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Original Article

Fish assemblage structure and habitat use of the snow fed stream Assiganga - a major tributary of river Bhagirathi in Central Himalaya (India)

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Abstract: Assiganga stream is an important tributary of Bhagirathi River in central Himalaya (India). The stream is characterized by heterogeneity in habitat and substratum features harboring diverse fish fauna. At present this stream is facing threat of being fragmented by the construction of two hydro-electric projects. Present study aimed to study fish diversity and their habitat use in Assiganga stream. This study reports fifteen species (14 indigenous and 1 exotic) belonging to 8 genera, 4 families and 3 orders. Snow trout, *Schizothorax richardsonii* (Cyprinidae family) and *Salmo trutta* (Salmonidae family) were the dominant species (> 65% of total fish catch) throughout the entire length of stream. The presence of rich benthic food, clear water, low turbidity (01-05 NTU), high DO (8.75-10.75 mg-l), and high water velocity (1.10-1.40 m-s) with characteristic rapids and cascades in upper reaches provides ideal habitat for the existence of native snow trout and exotic trout species. Few cat fishes, loaches, *Tor* spp. and lesser barils also have been reported during the study.

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Introduction

Fishes are invariable living components of water bodies and important food resource and indicators of the ecological health of water body. India has heterogeneity in climatic conditions, therefore, has a large network of rivers, both in Himalaya and plains harboring 2500 fish species (Jayaram, 2010). These rivers always remain the site of most of our evolutionary history and human activities, and have wide range of diversity in terms of fish and other aquatic organisms. Naturally functioning stable stream systems promote the availability in heterogeneity of habitats. The fresh water fishes show variations in relation to habitat and geographical condition. The study of the habitat parameters and diversity of fish population of a river lend support to fishermen and Ichthyologists (Kar, 2010). According to 'Convention on Biological Diversity', information's on aquatic biodiversity is lacking at global as well as at local level. In absence of this information, it is difficult to assess status of any species and to prepare its conservation and management plan. Fish resources in the fluvial systems of Garhwal (Central Himalaya) had not been completely explored because most of the streams are located in aloof mountainous steep terrain with dense forest cover. Some important studies from view point of fish diversity have been conducted in central Himalaya, Garhwal (Badola, 1975; Sharma, 1984; Singh et al., 1987; Lakra et al., 1987; Dobriyal and Kumar, 1988; Agarwal et al., 2005, 2011; Bisht et al., 2009; Agarwal and Singh, 2012). In spite of these studies, there is still complete dearth of information on some of the important central Himalayan streams. The stream Assiganga, a major tributary of river Bhagirathi (Ganga) is one of the unexplored streams in central Himalaya from view point of fish diversity and water quality. Moreover stream habitat is facing

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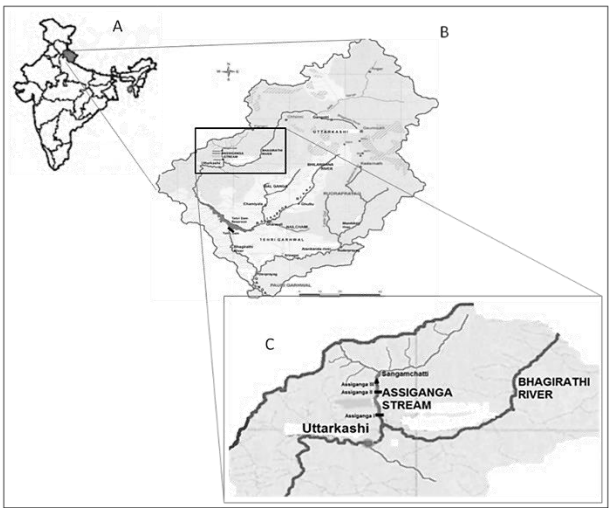

Figure 1. Geographical location of Assiganga stream. (A) India's state map showing Uttarakhand, (B) Upper Ganga river system in central Himalaya and (C) Assiganga stream from its origin to merging in river Bhagirathi.

threat of being altered by the hydro-electric projects being constructed on it. Hence an attempt is made to generate base line information on fish diversity and their habitat use in the Assiganga stream.

Study area: Assiganga stream is located between latitude 30°48'N and longitude 78°27'E in Uttarkashi District of Uttarakhand state (India). It is snow fed perennial stream with high water discharge during summer and monsoon seasons. The stream originates after joining of two small streams viz. the Kaldi Gad (elevation 4521 m asl) and Gajoli Gad (elevation 3836 m asl) at Sangamchati (elevation 1505 m asl). Thereafter stream traverse a distance of ~15 km before debouching with river Bhagirthi at Gangori (elevation 1160 m asl) upstream to the northern side of Uttarkashi (Latitude 31°27'34"N to 31'13'N and Longitude 77°58'51"E to 78°53'E) (Fig. 1). The water is pristine or near pristine with low depths, high transparency and dissolved oxygen.

The morphometry of stream varies considerably from Dodital to Gangori. Throughout the length, stream has torrential flow and passes through deep gorges at many places. It has low volume in the upper stretch which increases downward due to joining of several 1st and 2nd order tributaries. The uppermost reaches are gorge-like and rocky or full of huge boulders. In the middle stretch, streambed consists of partially or fully matured boulders (Fig. 2), while pebbles, cobbles, and silt are observed in the lower stretch besides fully mature boulders of varying size. Stream habitat is characterized by diverse microhabitats as pools, riffles, rapids, runs, and cascades.

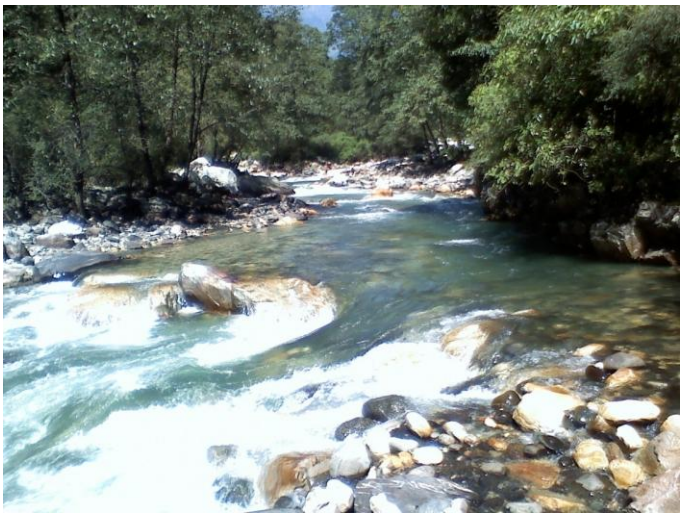

Figure 2. Substratum and habitat features of Assiganga Stream.

Materials and methods

Regular monthly sampling of fishes and physico-chemical parameters was carried out in the Assiganga stream during the year 2010-12. Fish collection was made with the help of skilled fisherman during daytime (6:00-18:00 hrs), while 'baur' (indigenous trap) and 'gill net' were also fixed during late evening hours (17:00 -18:00 hrs) and recovered in early morning hours (5:00-7:00 hrs). Fishing methods employed were cast net (dia. 2.0 m, mesh size 1.8 x 1.8 cm), gill net (mesh size 1.2 x 1.2 cm, L x B = 12 m x 1.5 m), baur or phans (fine nylon loops knotted over a long nylon cord of 5-8 m length), scoop net and hook and lines. Collected fish samples were preserved in 8-10% formaldehyde. Small fish specimen (<150 mm in total length) were preserved directly while the large specimen (>150 mm in total length) were preserved with preservative injection or slitting the abdomen. Fish identification was performed on the basis of morphometric and meristic characters (Day, 1878; Tilak, 1987; Talwar and Jhingran, 1991; Shrestha, 2008; Badola, 2009; Jayaram, 2010). The physico-chemical variables (ambient and water temperature, velocity, pH, total

Table 1. Stream habitat types with their description.

Habitat Type	Description
Pools	A segment of the stream with reduced current velocity, depth exceeding than surrounding habitats.
Riffles	A relatively shallow area with gradient less than 4% with swift flowing water completely or nearly covering obstructions and substrate of smaller rock gravel or bedrock having surface or subsurface agitation.
Rapid	A relatively deep stream section with swift currents and gradient exceeding 4% resulting in series of short drops, considerable surface agitation, pocket pools and rock and boulders exposed at all but high flows
Run	An area of swiftly flowing water with gradient over 4% with minor surface agitation and in which slope of the water surface is roughly parallel to the overall gradient of the stream.
Cascade	An area of continuous stepping with low water depth and swiftly flowing water.

Table 2. Status of ichthyofauna reported from Assiganga with their local names.

S. no.	Ichthyo species with order and family	Local name	Present status
	Order Cypriniformes		
	Family Cyprinidae		
1	*Schizothorax richardsonii*	Maseen	abundant
2	*S. plagiostomus*	Asela	common
3	*Schizothoraichthys curvifrons*	Chongu	rare
4	*S. progastus*	Chongu	rare
5	*Tor putitora*	Khasra	common
6	*T. tor*	Khasra	rare
7	*T. chilinoides*	Mahseer	rare
8	*Barilius bendelisis*	Fulra	rare
9	*Garra gotyla gotyla*	Gunthala	rare
	Family Cobitidae		
10	*Noemacheilus rupicola*	Gadiyal	rare
11	*N. montanus*	Gadiyal	rare
	Order Siluriformes		
	Family Sisoridae		
12	*Glyptothorax pectinopterus*	Kathrua	rare
13	*Glyptothorax madraspatanum*	Kathrua	rare
14	*Pseudecheneis sulcatus*	Kathrua	rare
	Order Salmoniformes		
	Family Salmonidae		
15	*Salmo trutta*	Brown trout	common

dissolved solids, DO, free CO_2, and turbidity) were analyzed using standard methods outlined in American Public Health Association (APHA, 1998). The temperature was measured using mercury thermometer, velocity by the float method and pH with the Hanna made electronic digital pH meter. The Total dissolved solids were calculated by digital TDS meter, DO with the Winkler's Iodometric method while turbidity was measured by digital turbidity meter (ELICO model 331E). Substratum material has been characterized as large boulder (>1024 mm size), small boulder (256-1024 mm), cobbles (64-128 mm), coarse gravels (16-64 mm), fine gravel (2-34 mm) and sand (0.062-2.0 mm) following (Armantrout, 1999). Stream habitat was classified as pools, riffles, rapid, run, and cascade

Table 3. Relative abundance of fish fauna of Assiganga stream.

Name of the species	Common name	Different seasons			
		Summer	Monsoon	Post monsoon	Winter
Schizothorax richardsonii	Maseen	11.56	5.78	9.10	5.05
S. plagiostomus	Asela	4.33	2.60	3.61	1.73
Schizothoraichthys curvifrons	Chongu	0.00	0.28	0.72	0.00
S. progastus	Chongu	1.58	0.57	1.15	0.00
Tor putitora	Khasra	3.17	2.16	2.89	2.16
T. tor	Khasra	1.73	0.00	1.44	0.00
T. chilinoides	Mahseer	1.44	0.00	1.73	0.57
Garra gotyla gotyla	Gunthala	0.72	0.00	0.72	0.14
Barilius bendelisis	Fulra	2.60	0.57	1.73	0.14
Glyptothorax pectinopterus	Naou	0.86	0.14	0.57	0.00
G. madraspatanum	Naou	0.72	0.00	0.00	0.00
Pseudecheneis sulcatus	Kathrua	2.02	0.72	0.57	0.28
Noemacheilus rupicola	Gadiyal	1.73	0.00	0.72	0.00
N. montanus	Gadiyal	1.30	0.14	0.00	0.00
Salmo trutta	Brown trout	6.50	4.33	3.61	4.33
Species richness		**14**	**10**	**13**	**8**

(Table 1). Fishes have been categorized as abundant, common and rare based on their average abundance. The relative abundance (RA) of fish species across the study sites was worked out by the following formula.

RA = (Number of samples of particular species × 100)/ Total number of samples.

Results

Fish composition: In the present study 15 fish taxa (14 indigenous and 1 exotic species) have been reported from entire stretch of Assiganga stream. All the species reported belongs to 8 genera, 4 families and 3 orders (Table 2).

Species richness pattern: The cyprinidae family was the dominant taxon in middle and lower stretches of the stream while in the upper stretch, salmonidae family predominated. The snow trout *Schizothorax richardsonii* and *Salmo trutta* were present throughout the stream and contributes > 65% of total fish catch. The *S. plagiostomus* and *Tor putitora* contribute 15-20% of total fish catch and are reported only in lower and middle stretch. The relative abundance of these species was followed by *Tor*, *Barilius* and *Garra* spp. (Table 3). Some cat fishes and loaches were recorded sporadically in few catches.

Physico-chemical parameters: The seasonal analysis of physico-chemical parameters of Assiganga stream showed characteristic features (Fig. 3). Stream water showed high dissolved oxygen content (8.7 ± 0.36 to 10.80 ± 1.5 mg^{-l}) throughout the year in all seasons. While free carbon dioxide was recorded low in all seasons (1.2 ± 0.133 to 1.45 ± 0.105 mg^{-l}). The total dissolved solids were found in optimum range and little variation was recorded in different seasons. Water was clear with low turbidity throughout the year with maximum value (05 ± 2.0 NTU) in monsoon months to minimum value (01 ± 0.0 NTU) in winter season. Annual pH value ranged between 7.75 ± 0.49 to 8.1 ± 0.27. The water temperature was recorded within the highest limit of cold water fishes. It was recorded 20.0 ± 1.33°C in the monsoon while 10.0 ± 0.5°C in winter season. The water velocity was recorded high throughout the year. It ranged between 1.1 ± 0.132 to 1.4 ± 0.087 m^{-s} in winter and monsoon season, respectively.

Discussion

The fish assemblage and their relative abundance in Assiganga stream varied in association with number of factors viz. flow rate, nature of substratum, water-

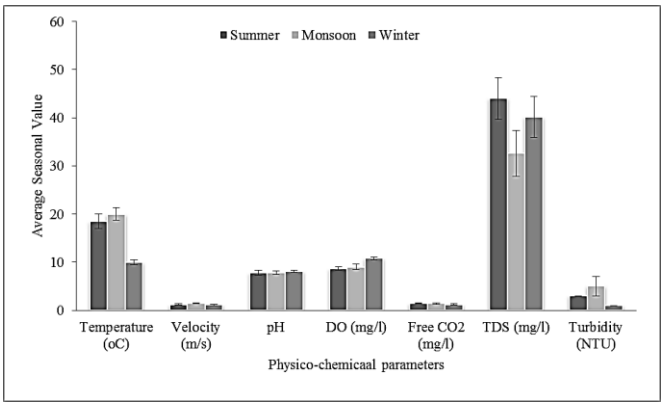

Figure 3. Seasonal variation in physico-chemical variables (mean ± SD) of Assiganga stream.

depth, food availability, physico-chemical properties, stream length and seasons. It is reported that the abundance and composition of fish species is highly variable in space and time and closely related to environmental variables (Vilar et al., 2011). High species richness along with high abundance (14 species) was recorded in summer season, whereas very low species richness as well as low abundance was recorded during winter season. Contrary to this (Bisht et al., 2009) has recorded high fish diversity in the monsoon season in a spring fed stream with low discharge, but the observation of low fish diversity in winter is similar in both the studies. Comparatively high fish diversity in the summer season might be due to optimum temperature and moderate volume of water in Asiganga. In monsoon season the stream is heavily flooded, while in winter season the water temperature is very low, which is not conducive for *Noemacheilus*, *Barilius* and *Tor* spp.

The fish distribution pattern also varied in the different stretches of stream. Upper course of Assiganga stream is most torrential and is frequented by *Salmo trutta*, *S. richardsonii*, *S. curvifrons*, and *S. plagiostomus*. The rapid zone of the stream is inhabited by *Garra*, *Glyptothorax* and *Pseudecheneis* spp. Intermediate stretch of the stream is less torrential with comparatively high temperature in contrast to upper region and is found to be inhabited by *Schizothoraichthys progastus* and *Tor putitora*. The lower stretch of the stream is slow moving meandering zone and is frequently inhabited by the *Tor tor* and *Barilius* spp. While the *Noemacheilus* spp. are found only in shallow area of stream and area of joining of other small stream in lower zone. Present observation is in agreement of Sehgal, (1999) that water temperature is always an important limiting factor affecting geographical distribution and local occurrence within one water system. Sehgal, (1999) also reported that *Schizothorax* sp. and *Salmo trutta* having upper temperature tolerance limit of 20°C.

The present study reveals that fish species with powerful muscular cylindrical bodies (snow trout and the exotic trout) inhabits most preferably the bottom water layers of deep fast moving segment of the stream. While the fishes (*Barilius* and *Tor* spp.) without any striking modifications to current are recorded mostly from the shallow and deep pools, respectively. The small loaches (*Noemacheilus* spp.) with special attachment devices are found among the shallow water in pebbles and shingles. *Garra*, *Glyptothorax* and *Pseudecheneis* spp. having adhesive organs on their ventral surface were found clinging to rocks and boulders in fast water currents. Menon, (1954) also related the distribution pattern of Himalayan fish to the morphological characteristics. Hill stream fishes have special morphological modification which helps them to inhabit the torrential streams (Singh and Agarwal, 1991, 1993; Singh et al., 1993).

The reference stream is characterized with heterogeneity in habitat (cascade, falls, runs, rapids, riffles and pools) and substratum type (boulder, cobbles, gravels and sand). This habitat heterogeneity results into variation in the availability of fish fauna in different stretches of the stream. Fish assemblage structure is strongly related to habitat structure (Meffe and Sheldon, 1988; Schoener, 1974; Galacatoes et al., 1996) where habitat have been identified as one of the primary criteria on which many biological communities are organized. The fish species richness often increases as habitat complexity increases, with depth, velocity and cover being the most important variables governing this relationship (Schlosser, 1982; Fellly and Felly, 1987;

Pusey et al., 1995). The shoals of *Tor* and *Barilius* spp. were found always in pools (shallow as well as deep pools). This pool habitat is favorable for *Tor putitora* and *T. tor* and they prefers deep water in the adult stages and shallow water in the breeding seasons. *Schizothoracines* spp. preferred mostly rapid and riffle habitat but occasionally reported from pools. True hill stream fishes, *Glyptothorax*, *Pseudecheneis* and *Garra* spp. were recorded mostly from the rapids and cascades habitat. The *Noemacheilus* spp. were found only from the shallow side pools of stream and its small tributaries having low velocity. The introduced exotic trout *Salmo trutta* is thriving well in the Assiganga especially in the upper region due to low temperature, fast current with high dissolved oxygen, and cascade and rapid type of habitat. It was frequently recorded from rapids and cascades habitat type with sporadic presence in riffles and pools. All these observations divulge that hill stream fishes are habitat specialists and the pool habitat is most preferable habitat. Similar observation was found in streams of lower Middle Western Himalaya by Johal et al. (2002). Various earlier studies (Probst et al., 1984; Mc Clendon and Rabeni, 1987; Lakra et al., 2010) also observed that fish distribution is highly related to habitat composition.

Various anthropogenic activities have been taking place all along the stream. At present, 2 hydro power projects namely Assiganga-I (5 MW) and Assiganga-II (3 MW) are under construction while one more project, Assiganga-III (3 MW) have been proposed on it. The construction of these HPP is obstructing the natural flow of Assiganga stream. This obstruction is causing the dry up of fragmented stream segment, changes in substratum type, physico-chemical characteristics and the physiography of the stream. The substratum provides feeding and breeding ground to fishes and is major factor which influences the distribution and abundance of fish fauna. Assiganga stream possess rocky substratum with boulder and cobbles and gravels favorable for some important hill stream fishes. The alteration in rocky and boulder substratum will be detrimental for many stream fishes. Developing hatchlings hiding in the crevices of rocks, stone, cobbles and gravels react differently to the current and turbidity of the water (Shreshtha, 1993). The forced flowing of stream through tunnel will also destruct the stream habitat which will directly affect the distribution and abundance of fish fauna.

Observations on the physico-chemical characteristics of Assiganga stream very well co-relate the occurrence and distribution of fish species. Low temperature, high oxygen and fast flow of stream with riparian zone enriched with huge vegetation is highly supported by *Schizothorax* sp. and *S. trutta* while the high velocity and oxygen with characteristic cascades, rapids and riffles favored the existence of cat fishes (*Glyptothorax* and *Pseudecheneis* spp.) and *Garra* spp. Comparatively high temperature in the lower stretch and side pools was preferential to the *Noemacheilus* and *Barilius* spp. Bisht et al., (2009) has also reported that the seasonal distribution and relative abundance of fish fauna is directly related to change in physico-chemical properties, channel course, water discharge and pattern and geometry of tributaries. Vilar et al., (2011) also reported that abundance and composition of fish species is closely related to various environmental variables. All of these alterations may result into the extermination of some of the native species (Agarwal et al., 2011). The alteration in physico-chemical properties controls the distribution of various sections of the biotic fauna and flora (Bahuguna and Badoni, 2002).

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