Ecological Study of the Tributaries of Glacial-fed River (Tamor) and Rain-fed River (Kamala) in Nepal, and the Comparison of their Vital Characteristics.

Conference Paper · January 2016

Bibhuti Ranjan Jha
Kathmandu University

Smriti Gurung
Kathmandu University

Kumar Khatri
Tribhuvan University

Anuja Thapa
Saskatchewan First Nations Family and Community Institute

Ecological Study of the Tributaries of Glacial-fed River (Tamor) and Rain-fed River (Kamala) in Nepal, and the Comparison of their Vital Characteristics

Jha, B. R.*, Gurung, S., Khatri, K., Gurung, B., Thapa, A., Acharya, S., Kayastha, R.

Abstract

Headwaters and their tributaries serve important ecosystem functions including water quality and biodiversity hotspots. They are often the indicators of ecological health of rivers. Headwater dynamics in glacial-fed and rain-fed rivers may vary in terms of source of origin, climate, biogeography, geology and physico-chemical parameters, which may affect the biotic assemblages of these ecosystems. This study was carried out in March 2015 to compare the fish and macroinvertebrate assemblages in the tributaries of glacial-fed (Tamor) and rain/spring-fed (Kamala) rivers in order to assess the differences in ecological roles of these tributaries. Standard electrofishing gear was used for fish sampling and macroinvertebrates were sampled qualitatively from different habitats. Selected physico-chemical parameters such as pH, DO, temperature and conductivity were also measured in the field using multiparameter probes. Fish species and abundance was observed to be lower in glacial-fed tributaries (9 species; 19-52/10 minutes) compared to rain/spring-fed tributaries (15 species; 92-115/10 minutes). *Barilius bendelisis* and *Garra gotyla gotyla* were found common to both categories of tributaries. Similarly, 37 families of macroinvertebrates were observed in the study with molluscs and crustaceans exclusively in rain/spring-fed tributaries. One way ANOVA revealed pH to be higher for glacial-fed tributaries while conductivity and temperature was found to be higher for rain/spring-fed tributaries. The study has shown that both the fish and the macroinvertebrate assemblages were found to vary between the glacial-fed and rain-fed tributaries. The results from the study could in turn be used as baseline information for future studies including climate change.

Key words? Ecological study, rivers, glacial-fed, rain-fed, fish assemblage, macroinvertebrates

*** Bibhuti Ranjan Jha, Ph. D. - Corresponding Author and PI**

Associate Professor

Department of Environmental Science and Engineering

Kathmandu University

The Seventh National Conference on Science and Technology, March 29-31, 2016
Nepal Academy of Science and Technology (NAST)
O-WB-1-328 10458 Ecological Study of the Tributaries of Glacial-fed River (Tamor) and Rain-fed 10459 River (Kamala) in Nepal, and the Comparison of their Vital Characteristics

29 March 16 – 16:30

Introduction

Rivers are the one of the important natural capitals of our planet [1].The distributions of all the earthly materials and minerals on earth's surfaces are determined by the rivers and hence have played role in shaping the surfaces [2]. Similarly, the tributaries of large river also have multiple functions in addition to collecting and feeding water resource to main channel from faraway places of the watershed and their significance is best explained by their geological as well as ecological functions [3]. Rivers and their tributaries also connect culture, economies and nations [4]. Therefore, their health and conditions form the basis of the integrity of these ecosystems.

Although, headwaters and their tributaries are recognized as important ecosystems as freshwater resources [5, 6], biodiversity repositories [7], and are sensitive to disturbances, yet they have received very little attention [8, 9]. Furthermore, climate change may have severe impacts on the climatically sensitive biota of mountain streams thereby, threatening the biodiversity and integrity of these ecosystems [8, 10]. Though similarities on fundamental functions, headwater dynamics in glacial-fed and rain-fed rivers may vary in terms of source of origin [11], climate, biogeography [7], geology [12] and physico-chemical parameters [13]. Pertaining to these reasons, long term management of these ecosystems is necessary.

In order to achieve this, assessment of aquatic biodiversity and water quality of headwater tributaries is important. Among diverse aquatic biota, fish and macroinvertebrates are important organisms, both ecologically and economically. Fish provide employment opportunities as well as food to millions of people all over the world [14], while macroinvertebrates form the bulk of food resources for fishes thereby maintaining the trophic cycle in aquatic ecosystems [15]. In addition, these are often used as bioindicators for determining the ecological health of rivers and streams because of their different responses to disturbances in the aquatic habitats [6, 16]. This study attempts to assess and compare the fish and macroinvertebrate assemblages in the two types of headwater tributaries (glacial-fed and rain/spring-fed) in Eastern region of Nepal.

Goals and Objectives

The primary objective of this work remains the generation of river/fish base information from the different rivers and streams of Nepal by standard scientific methods so that it could be applied for various purposes including the study of climate change and subsequent changes in adaptation. It's more about building base for the future, yet there are some specific objectives, which show the patterns of the state of the rivers and streams in Nepal and some signs of climate changes.

The specific objectives could be enumerated as:

1. To study the fish assemblage of the specified tributaries of a glacial-fed River Tamor.
2. To study the fish assemblage of the specified tributaries of rain-fed River Kamala.
3. To compare the differences of fish assemblage in the tributaries of glacial-fed and rain-fed rivers.

4. To see if the information of macroinvertebrate assemblage and physic-chemical parameters complement the fish base information.

Study Area

The study area comprised of some of the tributaries of two major rivers (Tamor and Kamala) in Taplejung, Panchthar and Udaypur districts of Nepal. Taplejung has an area of 3646 km² and lies within 27˚ 15' to 27˚ 57' N and 87˚ 27' to 88˚ 12' E. The elevation ranges from 777m (Kabeli, Dobhan) to 8598m (Kanchanjunga) [17]. Likewise, Panchthar covers the total area of 1249 km². It lies within 26˚ 29' to 26˚ 59' N and 80˚ 02' to 87˚ 30' E. The maximum and minimum temperatures of the district are recorded at 22˚C and 15˚C respectively. The elevation ranges from 383m to 4575m [18]. Udaypur district lies within 26˚ 39' to 27˚ 1' 10" N and 86˚ 0' 9" to 87˚ 1' 0" E. The district can be further divided into three regions: Mountain land (1100m to 2310m), Plain and Plateau (550m to 1100m) and Terai region (55m to 360m) [19].

The field sampling was conducted from March 17- March 21, 2015. Three tributaries of Tamor: Maiwa, Mewa and Hewa, and two tributaries of Kamala: Tawa and Lalleri were selected for the study. A total of eight sites were chosen for sampling as shown with exact coordinates in Table 1.

Site Name	Site Code	Geographical Co-ordinates	Elevation (masl*)
Maiwa	M1	N 27˚22.064' E 087˚37.098'	664
Mewa	M2	N 27˚22.675' E 087˚37.617'	666
Hewa	H1	N 27˚10.061' E 087˚47.321'	629
Hewa	H2	N 27˚09.802' E 087˚45.560'	550
Tawa	T1	N 26˚59.211' E 086˚ 27.743'	330
Lalleri	L1	N 26˚59.347' E 086˚27.430'	327
Tawa	T2	N 26˚57.512' E 086˚23.361'	258
Tawa	T3	N 26˚56.925' E 086˚17.291'	167

Table 1: Co-ordinates and elevation of sampling site
masl*: meter above sea level

Methodology

The method of fish sampling applied in the study was a standard electrofishing by wading method [20, 21], which is a scientific method accepted all over the world. This required one or more electrofishing gear and other simple accessories such as rubber boots, nets, buckets, and measuring devices. The fish sampling was done by electrofishing gear in two runs of approximately 20 minutes and the captured fishes were studied for variety of fish base characteristics such as type, abundance, length, weight, sex, etc. The abundance of fish was measured in temporal unit called catch per unit effort (CPUE), which is expressed as number of fish per10 minutes of electrofishing. The fishes were only shocked for a few seconds just enough to gather in the net for the readings. They were liberated back in their natural habitat once the necessary information was collected. A standard protocol was used to record all the information. The sampled fish were identified up to the species level using the widely used keys of the region [22, 23, 24, 25, 26, 27]. A few specimens of all the species was preserved in 70% ethanol, tagged, and kept for a record as type specimen.

Qualitative sampling of macroinvertebrates [28] was carried out for assessment of macroinvertebrate assemblages at each site. Around one hundred meter river stretch was sampled using a hand net of mesh size 250µm. Macroinvertebrates were collected from different substrates by kicking them and placing the net in front of the substrates so that macroinvertebrates drifted towards the net. Macroinvertebrates were also collected by handpicking from underneath the stones, wood and other detritus. They were placed onto a white tray, washed and carefully placed in sampling bottles containing 70% ethanol and brought to the laboratory for further investigation. Identification was done following [29].

Selected water quality parameters such as temperature, pH, DO and conductivity were measured on sites by using multi parametric probes (Orion multi-meter). Replicates were taken for further statistical analysis.

Result and Discussion

Altogether 1,927 fishes were captured during the sampling period from all eight sites. They represented 4 orders, 8 families, 19 genus and 22 species. Cypriniformes had the highest families (4 families) followed by Siluriformes (2 families) and, Perciformes and Synbranchiformes (1 family each). Cyprinidae represented 11 species, Nemacheilidae 3 species, Cobitidae and Sisoridae 2 species each, and Psilorhynchidae, Amblycipitidae, Channidae and Mastacembelidae 1 species each. Cyprinidae is the largest family of freshwater fishes and may account for more than 40% of the species in a watershed [30]. Table 2 recapitulates the total and average abundance (CPUE) of different species. A total of 9 and 15 fish species were recorded from glacial-fed and rain-fed streams respectively (Table 3).

Fish Species	M1	M2	H1	H2	T1	L1	T2	T3	Average
Acanthocobitis botia							0.75	7.5	1.03
Amblyceps mangois					8.33	2.00	7.00	5.75	2.88
Barilius bendelisis			6.75		3.67			0.25	1.33
Barilius vagra					11.33	33.00	9.25	17.25	8.85
Botia lohachata								0.25	0.03
Crossocheilus latius						0.33			0.04
Channa punctata					1.00	1.67	2.00		0.58
Danio rerio					12.33	4.33			2.08

Garra gotyla gotyla	0.28		5.75	2.00	1.33	7.33	5.50	2.00	3.02
Labeo rohita						0.67	0.50		0.15
Lephidocephalichthys guntea					10.67	7.33	42.75	19.50	10.03
Mastacembelus armatus						0.33	10.00	1.0	1.42
Myersglanis blythii	0.26	1.70							0.24
Neolissochilus hexagonolepis			1.25						0.16
Pethia conchonius						2.00	1.75	1.00	0.59
Psilorhynchus pseudecheneis	10.06	6.82	7.00	2.00					3.24
Pseudecheneis sulcata	0.28		1.25	0.50					0.25
Puntius sophore					10.00	7.00		1.00	2.25
Schistura beavani					38.34	26.33	35.50	51.50	18.96
Schistura rupecola	5.38		23.75	7.00					4.52
Schizothorax plagiostomus	5.32	4.64	6.00	12.25					3.53
Schizothorax richardsonii	15.82	5.91	0.25	1.00					2.87
Grand Total	**37.4**	**19.07**	**52.0**	**24.75**	**97.0**	**92.32**	**115**	**107**	**68.05**

Table 2: Abundance of fish species in different sampling sites (catch/10 minutes of sampling)

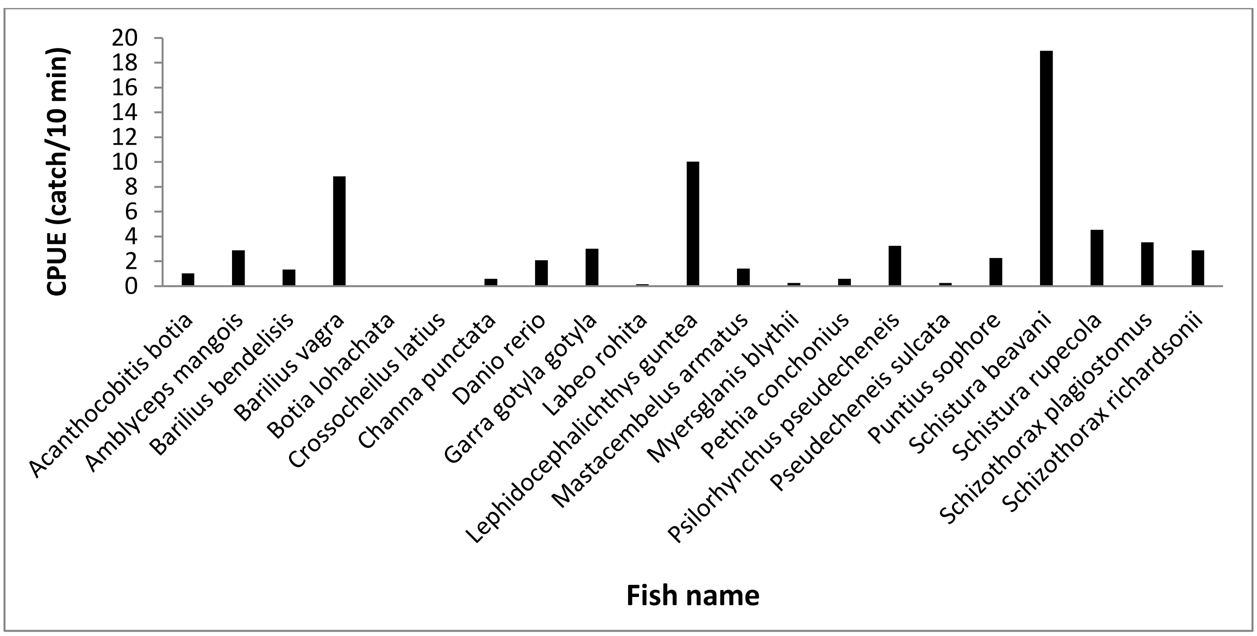

Figure 1: Average abundance of different fish species recorded during the study period

S.N.	Fish species (Glacial-fed)	Fish species (Rain-fed)
1.	***Barilius bendelisis***	*Acanthocobitis botia*
2.	***Garra gotyla gotyla***	*Amblyceps mangois*
3.	*Myersglanis blythi*	***Barilius bendelisis***
4.	*Neolissochilus hexagonolepis*	*Barilius vagra*
5.	*Pseudecheneis sulcata*	*Botia lohachata*
6.	*Psilorhynchus pseudecheneis*	*Channa punctatus*
7.	*Schistura rupecola*	*Crossocheilus latius*
8.	*Schizothorax plagiostomus*	*Danio rerio*
9.	*Schizothorax richardsonii*	***Garra gotyla gotyla***
10.		*Labeo rohita*
11.		*Lephidocephalichthys guntea*
12.		*Mastacembelus armatus*
13.		*Pethia conchonius*
14.		*Puntius sophore*
15.		*Schistura beavani*

Table 3: Comparison of fish species in glacial-fed and rain/spring-fed tributaries

Overall, the fish abundance was higher for rain/spring-fed streams compared to glacial-fed streams, with highest abundance recorded at site T2 (115) followed by T3 (107), T1 (97), L1 (92), H1 (52), M1 (37), H2 (25) and M2 (19). In terms of species diversity, site L1 accounted for highest number of fish species (12 species) followed by T3 (11 species), T2 (10 species), T1 (9 species), H1 (8 species), M1 (7 species), H2 (6 species) and M2 (4 species) (Table 2). The total average abundance for all species was found to be 68.05, among which the abundance of *S. beavani, L. guntea, B. vagra* and *S. rupecola* was found to be fairly good whereas *B. lohachata, C. latius, L. rohita, M. blythii, N. hexagonolepis, and P. sulcata* were found to have low abundance (Figure 1).

Species like *A. mangois, C. punctata* and *L. guntea* have adaptive features which make them capable of breathing air therefore, can survive even in low dissolved oxygen and hypoxic conditions [31, 32]. This could be the reason for high abundance of *L. guntea* (42.75/10 minutes) at site T2. Also, it has been observed that relatively higher diversity and abundance of fish are observed at agricultural sites because of nutrient input in water [20, 33]. Contrary to this,[34] observed low species diversity in agricultural lands.

Garra gotyla gotyla was observed in almost all sites except at M2. This species is widely distributed in Nepal, and has been reported up to 1560 masl [20]. Altogether, 11 vulnerable species, 4 endangered species and 2 rare species were observed in this study according to threat category defined by Jha 2006 [20, 35] and also as mentioned in IUCN (2010).

In both the systems, One-way ANOVA revealed that the variation of abundance of the various fish species were highly significant (Figure 2 & 3) as P values were 0.010 and 0.001 and both were less than 0.05. The statistics show that in both the Glacial-fed and Rain-fed tributaries population structure of the species is very natural. A very strong evidence of relationship between the two species *G. gotyla gotyla* and *B. bendelisis* was also found in glacial-fed and Rain-fed streams (chi-square= 18.261; degree of freedom=1; P<0.001) (Figure 4).

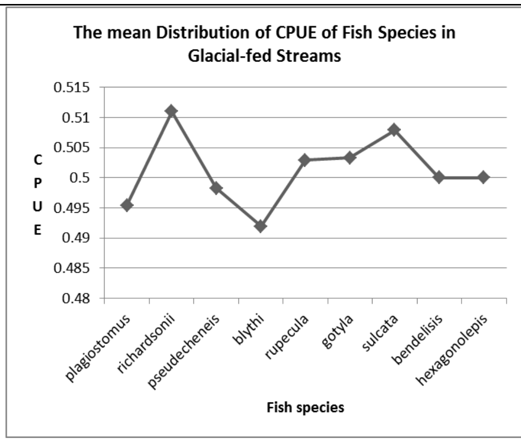

Figure 2: Means Plots of Glacial-fed system showing the significant variation of fish species abundance (P<0.05).

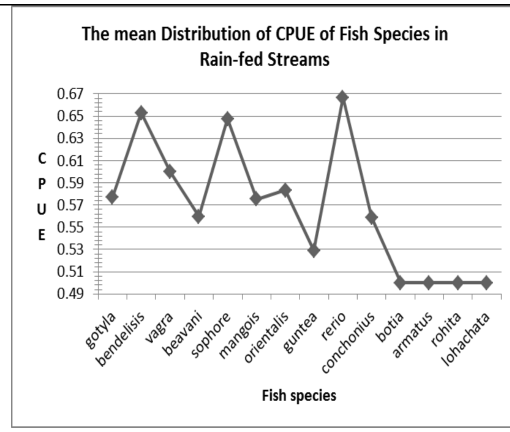

Figure 3: Means Plots of Rain-fed system showing highly significant variation in fish species abundance (P<0.001)

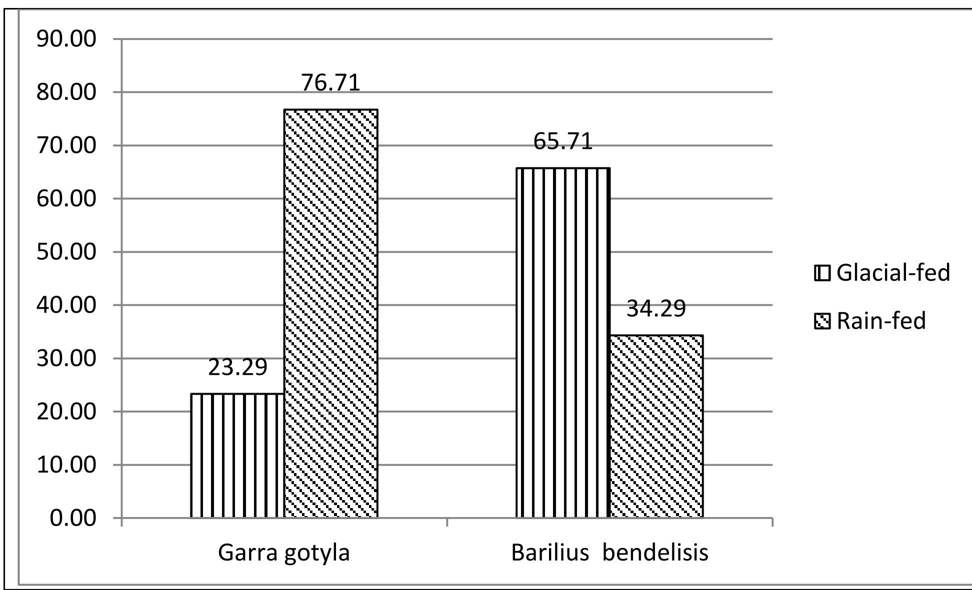

Figure 4: The distribution of abundance of the two common species in Glacial-fed and Rain-fed systems.

The t-Test using CPUE data of tributaries of the two tributaries system revealed highly significant differences between the fish composition of the two tributaries system (P<0.001).

Sites	Macroinvertebrate assemblages
Maiwa	Heptageniidae, Heptageniidae (Iron sp.) Baetidae, Ephemerellidae, Ephemerellidae (Drunella sp.), Perlidae, Stenopsychidae, Hydropsychidae, Corydalidae, Gomphidae, Tabanidae, Simuliidae, Blephariceridae, Naucoridae, Corydalidae, Gomphidae.
Mewa	Heptageniidae, Heptageniidae (Iron sp.), Ephemeridae, Ephemerellidae, Perlidae, Stenopsychidae Uenoidae, Brachycentridae, Corydalidae, Gomphidae, Limoniidae, Chironomidae, Naucoridae, Elmidae.
Hewa1	Heptageniidae (Iron sp.), Ephemerellidae, Ephemerellidae (Drunella sp.), Baetidae Perlidae, Hydropsychidae, Glossosomatidae, Gomphidae, Limoniidae, Gerridae.
Hewa2	Heptageniidae (Iron sp.), Heptageniidae, Ephemerellidae (Drunella sp.), Ephemerellidae, Baetidae, Caenidae, Perlidae, Hydropsychidae, Corydalidae, Gomphidae, Limoniidae, Dolichopodidae, Chironomidae, Naididae
Tawa1	Heptageniidae, Ephemerellidae, Baetidae, Leptophlebiidae, Perlidae, Hydropsychidae, Glossosomatidae, Philopotamidae, Gomphidae, Tabanidae, Limoniidae, Chironomidae,Veliidae Psephenidae, Thiaridae, Lymnaeidae
Lalleri	Leptophlebiidae, Hydropsychidae, Gomphidae, Simuliidae, Gerridae, Potamidae
Tawa2	Hydropsychidae, Corydalidae, Gomphidae, Tabanidae, Lymnaeidae
Tawa3	Baetidae, Leptophlebiidae, Caenidae, Hydropsychidae, Gomphidae, Nepidae, Planorbidae

Table 4: Macroinvertebrate taxa with total number of families

Similarly, 37 families of macroinvertebrates belonging to 3 Phyla and 9 Orders were observed in the investigated sites (Table 4). A total of 26 and 25 macroinvertebrate families were recorded from glacial-fed and rain/spring-fed streams respectively of which 1 each could be identified only up to the Order (Table 5). However, this does not imply that same families were observed in both types of streams. Trichoptera, Ephemeroptera and Diptera represented the highest number of macroinvertebrate families (6 families each) followed by Hemiptera (4 families), Gastropoda (3 families each), Coleoptera, Decapoda and Oligochaeta (2 families each) and finally Plecoptera, Odonata and Megaloptera (1 family each). taxa (3 families) followed by Oligochaeta (2 families each) and, Ephemeroptera, Diptera, Coleoptera and Hemiptera (1 family each).

S.N.	Macroinvertebrate Family (Glacial-fed streams)	Macroinvertebrate Family (rain-fed streams)
1	**Perlidae**	**Perlidae**
2	**Heptageniidae**	**Heptageniidae**
3	**Baetidae**	**Baetidae**
4	**Caenidae**	**Caenidae**
5	Ephemeridae	**Ephemerellidae**
6	**Ephemerellidae**	Leptophlebidae
7	**Corydalidae**	**Corydalidae**
8	Stenopsychidae	**Hydropsychidae**
9	**Hydropsychidae**	G**lossosomatidae**
10	Uenoidae	Philopotamidae
11	Brachycentridae	**Gomphidae**
12	**Glossosomatidae**	**Tabanidae**
13	**Gomphida**e	**Chironomidae**
14	**Tabanidae**	**Simuliidae**
15	**Limoniidae**	**Limoniidae**
16	**Simuliidae,**	V**ellidae**
17	**Chironomidae**	**Gerridae**
18	**Dolichopodidae**	Nepidae
19	**Blephariceridae**	Gomphidae
20	**Naucoridae**	**Psephenidae**
21	**Elmidae**	**Lymnaeidae**
22	**Gerridae**	**Thiaridae**
23	Hirudinea	Planorbidae
24	**Naididae**	**Potamidae,**
25		**Decapoda(Shrimp**)

Table 5: Comparison of macroinvertebrate taxa in glacial fed and rain-fed streams
Note: Bold letters mean common species found in glacial and rain fed streams

Molluscs and Crustaceans were observed exclusively in rain/spring-fed streams in this study. These taxa have been reported to be widely distributed in the lowland rivers and streams of Nepal [36]. In terms of composition and abundance, macroinvertebrate diversity was also found to vary in the two types of tributaries as in the case of fish diversity.

One way ANOVA revealed that pH ($p<0.05$), conductivity and temperature ($p<0.01$) showed significant variation between glacial-fed and rain/spring-fed tributaries. pH was significantly higher in glacial-fed streams ($p<0.05$) whereas conductivity and temperature were significantly higher in rain/spring-fed streams ($p<0.01$) (Table 6). One way ANOVA also revealed that all four parameters; temperature, pH, DO and conductivity showed significant variation between different sites ($p<0.01$).

Sites	Temperature (˚C) (±SD)	pH (±SD)	DO (mgL^{-1}) (±SD)	Conductivity (μScm^{-1}) (±SD)
M1	**18.80 ± 0.10**	7.50 ± 0.30	7.76 ± 0.25	**57.10 ± 1.34**
M2	**13.40**	7.90 ± 0.35	10.05 ± 0.05	**55.87 ± 0.06**
H1	**17.77 ± 0.25**	7.23 ± 0.12	8.42 ± 0.07	**65.90 ± 1.01**
H2	**15.13 ± 0.12**	7.87 ± 0.21	9.13 ± 0.06	**71.00 ± 0.53**
T1	**25.63 ± 0.06**	7.17 ± 0.06	8.27 ± 0.29	**314.00 ± 1.73**
L1	**25.53 ± 0.35**	7.23 ± 0.15	8.67 ± 1.01	**300.67 ± 0.58**
T2	**25.73 ±0.15**	7.37 ± 0.06	9.85 ± 0.13	**315.67 ± 1.53**
T3	**22.00**	7.60	8.78 ± 0.85	**402.67 ± 0.58**

Table 6: Selected Physico-chemical parameters of the river water

Conclusion

Despite the similarities in functions such as connecting watersheds and culture, geological functions such as eroding and transporting earthly materials, and ecological functions such as the sites for breeding and refuge, the comparison of fish assemblage clearly revealed the differences between the two systems, glacier-fed and rain/spring-fed. This finding was further complemented by the comparison of macroinvertebrate assemblage between the two systems. Thus, in terms of biological characteristics, the tributaries of glacier-fed and rain/spring-fed river systems show different composition and size. The cool and oligotrophic glacier-fed tributaries supported less biodiversity compared to warm and nutrient rich rain-fed tributaries. This finding was further complemented by the variation of physico-chemical parameters between the two systems. The data generated in this study is primary scientific data coming from one of the most data deficit regions of the world. Hence, the findings from this study would serve as a base for the further study of water regime, biodiversity and climate change of the region and country as a whole.

References

[1] Miller, G.T. 2007. People and Environment. Printed by Cengage Learning India Private Limited.pp696

[2] Sponseller, R. A., J. B. Heffernan, and S. G. Fisher. 2013. "On the multiple ecological roles of water in river networks". *Ecosphere* 4(2):1-14.

[3] Rice, S.P., Kiffney, P., Greene, C. and Pess, G.R. 2008. " The Ecological Importance of Tributaries and Confluences." In River Confluences, Tributaries and the Fluvial Networks. Edited by Stephen P Rice, André G Roy and Bruce Rhoads. Publishers John Wiley & Sons Ltd DOI: 10.1002/9780470760383,Ch11

[4] Lansing, J.S., Lansing, P.S. and Erazo, J.S. 1998. "The Value of a River." *Journal of Political Ecology* 5:1-21

[5] Wipfli, M., Richardson, J., & Naiman, R. 2007. "Ecological linkages between headwaters and downstream ecosystems: Transport of organic matter, invertebrates, and wood down headwater channels." *American Water Resources Association*, 43(1), 72-85.

[6] Silveri, L. 2008. *Plecoptera in Trentino: Distribution and Ecology.* Ph.D. thesis, University of Parma. Italy.

[7] Meyer, J., Strayer, D., Wallace, J., Eggert, S., Helfman, G., & Leonard, N. 2007. "The contribution of headwater streams to biodiversity in river networks." *American Water Resources Association,* 43(1), 86-103.

[8] Jacobsen, D., Milner, A., Brown, L., & Dangles, O. 2012). "Biodiversity under threat in glacier-fed river systems." *Nature Climate Change,* 2: 361-364.

[9] Callanan, M., Baars, J., & Kelly-Quinn, M. 2014. "Macroinvertebrate communities of Irish headwater streams: contribution to catchment biodiversity." *Biology And Environment: Proceedings Of The Royal Irish Academy,* 114B (3): 143-162.

[10] Tachamo-Shah, R., Sharma, S., Hasse, P., Jahnig, S., & Pauls, S. 2015. "The climate sensitive zone along an altitudinal gradient in central Himalayan rivers: A useful concept to monitor climate change impacts in mountain regions." *Climate Change,* 132(2):265-278.

[11] 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

[12] Storey, R., Parkyn, S., Neale, M., Wilding, T., & Croker, G. 2011. "Biodiversity values of small headwater streams in contrasting land uses in the Auckland region." *New Zealand Journal Of Marine And Freshwater Research*. 45(2): 231-248.

[13] Olafsson, J., Gislason, G., & Aoalsteinsson, H. 2002. "Icelandic running waters; anthropological impact and their ecological status." *TemaNord.* 266: 86-88.

[14] Bishop, K., Allen, S., Pollard, D., & Cook, M. 1990. Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory port (Research Report: 4). Vol. II. Canberra: Australian Government Publishing Service.

[15] Bae, M., Kwon, Y., Hwang, S., Chon, T., Yang, H., Kwak, I., Park, J., Ham, S., & Park, Y. 2011. "Relationships between three major stream assemblages and their environmental factors in multiple spatial scales." *International Journal of Limnology*. 47: 91-105

[16] Wynes, D., & Wissing, T. 1981. "Effects of water quality on fish and macroinvertebrate communities of The Little Miami River". *The Ohio Journal of Science.* 81(5-6):259-267.

[17] DDC, Taplejung. (n.d.). Retrieved July 26, 2015, from http://www.ddctaplejung.gov.np

[18]DDC, Panchthar. (n.d.). Retrieved July 26, 2015, from http://www.ddcpanchthar.gov.np

[19] DDC, Udaypur. (n.d.). Retrieved July 27, 2015, from http://www.ddcudayapur.gov.np

[20] Jha, B. 2006. Fish ecological studies and its application in assessing ecological integrity of rivers in Nepal. Ph.D. Thesis, Kathmandu University, Nepal. Agricultural University (BOKU), Vienna, Austria.

[21] Sharma C. M. & Jha B. R. 2012. Spatial and Temporal Distribution of Fish Assemblage in Indrawati Sub-Basin. WWF, Nepal (Agreement # WL47).

[22] Day, F. 1878. Fishes of India being a natural history of the fishes known to inhabit the seas and freshwaters of India, Burma and Ceylon, Vols. I and II. Today and Tomorrow book Agency, New Delhi.

[23] Shrestha J. 1994. Fishes, fishing implements and methods of Nepal, Smt. M.D. Gupta, Lalitpur colony, Lashkar (Gwalior), India.

[24] Talwar P.K. & Jhingran A.G. 1991. Inland fishes of India and adjacent countries, vol. 1, Oxford and IBH Publishing Company Pvt. Ltd.

[25] Jayaram, K. C. 1999. The Fresh Water Fishes of Indian Region. Narendra Publishing House, Delhi, India.

[26] Shrestha J. 2001. Taxonomic revision of fishes of Nepal, in Jha P.K. et al., (Ed.), Environment and Agriculture: Biodiversity, Agriculture and Pollution in South Asia, p171-180, Ecological Society (ECOS), Kathmandu, Nepal

[27] Shrestha, J., Singh, D. & Saund, T. 2009. Fish diversity of Tamor River and its major tributaries of Eastern Himalayan Region of Nepal. Nepal Journal of Science and Technology, 10, 219-223.

[28] Barbour, M., Gerritsen, J., Snyder, B., & Stribling, J. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water

[29] Merritt, R.W. and Cummins, K.W. 1996. An introduction to the Aquatic insects of North America, 3rd edition, Kandall/Hunt publishing company.

[30] Beamish, F., Sa-ardrit., & Tongunui, S. 2006. "Habitat characteristics of the Cyprinidae in small rivers in Central Thailand." *Environmental Biology of Fishes,* 76(2): 237-253

[31] Das, H., & Dutta, A. 2012. "Effects of industrial effluents on ecology of a wetland of Nalbari District, Assam with specia:l reference to Ichthyofauna." *An International Quarterly Journal of Environmental Sciences.* 1: 147-153.

[32] Roy, R., Bahadur, M., & Barat, S. 2013. "Comparative study of antibiotic resistance profile of Enterebacteriaceae bacterial isolates from the gut of intestinal air-breathing fish, Lephidocephalichthys guntea and its habitat." *International Journal of Science and Research,* 4(6): 2565-2569.

[33] Crail, T., Gottgens, J., & Krause, A. 2011. "Fish community response to evolving channel complexity in an agricultural headwater system." *Journal of Soil and Water Conservation,* 66(5): 295-302.

[34] Infante, D., Allan, J., & Linke, S. 2009. "Relationship of fish and macroinvertebrate assemblages to environmental factors: Implications for community concordance." *Hydrobiologia,* 623: 87-103.

[35] Allen, D. J. Molur, S. & Daniel, B. A. (eds) 2010: The status and distribution of freshwater biodiversity in the Eastern Himalay. IUCN. Cambridge UK.

[36] Nesemann, H., Sharma, S., Sharma, G., Khanal, S., Pradhan, B., Shah, D., & Tachamo, R. 2007. *Aquatic invertebrates of the Ganga River system*. Kathmandu: H. Nesemann.