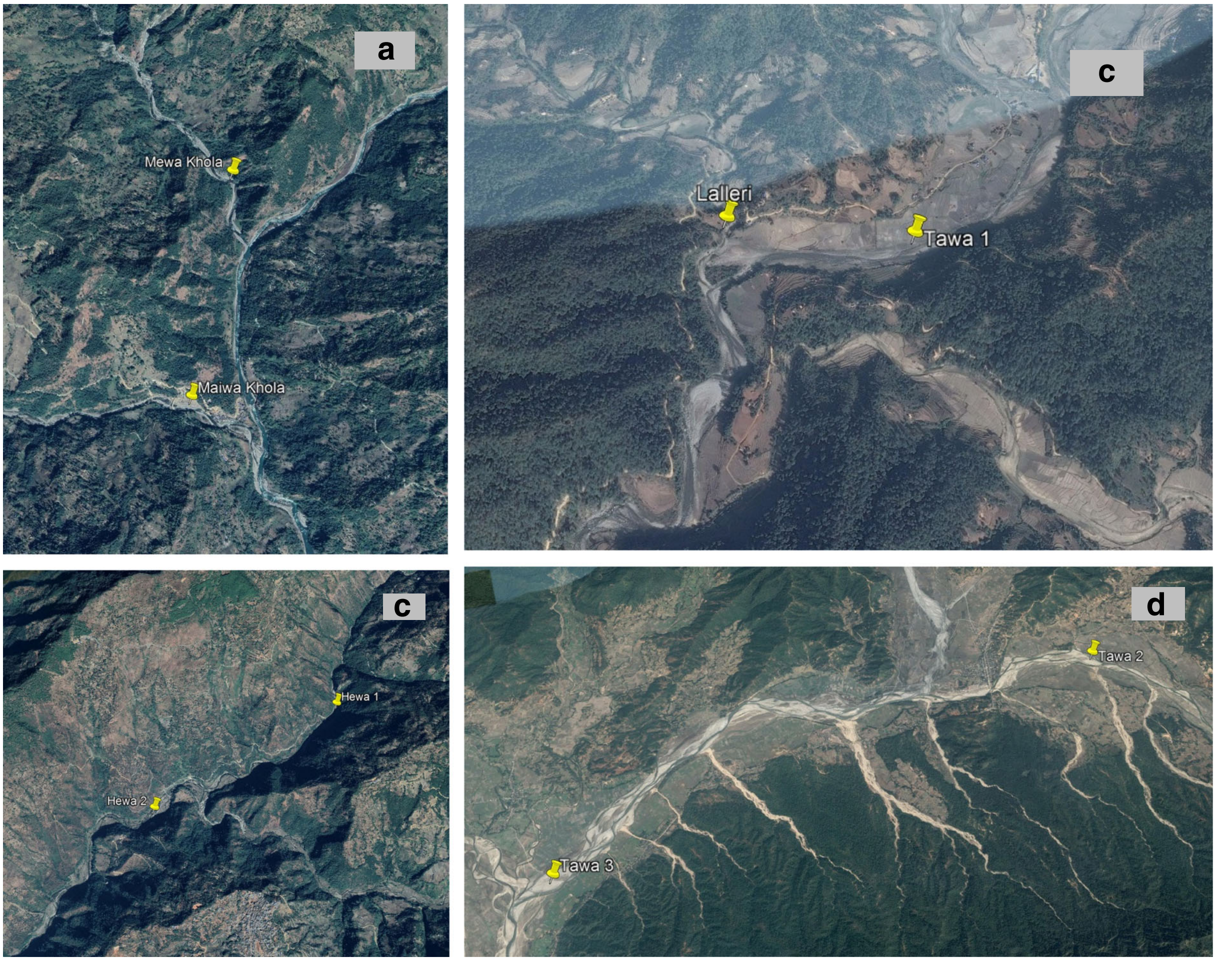

Fig. 1 Map of the study area

glacial fed and rain fed streams. Temperature and conductivity were significantly higher in the rain-fed streams. Significant seasonal variation ($p < 0.01$) in temperature, conductivity and DO was observed between the tributaries of Tamor and the Kamala River. As expected, the water temperature was significantly higher in summer and lowest during the winter in both the rivers. On the other hand, conductivity and DO were significantly higher during the spring and lowest during the winter.

Fish assemblage and diversity

A total of 8940 fishes belonging to 4 orders, 10 families, 26 genera and 34 species were identified. The order Cypriniformes was represented by four Families (Cyprinidae, Balitoridae, Cobitidae, Psilorhynchidae) followed by order Perciformes with three families (Badidae, Channidae, Gobiidae); order Siluriformes with two families (Sisoridae, Amblycipitidae) and order Synbranchiformes with only one family (Mastacembelidae). Cyprinidae was the most dominant family and was represented by 16 species followed by Chaniidae (four species); Nemacheilidae and Sisoridae (three species each); Cobitidae and Mastacembelidae (two species each); Gobiidae, Badidae, Psilorhynchidae, Amblycipitidae (only one species each).

Out of 8940 fishes, a total of only 1769 individuals belonging to 13 species were observed from the glacial-fed streams while the bulk of the fishes with a total of 7171 individuals belonging to 27 species were observed from the rain-fed streams. Seven fish species were exclusively observed in the glacial – streams while twenty-one species were exclusively observed in the rain-fed streams (Table 3); whereas

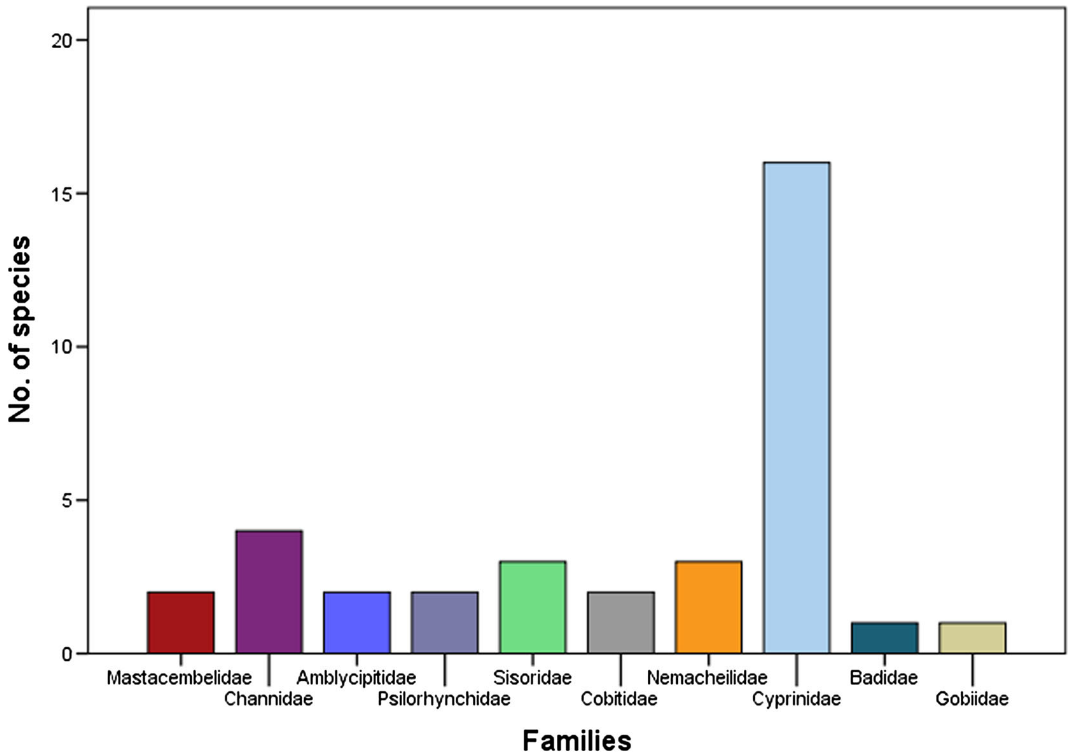

Fig. 2 Fish families with corresponding fish species

six species viz. *Barilius barila, Schistura beavani, Barilius bendelisis, Garra gotyla, Glyptothorax trilineatus* and *Barilius vagra* were common to both the stream types (Table 3).

Previous studies on fish diversity from the tributaries of Tamor River have also reported the occurrence of *Barilius barila, Barilius bendelisis, Barilius vagra, Garra gotyla, Neolissochilus hexagonolepis, Schizothorax richardsonii* (Rajbanshi 2002; Gubhaju 2002; Shrestha et al. 2009). The overall Catch per Unit Effort (CPUE) for both the Tamor and Kamala River headwater streams was found to be 74.89 fishes per 10 min and the most abundant fish species were *Schistura beavani* (26.14), *Barilius vagra* (8.46) and

Table 2 Physico-chemical parameters of the tributaries of the Tamor and the Kamala Rivers

River type	Tributaries	Parameters			
		pH	Temperature (°C)	Dissolved oxygen (ppm)	Conductivity (µS)
Glacial fed (Tamor River)	Maiwa	7.07 ± 0.46	16.41 ± 3.07	6.62 ± 1.90	57.98 ± 7.40
	Mewa	7.47 ± 0.38	14.24 ± 2.66	7.38 ± 2.46	48.1 ± 6.48
	Hewa 1	7.23 ± 0.16	17.28 ± 5.5	6.29 ± 1.65	50.26 ± 11.22
	Hewa 2	7.51 ± 0.26	16.73 ± 3.49	6.3 ± 2.49	62.63 ± 6.05
	Average	7.32 ± 0.37	16.17 ± 3.89	6.65 ± 2.11	54.74 ± 9.78
Rain/Spring fed (Kamala River)	Tawa 1	7.99 ± 0.53	23.89 ± 3.72	6.03 ± 1.70	241.15 ± 58.14
	Lalleri	8.12 ± 0.63	24.95 ± 4.94	5.45 ± 2.57	283.52 ± 26.24
	Tawa 2	8.22 ± 0.54	25.18 ± 6.20	5.41 ± 2.04	286.5 ± 43.03
	Tawa 3	7.62 ± 0.92	24.02 ± 6.86	5.46 ± 3.36	354.18 ± 29.73
	Average	7.99 ± 0.69	24.51 ± 5.41	5.60 ± 2.4	293.83 ± 60.1

Table 3 Different fish species observed in the tributaries of the Tamor and the Kamala

Fishes in Tamor's tributaries (Glacial-fed) (M1, M2, H1, H2)	Fishes in Kamala's tributaries (rain-fed) (T1, L1, T2, T3)
Barilius barila	*Mastacembelus armatus*[b]
Schistura beavani	*Badis badis*[b]
Barilius bendelisis	*Channa barca*[b]
Myersglanis blythii[a]	*Barilius barila*
Garra gotyla	*Schistura beavani*
Neolissochilus hexagonolepis[a]	*Barilius bendelisis*
Schizothorax plagiostomus[a]	*Acanthocobitis botia*[b]
Psilorhynchus pseudecheneis[a]	*Pethia conchonius*[b]
Schizothorax richardsonii[a]	*Escomus danricus*[b]
Schistura rupecola[a]	*Bangana dero*[b]
Pseudecheneis sulcata[a]	*Channa gachua*[b]
Glyptothorax trilineatus	*Glossogobius giuris*[b]
Barilius vagra	*Garra gotyla*
	Lepidocephalichthys guntea[b]
	Crossocheilus latius[b]
	Botia lohachata[b]
	Amblyceps mangois[b]
	Cabdio morar[b]
	Channa orientalis[b]
	Macrognathus pancalus[b]
	Channa punctata[b]
	Cirrhinus reba[b]
	Danio rerio[b]
	Puntius sophore[b]
	Barilius shacra[b]
	Glyptothorax trilineatus
	Barilius vagra

[a] represents the fishes found only in glacial-fed streams
[b] represents the fishes found only in rain/spring-fed streams

Garra gotyla (7.63). The least abundant fish species were found to be of *Cirrhinus reba* (0.01) followed by *Glyptothorax trilineatus* and *Channa gachua* (0.02); *Glossogobius giuris* and *Macrognathus pancalus* (0.03); *Channa barca* and *Cabdio morar* (0.04); and *Barilius shacra* (0.05) (Table 4). The CPUE of the glacial fed streams was 28.64 fishes per 10 min whereas for the rain fed streams it was 121.14 fishes per 10 min. This clearly indicates that the rain fed streams have higher relative fish abundance than that of glacial fed streams. The rain fed Tawa streams had the highest abundance at all sites; T3 (177.42), T2 (123.10) and T1 (94.21) while the lowest has been recorded from the glacial-fed tributaries Mewa (15.24) and Maiwa (19.95) streams of glacial fed. The highest abundant fish species in glacial-fed streams were in the order: *Schizothorax richardsonii* (10.31), *Schistura beavani* (5.09) *Schistura rupecola* (3.72) while the least abundant was *Glyptothorax trilineatus* (0.02). The highest abundant fish species of rain fed streams were in the order *Schistura beavani* (47.19), *Barilius vagra* (15.52), *Garra gotyla* (14.52) and *Lepidocephalichthys guntea* (9.39) whereas the least abundant was of *Cirrhinus reba* (0.02) and *Glyptothorax trilineatus* (0.02) (Table 4).

The species richness, Shannon Weiner Diversity, Evenness and Simpson's Index of diversity of the fishes from the tributaries of Tamor River and Kamala River are presented in Table 5. The tributaries of the glacial-fed Tamor River were characterized by lower species richness and Shannon Weiner diversity as opposed to the tributaries of the rain-fed Kamala River which were characterized by higher species richness and Shannon Weiner diversity (Table 5). Independent t-test revealed significant variation in Shannon-Weiner Diversity Index (H′) ($p = 0.015$) and Species Richness (S) ($p = 0.005$) between the glacial fed and rain fed streams of the study (Table 5).

Conservation status of fish diversity

The threat status/category of the fish species based on International Union for Conservation of Nature (IUCN) and Jha (2009) have been presented in Table 6.

Discussion

Physico-chemical parameters

The observed pH values in the tributaries of the Tamor River and the Kamala River are indicative of neutral to slightly alkaline nature for these water bodies and are within the required range for optimum biological productivity (Ekubo and Abowei 2011). Similarly, as a general rule, DO greater than 5 ppm is considered good for fish survival (Lichtkoppler 1979; Howell and Simpson 1994; USEPA 2000) and the observed DO concentrations (6.65 ppm and 5.60 ppm in the tributaries of the Tamor River and the Kamala River respectively) in the study areas indicate favourable DO values for fish survival.

Table 4 CPUE values at the sampling sites

S. no.	Species	Tributaries of Tamor					Tributaries of Kamala					Total average
		M1	M2	H1	H2	Average	T1	L1	T2	T3	Average	
1	*Mastacembelus armatus*	0.00	0.00	0.00	0.00	0.00	**0.44**	**0.63**	**5.08**	**3.13**	**2.32**	1.16
2	*Badis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.94**	**0.23**	0.12
3	*Channa barca*	0.00	0.00	0.00	0.00	0.00	**0.06**	**0.25**	0.00	0.00	**0.08**	0.04
4	*Barilius barila*	0.00	0.00	0.00	**1.94**	**0.48**	**5.37**	**5.37**	**4.63**	**9.13**	**6.12**	3.30
5	*Schistura beavani*	**0.06**	0.00	**3.75**	**16.56**	**5.09**	**51.23**	**28.33**	**55.63**	**53.56**	**47.19**	26.14
6	*Barilius bendelisis*	0.00	0.00	**1.44**	0.00	**0.36**	**1.31**	**0.19**	0.00	**0.06**	**0.39**	0.37
7	*Myersglanis blythii*	**0.07**	**0.43**	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.06
8	*Acanthocobitis botia*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**4.52**	**8.00**	**3.13**	1.57
9	*Pethia conchonius*	0.00	0.00	0.00	0.00	0.00	0.00	**0.50**	**4.56**	**5.13**	**2.55**	1.27
10	*Escomus danricus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.94**	**0.69**	**1.16**	0.58
11	*Bangana dero*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.13**	**1.06**	**0.30**	0.15
12	*Channa gachua*	0.00	0.00	0.00	0.00	0.00	**0.06**	0.00	0.00	**0.06**	**0.03**	0.02
13	*Glossogobius giuris*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**	**0.19**	**0.06**	0.03
14	*Garra gotyla*	**0.07**	0.00	**2.06**	**0.81**	**0.74**	**4.01**	**17.02**	**3.19**	**33.88**	**14.52**	7.63
15	*Lepidocephalichthys guntea*	0.00	0.00	0.00	0.00	0.00	**4.17**	**3.13**	**19.50**	**10.75**	**9.39**	4.69
16	*Neolissochilus hexagonolepis*	0.00	0.00	**0.25**	**0.63**	**0.22**	0.00	0.00	0.00	0.00	0.00	0.11
17	*Crossocheilus latius*	0.00	0.00	0.00	0.00	0.00	**0.38**	**0.19**	**0.13**	**0.19**	**0.22**	0.11
18	*Botia lohachata*	0.00	0.00	0.00	0.00	0.00	**0.19**	0.00	0.00	**5.38**	**1.39**	0.70
19	*Amblyceps mangois*	0.00	0.00	0.00	0.00	0.00	**5.16**	**3.31**	**3.38**	**5.56**	**4.35**	2.18
20	*Cabdio morar*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.13**	**0.19**	**0.08**	0.04
21	*Channa orientalis*	0.00	0.00	0.00	0.00	0.00	**0.31**	**0.73**	**0.75**	**0.31**	**0.53**	0.26
22	*Macrognathus pancalus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.25**	**0.06**	0.03
23	*Schizothorax plagiostomus*	**0.73**	**1.16**	**6.79**	**3.06**	**2.94**	0.00	0.00	0.00	0.00	0.00	1.47
24	*Psilorhynchus pseudecheneis*	**4.65**	**4.18**	**2.38**	**0.88**	**3.02**	0.00	0.00	0.00	0.00	0.00	1.51
25	*Channa punctata*	0.00	0.00	0.00	0.00	0.00	**1.63**	**0.38**	**4.19**	**1.50**	**1.92**	0.96
26	*Cirrhinus reba*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**	0.00	**0.02**	0.01
27	*Danio rerio*	0.00	0.00	0.00	0.00	0.00	**5.90**	**4.88**	**0.63**	**0.19**	**2.90**	1.45
28	*Schizothorax richardsonii*	**13.44**	**9.41**	**9.25**	**9.13**	**10.31**	0.00	0.00	0.00	0.00	0.00	5.15
29	*Schistura rupecula*	**0.74**	0.00	**9.88**	**4.25**	**3.72**	0.00	0.00	0.00	0.00	0.00	1.86
30	*Puntius sophore*	0.00	0.00	0.00	0.00	0.00	**5.00**	**4.38**	**9.56**	**7.38**	**6.58**	3.29
31	*Barilius shacra*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.25**	**0.13**	**0.09**	0.05
32	*Pseudecheneis sulcata*	**0.19**	0.00	**0.63**	**0.13**	**0.24**	0.00	0.00	0.00	0.00	0.00	0.12
33	*Glyptothorax trilineatus*	0.00	**0.06**	0.00	0.00	**0.02**	0.00	0.00	0.00	**0.06**	**0.02**	0.02
34	*Barilius vagra*	0.00	0.00	0.00	**5.56**	**1.39**	**8.99**	**20.56**	**2.81**	**29.73**	**15.52**	8.46
	Total	**19.95**	**15.24**	**36.42**	**42.94**	**28.64**	**94.21**	**89.83**	**123.10**	**177.42**	**121.14**	**74.89**

The CPUE of the fish species other than 0 are in bold number

Glacial meltwaters are generally characterized by low conductivity (Milner and Petts 1994) cold temperature (Milner et al. 2001) and this accounts for the lower temperature of the tributaries of Tamor River. In contrast, the tributaries of Kamala River had higher temperature and higher conductivity values. Kamala River and its tributaries originate in the Siwalik range where the rivers are known to have high potential for sediment transport (Shrestha et al. 2008) which could be attributed to higher conductivity values.

Table 5 Diversity indices of the study sites

S. no.	Study site	Species richness (S)	Shannon Weiner diversity (H′)	Evenness (J')	Simpson's index of diversity (1-D)
1	M1 (Tamor)	8	**0.92**	**0.44**	0.71
2	M2 (Tamor)	**5**	0.98	0.61	**0.54**
3	H1 (Tamor)	9	1.51	0.69	**0.88**
4	H2 (Tamor)	10	1.62	0.70	0.73
5	T1 (Kamala)	16	1.68	0.61	0.67
6	L1 (Kamala)	15	1.92	0.71	0.81
7	T2 (Kamala)	20	**2.21**	**0.74**	0.84
8	T3 (Kamala)	**25**	2.14	0.66	0.83

The CPUE of the fish species other than 0 are in bold number

Fish assemblages

The study revealed consistently higher CPUE values (121.14) for the tributaries of the rain-fed Kamala River as opposed to lower CPUE values for the tributaries of the glacial-fed Tamor River thus clearly indicating higher abundance of fish species in the Kamala's tributaries. Significant seasonal variation in CPUE was observed only in the tributaries of Tamor River ($p = 0.02$) with highest abundance in the pre-monsoon (CPUE of 59) and the lowest abundance during the winter (CPUE of 10.54). Shannon Weiner Diversity Index and the Simpson's Diversity also showed significant variation in the two types of streams with higher values of these indices in the tributaries of the rain-fed Kamala River. Glacial streams are generally characterised by low temperature and low nutrient content (Milner and Petts 1994) which could be attributed to lower species diversity and abundance in the tributaries of the glacial- fed Tamor River. The order Cypriniformes was the most abundant taxon and this finding is consistent with previous studies in a large number of streams and rivers in Nepal (Shrestha et al. 2009; Shrestha and Edds 2012; Yadav 2017) as well as elsewhere (Negi and Negi 2010; Bandyopadhyay and Mondal 2014; Nanda 2016). Cyprinids are often the most abundant freshwater fishes found in Asia

Table 6 Threat status of fish species

Fish species	IUCN	Jha (2009)
Acanthicobitis botia	Least Concerned	Vulnerable
Amblyceps mangois	Least Concerned	Rare
Badis badis	Least Concerned	Data deficient[a]
Bangana dero	Least Concerned	Data deficient[a]
Barilius barila	Least Concerned	Fairly Common
Barilius bendelisis	Least Concerned	Vulnerable
Barilius shacra	Least Concerned	Endangered
Barilius vagra	Least Concerned	Vulnerable
Botia lohachata	Data deficient[a]	Vulnerable
Cabdio morar	Least Concerned	Data deficient[a]
Channa barca	Data deficient[a]	Data deficient[a]
Channa gachua	Least Concerned	Data deficient[a]
Channa orientalis	Data deficient[a]	Endangered
Channa punctata	Least Concerned	Vulnerable
Cirrhinus reba	Least Concerned	Endangered
Crossocheilus latius	Least Concerned	Endangered
Danio rerio	Least Concerned	Data deficient[a]
Esomus danricus	Least Concerned	Endangered
Garra gotyla	Least Concerned	Common
Glossogobius giuris	Least Concerned	Endangered
Glyptothorax trilineatus	Least Concerned	Endangered
Lepidocephalichthys guntea	Least Concerned	Vulnerable
Macrognathus pancalus	Least Concerned	Endangered
Mastacembelus armatus	Least Concerned	Endangered
Myersglanis blythii	Data deficient[a]	Rare
Neolissochilus hexagonolepis	Near Threatened	Vulnerable
Pethia conchonius	Least Concerned	Vulnerable
Pseudecheneis sulcata	Least Concerned	Endangered
Psilorhynchus pseudecheneis	Least Concerned	Endangered
Puntius sophore	Least Concerned	Vulnerable
Schistura beavani	Least Concerned	Common
Schistura rupecula	Least Concerned	Fairly Common
Schizothorax plagiostomus	Data deficient[a]	Data deficient[a]
Schizothorax richardsonii	Vulnerable	Vulnerable

[a] no status due to lack of data

(Lévêque et al. 2008). Fish assemblages are known to be affected by a large number of environmental variables (Negi and Negi 2010) and these include substratum and habitats, availability of food, temperature, flow and velocity of water, dissolved oxygen, etc. (Daga et al. 2012; Gebrekiros 2016). The different sources of the rivers are known to generate specific ecological regimes thereby providing different habitats with different biological communities (Maiolini and Lencioni 2001; Milner et al. 2001). At larger spatial scales, the assemblages reflect evolutionary history and biogeographic processes (Lévêque et al. 2008). The findings of this study also comply with these studies. For instance, *Garra gotyla* has been recognised as a fairly common fish species particularly in the lower basins of South Asian rivers (Pokharel 2011; Rayamajhi and Jha 2010). The CPUE revealed that its abundance in the rain fed streams was higher (14.52) as opposed to very low abundance (0.74) in the tributaries of Tamor River. However, *Barilius bendelisis* and *Myersglanis blythii* regarded as common species in glacial rivers (Pokharel 2011; Negi and Negi 2010), were found in low abundance in this study. Similarly, *Glyptothorax trilineatus* a rare fish species with sparse distribution but with wide range (Shrestha 2003) was also observed in low abundance. The genus *Schizothorax* is a cold water fish common in Himalayan and sub-Himalayan regions (Pathak et al. 2014) and was represented by *Schizothorax richardsonii* and *Schizothorax plagiostomus.* Some of the fish species such as *Schizothorax richardsonii*, *Schizothorax plagiostomus* (Shrestha 2003) and *Neolissochilus hexagonolepis* observed exclusively in glacial fed streams are potamodromous known to undergo local migration (Toppo et al. 2011). Previous studies on fish diversity from the tributaries of Tamor River have also reported the occurrence of *Barilius barila, Barilius bendelisis, Barilius vagra, Garra gotyla, Neolissochilus hexagonolepis, Schizothorax richardsonii* (Rajbanshi 2002; Gubhaju 2002; Shrestha et al. 2009). *Glyptothorax trilineatus, Garra gotyla* and *Pseudecheneis sulcata* possess an adhesive organ adapted to survive in rapid waters in contrast to *Barilius vagra* which is quite common in pool habitats (Singh and Agarwal 2013). In this study also, the abundance of *Barilius vagra* was higher in pool habitats particularly in L1 (with CPUE of 20.56) and T3 (with CPUE value of 29.73). *Badis badis*, *Lepidocephalichthys guntea* and *Mastacembelus armatus* also considered as ornamental fish species were observed only the tributaries of Kamala River (rain/spring-fed river). A study in West Bengal, India has inferred that these ornamental fishes are especially affected by the different human activities (Dutta et al. 2013).

Threat status of the fish species

The comparison of the conservation status between IUCN Red List and Jha et al. (2006), Jha (2009) shows significant differences of the current conservation status of the observed fish species. Of the 36 species recorded from this study, IUCN Red List has cited 27 fish species as "Least Concerned" (Table). However, the same fish species have been either assigned as "Vulnerable" (7) or "Endangered" (10) or "Rare" (1) by Jha et al. (2006), Jha (2009). Of the five fish species viz. *Botia lohachata*, *Channa orientalis*, *Channa barca*, *Myersglanis blythii* and *Schizothorax plagiostomus* listed as "Data Insufficient" by IUCN; only two species viz. *Channa barca* and *Schizothorax plagiostomus* have been also listed as "Data Insufficient" by Jha (2009). However, *Botia lohachata* has been categorised as "Vulnerable"; *Channa orientalis* as "Endangered" and *Myersglanis blythii* as "Rare". The abundance of these three fish species based on CPUE in this study were also low (Table). Similarly, *Badis badis, Bangana dero, Cabdio morar, Channa gachua* and *Danio rerio* designated as "Least Concerned" by IUCN Red List have been categorized as "Data Insufficient" by Jha (2009). These fish species were found only in the tributaries of Kamala River with relatively low CPUE values which resonate with the conservation status given by Jha et al. (2006), Jha (2009). Other fish species which were observed only in the tributaries of Kamala River were also either in the "Vulnerable" or "Endangered" category which probably reflects the use of plant extracts as fish poison by the local fishermen thereby affecting the abundance of these fish species.

The study revealed the difference in the fish assemblages between the seasons and between the tributaries of the glacial-fed and rain-fed rivers clearly reflecting differences in ecological regimes of these river systems. The findings of the study on one hand contribute to the knowledge on baseline information on fish assemblages of headwater streams and on the other hand it also compliments the existing threat categories of the vast IUCN fish datasets. The ruggedness of the terrain and enormous number of lotic systems make aquatic biodiversity assessments often difficult. A long-term aquatic biodiversity assessment encompassing longer temporal and larger spatial scale becomes necessary to evaluate anthropogenic impacts and develop effective conservation strategies.

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References

Bandyopadhyay N, Mondal K (2014) Present status of ichthyofaunal diversity of different rivers of Duars of North Bengal, India. Journal of Today's Biological Sciences: Research & Review (JTBSRR) 3(1):1–8

Barmuta L, Watson A, Clarke A, Clapcott J (2009) The importance of headwater streams. Waterlines Report Series, National Water Commission, Canberra

Benda LE, Hassan MA, Church M, May CL (2005) Geomorphology of steepland headwaters: the transition from hillslopes to channels. J Am Water Resour Assoc 41:835–851

Bernhardt ES, Likens GE, Hall JR, Robert OH, Buso DC, Fisher SG, Burton TM, Meyer JL, McDowell WH, Mayer MS, Bowden WB, Findlay SEG, MacNeale KH, Stelzer RS, Lowe WH (2005) Can't see the forest for the stream? Instream processing and terrestrial nitrogen exports. Bioscience 55:219–230

Callanan M, Baars JR, Kelly-Quinn M (2014) Macroinvertebrate communities of Irish headwater streams: contribution to catchment biodiversity. Biology and Environment: Proceedings of the Royal Irish Academy 114(3):143–162

Clarke A, Nally R, Bond N, Lake P (2008) Macroinvertebrate diversity in headwater streams: a review. Freshw Biol 53:1707–1721

Craig LS, Palmer MA, Richardson DC, Filoso S, Bernhardt ES, Bledsoe BP, Doyle MW, Groffman PM, Hassett BA, Kaushal SS, Mayer PM, Smith SM, Wilcock PR (2008) Stream restoration strategies for reducing river nitrogen loads. Front Ecol Environ 6:529–538

Daga VS, Gubiani ÉA, Cunico AM, Baumgartner G (2012) Effects of abiotic variables on the distribution of fish assemblages in streams with different anthropogenic activities in southern Brazil. Neotropical Icthyl 10(3):643–652

Day F (2006) Lakes and rivers. Chelsea House, New York, 258 pp

Dutta AL, Chakraborty D, Dey SK, Manna AK, Manna PK (2013) Ornamental fishes of coastal West Bengal, India–prospects of conservation and involvement of local fisherman. Nat Res Forum 4:155–162

Ekubo AA, Abowei JFN (2011) Review of some water quality management principles in culture fisheries. Res J Appl Sci Eng Technol 3(2):1342–1357

FishBase (2017) Eds. Froese, R. and D. Pauly. www.fishbase.org

Gebrekiros S (2016) Factors affecting stream fish community composition and habitat suitability. J Aquacul Mar Biol 4(2):00076. https://doi.org/10.15406/jamb.2016.04.00076

Gubhaju SR (2002) Impact of damming on the aquatic fauna in Nepalese rivers. In: Petr T, Swar DB (eds) Cold water fisheries in the trans-Himlayan countries. FAO, Rome, pp 129–146

Hamilton F (1822) An account of the fishes found in the river Ganges and its branches. Archibald Constable and Co., London, pp 1–39

Hansen WF (2001) Identifying stream types and management implications. For Ecol Manag 143:39–46

Howell P, Simpson D (1994) Abundance of marine resources in relation to dissolved oxygen in Long Island sound. Estuaries 17:394–402

Jacobsen D, Milner A, Brown L, Dangles O (2012) Biodiversity under threat in glacier-fed river systems. Nat Clim Chang 2:361–364

Jha BR (2009) Fish ecological studies in assessing ecological integrity of rivers: application in rivers of Nepal. VDM Verlag, Germany. ISBN 10: 3639154967, ISBN-13: 978–3639154962. Paperback, pp 324

Jha BR, Waidbacher H, Sharma S, Straif M (2006) Fish species composition, number and abundance in different rivers and seasons in Nepal and the reevaluation of their threat category for effective conservation and management. Ecol Environ Conserv 12(1):25–36

Jha BR, Gurung S, Khatri K, Gurung B, Thapa A, Acharya S (2015) River ecological study: building the knowledge such as climate change in Nepal. J Mount Area Res 1:28–39

Khanal S (2001) Effects of human disturbances in Nepalese rivers on the Benthic invertebrate fauna Ph.D. Thesis, University of Agricultural Sciences (BOKU), Vienna, Austria

Leopold LB, Wolman MG, Miller JP (1964) Fluvial processing in geomorphology. Dover, New York

Lévêque C, Oberdorff T, Paugy D, Stiassny MLJ, Tedesco PA (2008) Global diversity of fish (Pisces) in freshwater. Hydrobiloogia 595(1):545–567

Lichtkoppler F (1979) Water quality management in fish ponds. Research and Development Series No. 22 International Centre for Aquaculture (J.C.A.A) Experimental Station Auburn University, Alabama, pp 45–47

Lowe WH, Likens GE (2005) Moving headwater streams to the head of the class. Bioscience 55(3):196–197

Maiolini B, Lencioni V (2001) Longitudinal distribution of macroinvertebrate assemblages in a glacially influenced stream system in the Italian alps. Freshw Biol 46:1625–1639

Meyer JL, Wallace JB (2001) Lost linkages and lotic ecology: rediscovering small streams. In: Press MC, Huntly NJ, Levin S (eds) Ecology: achievement and challenge. Blackwell Science, Malden, pp 295–317

Meyer J, Strayer D, Wallace J, Eggert S, Helfman G, Leonard N (2007) The contribution of headwater streams to biodiversity in river networks. J Am Water Resour Assoc 43(1):86–103

Milner AM, Petts GE (1994) Glacial rivers: physical habitat and ecology. Freshw Biol 32:295–307

Milner AM, Brittain JE, Castella E, Petts GE (2001) Trends in macroinvertebrate community structure in glacier-fed rivers in relation to environmental conditions: a synthesis. Freshw Biol 46:1833–1847

Morse JC, Stark BP, McCafferty WP (1993) Southern Appalachian streams at risk: implications for mayflies, stoneflies, caddisflies, and other aquatic biota. Aquat Conserv Mar Freshwat Ecosyst 3:293–303

Naiman RJ, Déchamps H, McClain ME (2005) Riparia: ecology, conservation and management of streamside communities. Elsevier/Academic Press, San Diego

Nanda P (2016) Fish diversity of river Pachin, Eastern Himalaya. Int J Biol Sci 5(7):20–25

Negi RK, Negi T (2010) Assemblage structure of stream fishes in the Kumaon Himalaya of Uttarakhand state, India. Life Sci J 7(1):9–14

Pathak AK, Sarkar UK, Singh SP (2014) Spatial gradients in freshwater fish diversity, abundance and current pattern in the Himalayan region of upper Ganges Basin, India. Biodiversitas 15(2):186–194

Peterson BJ, Wollheim WM, Mulholland PJ, Webster JR, Meyer JL, Tank JL, Marti E, Bowden WB, Valett HM, Hershey AE, McDowell WH, Dodds WK, Hamilton SK, Gregory S, Morrall DD (2001) Control of nitrogen exports from watershed by headwater streams. Science 292:86–90

Pokharel KK (2011) Study on fish ecology of the Seti Gandaki River Pokhara: II. Spatio-temporal variations in fish communities. Nepal J Sci Technol 12:350–357

Rajbanshi KL (2002) Zoo-geographical distribution and the status of coldwater fish in Nepal. In: Petr T, Swar DB (eds) Cold water fisheries in the trans-Himlayan countries. FAO, Rome, pp 221–246

Rayamajhi A, Jha BR (2010) *Garra gotyla*. The IUCN Red List of Threatened Species 2010. Accessed 05 Jul 2017

Shah P (2016) Study of the fresh water fish diversity of Koshi river of Nepal. International Journal of Fauna and Biological Studies 3(4):78–81

Sharma CM, Jha (2012) Spatial and temporal distribution of fish assemblage in Indrawati Sub-Basin. WWF, Nepal (Agreement # WL47)

Shrestha TK (2003) Conservation and management of fishes in the large Himalayan rivers of Nepal. Paper presented to the Second International Symposium on the Management of large rivers for fisheries

Shrestha TK (2008) Ichthyology of Nepal. Himalayan Ecosphere, Kathmandu, p 389

Shrestha OH, Edds DR (2012) Fishes of Nepal: mapping distributions based on voucher specimens. Emporia State Research Studies 48(2):14–21

Shrestha MB, Tamrakar NK, Miyazaki T (2008) Morphometry and sediment dynamics of the Churiya River area, Siwalik range, Nepal. Bol Geol 30(2):35–48

Shrestha J, Singh D, Saund T (2009) Fish diversity of Tamor River and its major tributaries of Eastern Himalayan region of Nepal. Nepal J Sci Technol 10:219–223

Singh G, Agarwal NK (2013) Fish diversity of Laster stream, a major tributary of river Mandakini in central Himalaya (India) with regard to altitude and habitat specificity of fishes. J Appl Natl Sci 5(2):369–374

Snyder C, Webb J, Young J, Johnson Z (2013) Significance of headwater streams and perennial spring in ecological monitoring in Shenandoah National Park. U.S. Geological Survey Open-File Report 2013–1178, pp 46

Talwar PK, Jhingran AG (1991) Inland fishes of India and adjacent countries, vol 1 and 2. Oxford and IBH Publishing Company Pvt. Ltd., New Delhi

Toppo S, Rahman H, Haque N (2011) In: Arrawatia ML, Tambe S (eds) Fish biodiversity of Riverine status of Sikkim. Information and public relations Department, Government of Sikkim. Biodiversity of Sikkim: exploring and conserving a global hotspot, 221–232. pp542

USEPA (United State Environmental Protection Agency) (2000) Ambient aquatic life water quality criteria for dissolved oxygen (saltwater). Cape Cod to Cape Hatteras, EPA/822/R-00/12

WECS (2005) Water and energy commission secretariat, national water plan for Nepal., Ministry of Water Resources, Government of Nepal, Kathmandu, Nepal

WECS (2011) Water and energy commission secretariat. Water resources of Nepal in the context of climate change. Government of Nepal (GoN), pp 67

White W, Crisman T (2014) Headwater streams of Florida: types, distribution and a framework for conservation. River Research and Applications

Wipfli MS, Richardson J, Naiman R (2007) Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. J Am Water Resour Assoc 43(1):72–85

Yadav SN (2017) Studies on fish diversity and need for their conservation of Singhiya River, Morang District, Eastern Nepal. Agriculture, Forestry and Fisheries 6(3):78–81