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Integrated study of Physicochemical parameters, Ichthyofaunal diversity, and Planktonic assemblages in the Giri Stream, Solan (H.P.), India

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Abstract

The current study was conducted to investigate the ecological interactions among physicochemical parameters, fish faunal diversity and planktonic community in the Giri stream, a tributary of Yamuna River in Solan district, Himachal Pradesh. The analysis of the physicochemical parameters was done to study the water quality of the stream water. The value of the WAWQI recorded in the stream was 71.13 which revealed poor water quality due to varied anthropogenic activities such as washing clothes, bathing, and drainage of waste material into the stream. During the current investigation, a total of 5 species belonging to 2 orders (Cypriniformes and Synbranchiformes) and 3 families (Cyprinidae, Danionidae and Mastacembelidae) were recorded, out of which Cypriniformes was the dominant order. Furthermore, a total of 9 genera of phytoplankton were recorded, majority of which belongs to Bacillariophyceae, followed by Chlorophyceae and Cyanophyceae. The Canonical correspondence analysis (CCA) was used to study the correlation between the physico-chemical parameters, plankton and fish diversity indicating varied relation of fishes with physicochemical parameters and plankton.

Key words : Physicochemical, CCA, Ecology, Giri, Plankton, Diversity.

Water is a crucial natural resource and a lifeline that provides habitat to aquatic organisms. Freshwater ecosystems, mainly hill streams, are dynamic and fragile ecosystems where complex ecological interactions occur between the abiotic and biotic factors. These aquatic ecosystems often function as the mirror of a collapsing environment due to various anthropogenic activities[5]. Understanding the ecological structure of biotic and abiotic factors *i.e.*, physicochemical parameters, fish and plankton diversity, helps to evaluate the health and stability of the freshwater ecosystem. Physicochemical parameters such as water temperature, DO, pH, TDS, electrical conductivity, total alkalinity, total hardness and inorganic nutrient concentration determines the quality of water and directly or indirectly influences the diversity of fishes and productivity of the water body[21]. Fish communities serve as valuable indicators of ecological wholeness and play a crucial role in maintaining the health and functioning of aquatic ecosystems as it provides ecosystem stability, food security, and economic value. It also reflects the current environmental conditions, and also the changes occurring within the environment[17]. Similarly, phytoplankton are indispensable and act as primary producers in the aquatic ecosystem. Phytoplankton are phototrophic microorganisms with simple nutritional requirements be they eukaryotes or prokaryotes[22]. Phytoplankton are easily affected by the change in the environment and also indicate the water quality. The present study aims to analyze the ecological interactions among key physicochemical variables, fish fauna and plankton diversity in the Giri stream, a tributary of Yamuna River in Himachal Pradesh.

Area of study :

The present study is aimed at Giri stream in Solan district of Himachal Pradesh, originates from the Kupper peak near the Kotkhai town of Shimla district and passes through Solan and Sirmaur and ultimately joins the Yamuna near Paonta Sahib, Sirmaur. In Solan district, the Giri stream (Fig. 1) flows through parts of the southeastern region, passing through Kandaghat, Rajgarh and Sangrah as it makes its way toward Sirmaur. The Giri stream exhibits a steep gradient resulting in fast flowing water with rocky bed material. The stream bed is often composed of boulders, cobbles and gravel. Sampling was done at two sampling sites *i.e.*, Yashwant Nagar and Giripul. GPS coordinates of these sampling sites were given in Table-1.

The stream was explored during 2024-25 and the ecological interaction among the physicochemical parameters, fish faunal diversity and planktonic community was assessed. Different physicochemical parameters were studied during the survey, including water and air temperature, pH, alkalinity, total hardness, TDS, conductivity, Ca^{+2} and Mg^{+2} hardness and concentration of phosphates and nitrates. The physicochemical parameters like water and air temperature, DO, TDS, and electrical conductivity were measured in the stream with the help of digital probes, while total alkalinity, total hardness, Ca^{+2} and Mg^{+2} hardness and concentration of phosphates and nitrates were analyzed in the laboratory as per APHA[1]. The Weighted Arithmetic Water Quality Index (WAWQI) given by Brown *et al.*[4] was used for analysis of water quality of the stream.

Different types of nets (mainly cast net) were used to capture the fish from the stream on the bases of habitat types. The collected specimens were then preserved in 5-10% formalin solution, depending on their size. Identification of the fishes done in the laboratory using identification keys given by Talwar and Jhingran[30], Jayaram[12] and Froese and Pauly[9]. Fish diversity was assessed using different diversity indices. Plankton sampling was also done with the help of plankton net and preserved by adding a few drops of 3-4% formalin in a bottle or jar and labelled properly. The identification of the plankton was done with a compound light microscope using Sedgwick Rafter Counting Chamber. The plankton were identified up to genus taxa using standard references of Edmondson[8], Ward and Whipple[33]. The correlation between physico-chemical parameters, fish fauna, and plankton was analyzed by multivariate testing using CCA (Canonical Correlation Analysis). All the statistical analysis was done using PAST software (version 4.03).

Giri is a perennial and a spring fed stream, sometimes receives water through snow melt and it comes under B-stream type according to Rosgen classification[18,19], due to its moderate gradient. Bed material is mainly dominated by boulders, cobbles and gravels. Riffles, pools, run were principal habitat, rapids were also seen during high flow.

Physico-chemical parameters :

Water quality of the stream was investigated by various physicochemical parameters, including water temperature, pH, TDS, DO, conductivity, total alkalinity, total hardness, calcium and magnesium hardness and concentration of phosphates and nitrates.

In the present study, the average water temperature of the stream ranged from 17.9 to 35ºC. The temperature of the water source affects the biological and chemical reaction. Other physicochemical properties such as DO, conductivity, pH, and solubility of gases are also dependent on the water temperature[20]. Singh *et al.*[23] reported that the water temperature was lowest in December (9ºC) and highest in May (23.7ºC) in Giri stream, Sirmaur. Similar observations were also seen in present study with minimum water temperature in December (17.9ºC) and maximum in May (35ºC).

The pH of the stream ranged from 8.0-11.4, indicating an alkaline nature of the water body and is higher than the standard limits of WHO[32], BIS[3], ICMR[10] and USPHS[31]. The variation in the values is the result of anthropogenic activities such as bathing, washing, littering etc., these activities influence the water quality. Kashyap *et al.*[14] also recorded the pH value ranged from 7.24- 7.63 in Yamuna River, Paonta Sahib, Sirmaur.

Dissolved oxygen recorded in the range of 6.6-10.6 mg/l. DO is important for aquatic organisms for respiration and is also used for decomposition of organic matter and other biological and chemical processes. The maximum value of DO (10.6 mg/l) was recorded in December, whereas the minimum value (6.6 mg/l) was recorded in April. This could be a result of increased water temperature, given the inverse relationship between temperature and dissolved oxygen. Sharma *et al.*[26] recorded the DO value from 9.37-10.23mg/l in the upper Ganga River basin. Singh *et al.*[23] observed the DO value from 7.25 mg/l - 12.00 mg/l in Giri stream, Sirmaur, which is higher than our observations. Electrical conductivity in the studied stream ranged from 300-360 µS/cm which slightly exceeds the acceptable limits (300 µS/cm) of ICMR[10] and USPHS[31]. The highest value (360 µS/cm) was observed in the month of December and lowest (300 µS/cm) in October. Sharma *et al.*[25] recorded the EC ranged between 104 – 158 µS/cm in two tributaries namely Neugal and Bhirl of Beas River in Kangra district of Himachal Pradesh, which was much less than our present findings.

Total dissolved solid (TDS) concentration is the sum of the cation and anion in the water including minerals, salts or metals dissolved in the given volume of water. The TDS in the stream ranged from 74-129 mg/l, which was within the limits set by BIS[3], WHO[32], USPHS[31] and ICMR[10]. Sharma *et al.*[29] recorded the TDS ranged from 140-224 mg/l in Ashwani stream, Solan which was much higher than our present findings.

Alkalinity in the stream ranged from 24-145.2 mg/l which is slightly higher than the permissible limits given by ICMR[10] and within the limits given by BIS[3]. Highest alkalinity value was seen in two months *i.e.*, January and February (145.2 mg/l) and lowest in March (24 mg/l). The higher value of alkalinity was due to anthropogenic activities (domestic wastewater discharge and bathing) in the stream.

The total hardness of the stream ranged from 108-420 mg/l. The hardness of the water mainly depends on the calcium and magnesium hardness which ranges from 104-200 mg/l and 4-260 mg/l, respectively which was higher than the permissible limits given by the BIS[3] and ICMR[10]. Kumar and Singh[15] recorded the total hardness in the Mann stream in Hamirpur, Himachal Pradesh ranged from 117.5-352.5 mg/l, which was slightly lower than our observations.

Nitrates and Phosphates act as the inorganic matter of the water bodies. Both the matter is used by the aquatic organism (fauna and flora) for the completion of their life cycle. High concentration of both these substances can cause high nutrient levels in the water bodies and eutrophication[24]. In the studied stream nitrate concentration ranged from 1.1-2.67 mg/l and phosphate from 0.004-0.12 mg/l. These values are within the permissible limits given by BIS[3] and USPHS[31].

The calculated value of WAWQI of the current stream was 71.13 (Table-2), which indicated poor water quality of the stream[>]. Chand et al.[7] assessed the water quality of Kasambhal spring (WQI: 93.48) and Ger Nallah spring (WQI: 86.14) which indicate very poor water quality of the springs of Chuhar Valley, Northwestern Himalaya. Sharma *et al.*[29] reported a WAWQI value of 98.56 for Ashwani stream water, indicating very poor water quality.

Fish Diversity :

The present study documented 5 fish species in the Giri stream (Table-3, Fig. 2) represented by 2 orders (Cypriniformes and Synbranchiformes) and 3 families (Cyprinidae, Danionidae and Mastacembelidae). Cypriniformes is the dominant order consisting of 4 fish species. Joshi *et al.*[13] reported 112 fish species belonging to 10 order, 29 families and 73 genera in Yamuna River with Siluriformes most dominant genera in the river. Sharma and Banyal[27] reported a total of 10 fish species belonging to 5 order and 5 families in the Man stream, which is dominated by Cypriniformes order.

The fish diversity indices collectively help to evaluate the richness, abundance and distribution of the fish species. The fish diversity varied significantly throughout the

Table-1. GPS coordinates of the sampling sites.

Sampling Sites	Location	Latitude	Longitude	Altitude (m)
Site I (Upstream)	Yashwantnagar	30°88' 70" N	77°20' 58" E	932
Site II (Downstream)	Giri Pul	30°88' 21" N	77°20' 99" E	928

different months (Table-4), indicating the dominance of single fish species *Tor putitora* in the months of December and February. Shannon and Simpson indices were highest in the month of May which indicates the high diversity of fish species. The Evenness index was 1 in five different months (December, February, March, April and May) which indicates the even distribution of individuals of all the species. A clear increase in fish diversity indices was seen in spring months (March to May) shows favorable ecological conditions for species richness and even distribution. This can be due to environmental factors like water temperature, breeding cycles, and food availability, which improves the diversity in these months.

Relationship between fish diversity and physicochemical parameters :

The CCA biplot (Fig. 3) shows the correlation between the fish diversity and the physicochemical parameters. The plot showed a positive relation between the *Tor putitora* and the physicochemical parameters like phosphates, nitrates, TDS, pH, total hardness and magnesium hardness and negative correlation with water and air temperature. *Opsarius bendelisis* was positively correlated to conductivity and DO and negatively with total alkalinity whereas *Schizothorax richardsonii* was positively correlated with total alkalinity and negatively with conductivity and DO. *Opsarius barna* showed slight positive correlation towards water temperature and negative correlation with phosphates, nitrates, TDS, pH, total hardness and magnesium hardness.

Plankton Diversity :

A total of 9 genera of phytoplankton falling under three major groups Bacillariophyceae (*Cymbella, Fragilaria, Gomphonema, Navicula, Nitzschia, Meridion),* Chlorophyceae (*Cladophora)* and Cyanophyceae (*Oscillatoria)* were recorded. Among the three groups, Bacillariophyceae is the most dominant group, whereas *Navicula, Cymbella, Nitzschia* and *Gomphonema* were the dominant genera found. Kumari *et al.*[16] similarly documented a marked dominance and high diversity of Bacillariophyceae in the Ashwani stream, Solan. During the study diatoms were found abundant in 17.9 - 25.6^{O}C. Sharma *et al.*[28] also found high diversity of diatoms at low water temperature in the head water stream of Garhwal Himalayas.

Jindal and Vatsal[11] reported the pollution tolerant plankton like *Navicula, Nitzschia* and *Synedra* which indicate high pollution load. Atici and Obali[2] recorded that plankton like *Diatoma, Cymbella, Nitzschia* and *Cyclotella* were tolerant to environmental pollution in Asap Tepe Dam Lake (Ankara), Turkey. The

Table-2. Depiction of Weighted Arithmetic Water Quality Index of the studied stream.

Parameters	Range	S_n	$1/S_n$	$K=1/(\Sigma 1/S_n)$	$W_n=K/S_n$	V_0	V_n	V_n/S_n	$Q_n=V_n/S_n*100$	W_n*Q_n
Dissolved oxygen (mg/l)	6.6-10.6	5	0.2	0.0961	0.0192273	14.6	9.1	1.82	182	3.499371
pH	8.0-11.4	8.5	0.1176471	0.0961	0.0113102	7	9.3875	1.104	110.44	1.2491101
Total Alkalinity (mg/l)	24-145.2	200	0.005	0.0961	0.0004807	0	82.8	0.414	41.4	0.0199003
Total Hardness (mg/l)	108-420	200	0.005	0.0961	0.0004807	0	239	1.195	119.5	0.0574416
Calcium Hardness (mg/l)	104-200	75	0.0133333	0.0961	0.0012818	0	133.5	1.78	178	0.2281641
Magnesium Hardness (mg/l)	4-260	30	0.0333333	0.0961	0.0032046	0	105.5	3.516	351.66	1.1269342
Total dissolved solid (mg/l)	74-129	500	0.002	0.0961	0.0001923	0	104.375	0.208	20.87	0.0040137
Conductivity (µS/cm)	300-360	300	0.0033333	0.0961	0.0003205	0	333.75	1.1125	111.25	0.0356506
Nitrates (mg/l)	1.1-2.67	45	0.0222222	0.0961	0.0021364	0	2.0475	0.0455	4.55	0.0097205
Phosphates (mg/l)	0.04-0.12	0.1	10	0.0961	0.9613657	0	0.0675	0.675	67.5	64.892183
			$\Sigma 1/S_n=10.401869$		1					71.13

Table-3. Fish species recorded in Giri stream

S.No.	Fish Species	IUCN Status
	Class: Actinopterygii	
	Order: Cypriniformes	
	Family: Cyprinidae	
1.	*Tor putitora* (Hamilton,1822)	EN
2.	*Schizothorax richardsonii* (Gray,1832)VU	
	Family: Danionidae	
3.	*Opsarius barna* (Hamilton,1807)	LC
4.	*Opsarius bendelisis* (Hamilton, 1807)	LC
	Order: Synbranchiformes	
	Family: Mastacembelidae	
5.	*Mastacembelus armatus* (Lacepède, 1800)	LC

EN: Endangered; VU: Vulnerable; LC: Least Concern

Table-4. Monthly variation of fish diversity in the stream

Indices	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Dominance_D	0.5556	0.82	1	0.375	1	0.3333	0.3333	0.25
Simpson_1-D	0.4444	0.18	0	0.625	0	0.6667	0.6667	0.75
Shannon_H´	0.6365	0.3251	0	1.04	0	1.099	1.099	1.386
Evenness_e^H/S	0.9449	0.6921	1	0.9428	1	1	1	1

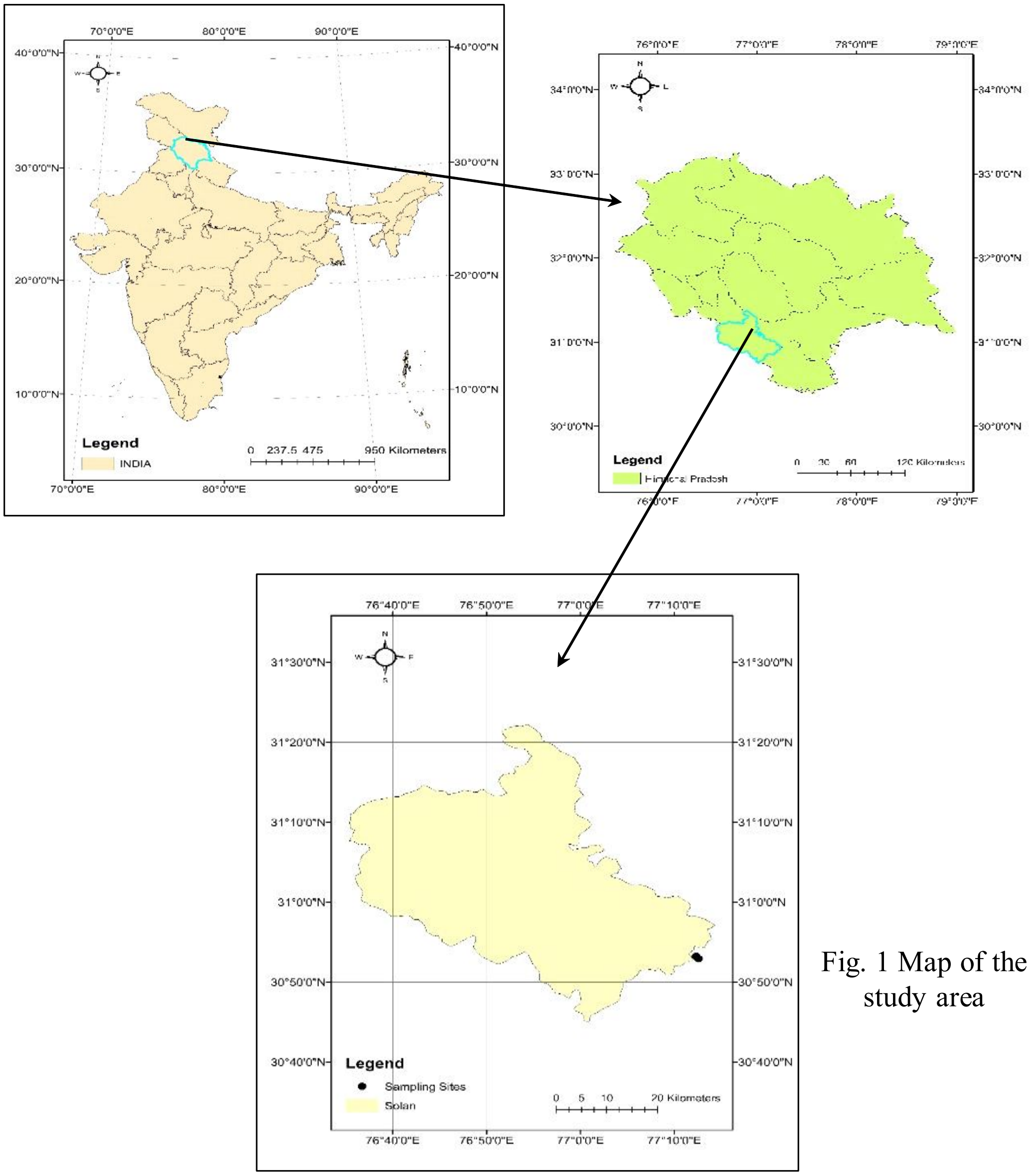

Fig. 1 Map of the study area

Tor putitora (Hamilton,1822)

Schizothorax richardsonii (Gray,1832)

Opsarius barna (Hamilton, 1807)

Opsarius bendelisis (Hamilton, 1807)

Mastacembelus armatus (Lacepède, 1800)

Fig. 2 Photoplate depicts the fish species recorded from the stream

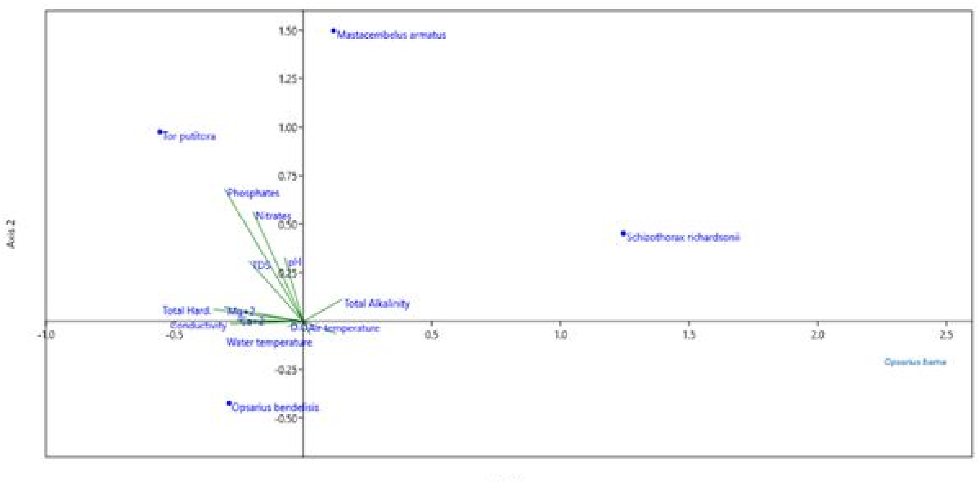

Fig. 3 CCA biplot showing correlation between physicochemical parameter and Fish diversity

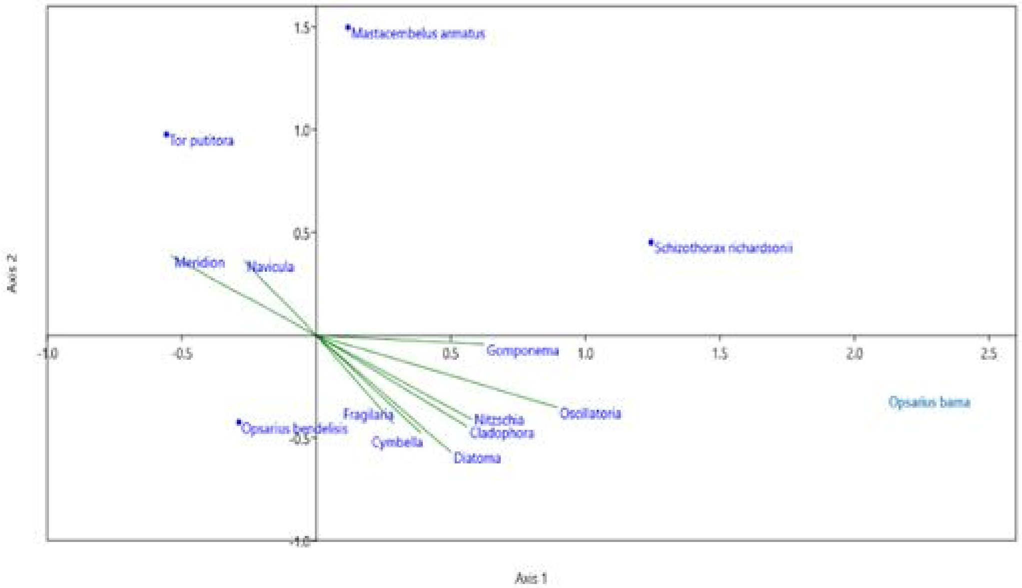

Fig. 4 CCA biplot showing correlation between Phytoplankton and Fish species

presence of similar genera (*Diatoma, Cymbella, Navicula and Nitzschia)* in the Giri stream indicates the pollution load in the stream.

Correlation between the Fish fauna and Plankton diversity :

The CCA biplot (Fig. 4) shows that the *Opsarius barna* is positively correlated with *Gomphonema*, *Oscillatoria*, *Nitzschia*, *Cymbella, Cladophora, Diatoma* and *Fragilaria* indicates that fish species may thrive in areas having high diversity of these plankton taxa and negatively correlated with *Meridion*, and *Navicula*. Whereas, *Tor putitora* is positively correlated with *Meridion* and *Navicula* and negatively correlated with *Gomphonema*, *Oscillatoria, Nitzschia*, *Cymbella, Cladophora Diatoma* and *Fragilaria*.

Being a tributary of Yamuna River, Giri stream holds an immense ecological significance and serves as a vital water source to local inhabitants. The present study depicts that the water quality of the stream is poor which indicates the influence of anthropogenic activities in the stream, though the fish and plankton diversity in the stream is stable, but can deteriorate with the increase in the human activities. Continued monitoring and proper management are recommended to maintain water quality, healthy environment for the faunal diversity and reduction of anthropogenic activities in or near the stream.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors contributions :

Conceptualization: Harinder Singh Banyal and Shivali Sharma; Methodology: Geetanjli, Shivali Sharma and Harinder Singh Banyal; Data collection: Geetanjli; Formal analysis: Geetanjli and Shivali Sharma; Writing – original draft: Geetanjli; Writing – review & editing: Geetanjli, Shivali Sharma and Harinder Singh Banyal; Supervision: Harinder Singh Banyal.

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