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THE PROFILE OF RIVER ECOSYSTEM, FOOD AND FEEDING HABITS OF HILLS-TREAM FISHES AND CONSEQUENCES OF RECENT ENVIRONMENTAL DEGRADATION IN GARHWAL HIMALAYA

ZARYS RZECZNEGO EKOSYSTEMU, POKARM I ODŻYWIANIE SIĘ RYB Z POTOKÓW GÓRSKICH ORAZ SKUTKI DEGRADACJI ŚRODOWISKA W GARHWAL HIMALAYA

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The Garhwal region of the Central Himalaya (in the Uttar Pradesh, India) offers an unique physio-topographic, climatic and environmental features. The glacial-snow-fed and non-glacial-fed or spring — fed rivers of the area makes the upper basin of the Ganga river system of North India (being characterized by low water temperature, steep gradient fast water current, high turbulence etc.). There are 65 fish species (belonging to 9 families of teleosts) reported so far. Various biotic communities (planktonic, benthic, nektonic and neustonic), detritus, debris, sand particles are being used as food matters by herbi-, herbiomni-, carnivomni-, carni-, larvi- and piscivorous fishes.

During recent years, hillstream environment has deteriorated owing to excessive deforestation, multipurpose river valley projects, over grazing, forest fires, modern tourism, over exploitation of natural resources.

INTRODUCTION

The Yamuna, the Ganga and the Ramganga drain out the Garhwal Himalaya with the help of innumerable smaller and larger glacial-snow fed as well as spring-rain fed hillstreams (Figure 1). Besides, there is also magnificient combination of perpetual snow-bound glaciers, glacier-garlanded snow-capped high peaks, deep valleys, stupendous deep gorges, spots of natural scenic beauty etc.

The perennial riverine ecosystem of Garhwal region harbours a rich fish fauna (Table 6, Singh et al.1987) though upper most reaches are practically devoid of any

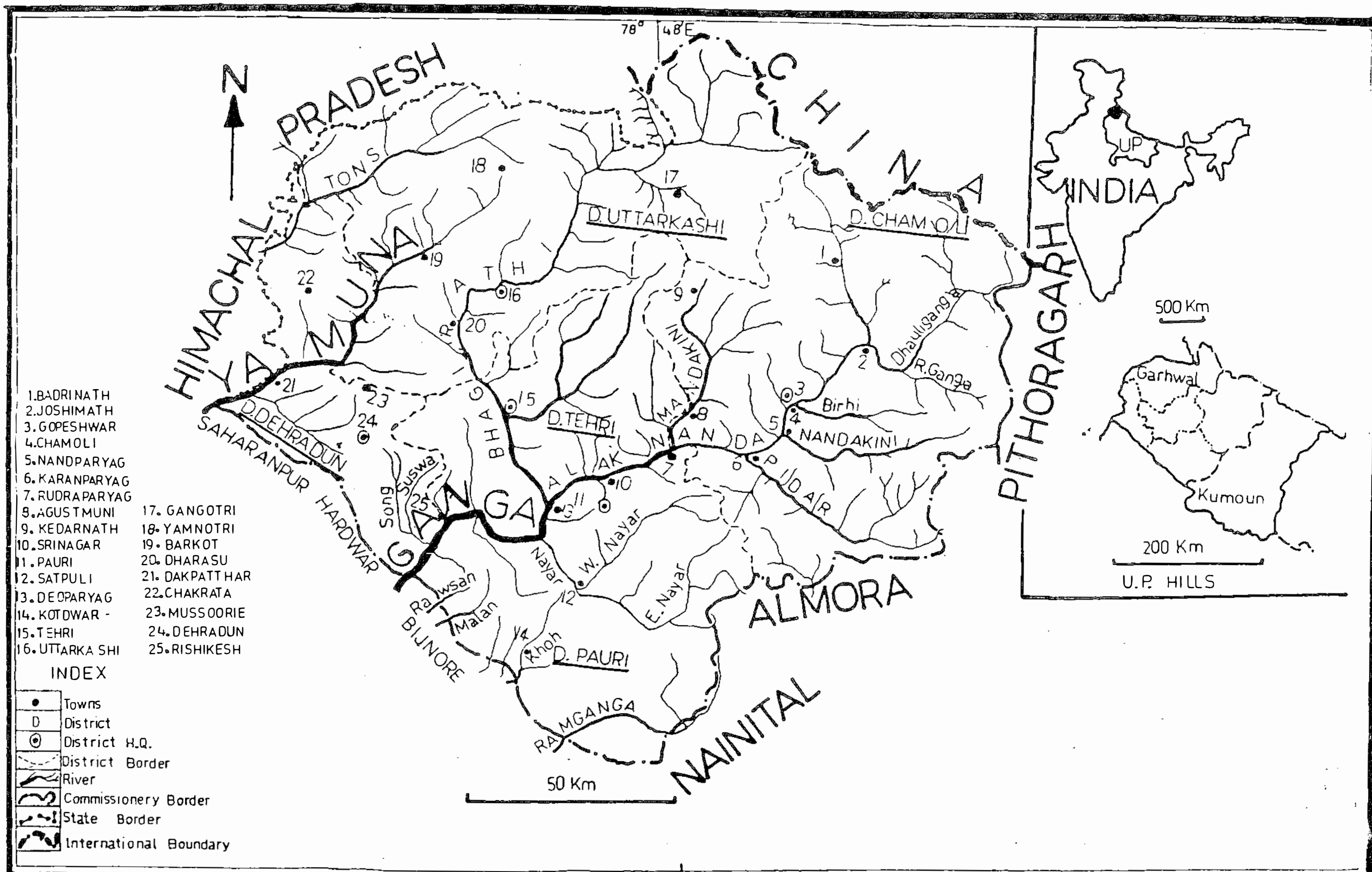

Fig. 1. Drainage pattern in Garhwal Himalaya

fish representative, because of hard climatic and bioecological circumstances. Most of these hillstream fishes are economically important and are consumed as alternative protein rich food in this region; some of these are commercially exploitable while others need the use of means and practices for their conservation.

The hillstreams in the Garhwal Himalaya are unique since they offer a variety of habitat, food matters, feeding grounds, migratory routes, breeding spots within the limits of relatively smaller area. Various aspects of fish and fisheries of few of these indigenous fish species have been described. Because these rivers are abound with immense potentialities for many economic as well as commercial activities including the development and propagation of commercially sustainable fisheries schemes; the information related to their population structure, food and feeding, behaviour, migratory patterns, reproductive strategies etc. are of vital significance. Food and feeding of hillstream fishes of Garhwal Himalayan streams is one of the such facets which needs comprehensive information because it directly affects their growth, economically exploitable biomass production and reproduction. However, ongoing developmental activities along the river valleys in this region are likely to affect adversly almost all the aspects of total environment, therefore, food and feeding of hillstream fishes will definitely get distrubed.

In this contribution, a brief profile of hillstream environment, feeding ecology of hillstream fishes, recent drastic deteriorating changes and their likely impact on food and feeding of fishes of this area has been reviewed briefly.

PHYSIOGRAPHY OF GARHWAL HIMALAYA

The Garhwal Himalaya as a geo-political unit of the Central Himalaya is the western part of Uttar Pradesh hills situated between the latitudes 29°26′–31°28′ N and longitues 77° 49′ – 80°6′E with a total area of about 30.090 square kilometers. Politically, it comprises five districts – Chamoli, Uttarkashi (larger and border districts), Tehri, Pauri and Dehradun. The northern region goes up to the snow-clad peaks as Indo-Tibetan boundary; in the east, it touches the borders of district Pithoragarh, Almora and Nainital (Kumoun division of Uttar Pradesh); the southern borders are common with district Bijnore (Rohilkhand division of U.P.), Hardwar and Saharanpur (Meerut division of U.P.) while river Tons and Yamuna separates it from neighbouring Himachal Pradesh (Figure 1).

Geographically, the Garhwal Himalaya is divisible in three sub zones – (i) the Greater Himalayas with snow-clad peaks with a height of over 7.000 m (e.g. Nandadevi), (ii) the Lower Himalayas (middle) with peaks and deep valleys, and (iii) the Shivaliks along with 'bhabar' (foothills), the latter has a height of not more than 325 m. The Upper and the Middle Himalayas in Chamoli und Uttarkashi districts are sculptured with a number of perpetually snow-bounded glaciers – the Gangotri (30°45′ –30°55′N, 79°5′ –79°15′ E, elevation – about 3900 m, approximately 30 km long and 2 km wide with a system of tributary glaciers as the Rakta Varna, the Shwet Varna, the Nilamber and the Pitamber), Chaurabari (30°50′ –31°0′ N, 79°0′ –79°5′ E, above Kedarnath peaks, 1400 m long and 500 m wide), Satopanth (30°41′ –30°47′ N, 79°19′ –79°25′ E, south west of Badrinath and Kumaling peaks), Bhagatkharak (30°48′ –30°50′ N, 79°15′ – 79°25′ E) besides North and South Rithi, Yamunotri, Pinder, Juma and Nandadevi glaciers; numerous magnificient series of glacier-garlanded peaks – Kedarnath (6940 m), Chaukhamba (7318 m), Kamet (7756 m), Trishul (7120 m), Nandadevi (7817 m), Dunagiri (7066 m), etc. Thus, the Garhwal Himalaya is the eternal home of glaciers, horned peaks, serrated crests of high ridges, creques, hanging valleys, torrential rapids, deep canyons, huge boulders and glistening lakes (Kharakwal 1977). The snow-clad peaks and glaciers in the Greater Himalayas (Uttarkashi and Chamoli districts and the parts of Tehri District) are the sources of a number of perennially and eternally flowing rivers which ultimately emerge from Uttar Pradesh Garhwal hills as the Yamuna, the Ganga and the Ramganga along with several spring-rain-fed rivulets.

MAJOR RIVERS AND THEIR CHARACTERISTICS

The Garhwal hills of the Central Himalaya are drained by many streams and rivulets (Figure 1). Almost all the valleys and glaciers individually are the sources of one or many streams of minor or major dimension. But, three major drainage systems emerge out of the southeren boundary of Garhwal Division and these follow their own courses the districts Saharanpur, Hardwar and Bijnore further to the Gangetic plains. These drainage systems are –

1. The Yamuna River System – It drains the western parts of Garhwal hills (Uttarkashi, Tehri and Dehradun districts) and also the eastern Himachal Pradesh. The river Yamuna owes its origin from the Yamunotri glacier (3300 m) in Uttarkashi district and collects streams on the left and right side while proceeding through Purola, Barkot, Kalsi, Lakhwar, Dakpatthar till it reaches to Paonta Sahib after covering a distance of over 150 km through deep gorges and valleys. The river Tons is the major tributary on side which contributes more water than the Yamuna itself, besides, it also receives many smaller streams through out entire sojourn.
2. The Ganga River System – It is, in fact, the combination of two sub-systems –

   A. The river Bhagirathi tickles down from the Gomukh in Gangotri glaciers (within the physical boundaries of Uttarkashi district). Before coming down to Uttarkashi town (1158 m), it receives the Jarganga, Asiganga, other glacial – as well as non-glacial-fed streams and rivulets. During its further course, the Bhilangna (glacial-fed, originating from the Khatling glacier 3590 m in Tehri district) merges with it at Tehri (630 m) till further downwards at Deoparyag (472 m), Bhagirathi meets with equally significant sister tributary – the Alaknanda forming the famous Ganga river. Through out the entire journey, all the stream and rivulets of the basin (in Uttarkashi and Tehri districts) pour themselves in it.

B. The Alaknanda originates from the Alkapuri glacier (a "combined" snout of the Bhagatkharak and Satopanth glaciers) near Badrinath peaks (3300 m) and while taking a treacherous course through awe-inspiring gorges and collecting many glacial- and non-glacial-fed streams, it meets with the Dhawalganga (which itself drains a large hilly basin) at Vishnuparyag (1372 m). Afterwards, the Alaknanda flows down through Chamoli (914 m, confluence with Birhi), Nandparyag (850 m, confluence with Nandakini), Karanparyag (795 m, confluence with the Pinder), Rudraparyag (610 m, confluence with the Mandakini) and finally to Deoparyag (472 m) to merge with the Bhagirathi and contributes to the formation of the Ganga river system. These tributaries of the river Alaknanda are quite major and interesting rivers in their own right and require detailed description. The Alaknanda catchment area comprises the district Chamoli, parts of districts Pauri and Tehri besides fringes of Kumoun division.

In fact, the Ganga results from the confluence of the Bhagirathi and the Alaknanda at Deoparyag. The combined river traverses down through Byasghat, Byasi, Gular, Laxmanjhula and Rishikesh to Hardwar. On the way, it collects, on right side, the Nayar and other smaller tributaries and, on the left side, the Gular, Song, Suswan etc. The catchment area includes parts of districts Pauri (nort-eastern, central and south-western parts), Tehri (eastern and south-eastern parts) and Dehradun (eastern parts).

3. The Ramaganga River System – Only south-eastern parts of Pauri district comprise the Ramganga catchment area, otherwise, it is the drainage system of western Kumoun division.

The Shivaliks form the southern fringes of Garhwal hills. While in Dehradun district, it hardly allows the passage of any stream through it but in Pauri district, it is traversed by many spring-rain-fed streams particularly Rawson, Malan, Khoh etc.

On the basis of source of supply, the streams in Garhwal region belong to two categories –

I. Glacial-snow-fed: the Yamuna, the Tons, the Asiganga, the Jarganga, the Bhagirathi, the Bhilangna, the Alaknanda, the Saraswati, the Dhawalganga (or Dhauliganga), the Rishiganga, the Birahi, the Nandakini, the Pinder, the Mandakini, the Ramganga etc., all owe their origin from perpetual glaciers and maintain the regular water supply.

II. Non-glacial-fed or Spring-rain-fed: the Nayer (inclusive of Eastern and Western Nayar), the Lastar, the Hinwal, the Badiyar, the Gular, the Suswan, the Song, the Aswan, the Khoh, the Malan, the Rawson etc., these are wholly depended

Table 1

Comparative values of physico-chemical parameters of the Godawari (tropical river)* and the Bhagirathi (hillstream)**

S. No.	Parameter(s)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Water Temp.	G	28.7	27.5	31.9	32.0	36.4	29.3	30.4	31.2	30.0	28.3	29.0	27.9
	(0°C)	B	8.7	11.4	12.9	12.8	13.8	13.8	17.4	16.7	14.4	13.9	10.10	9.8
2.	pH	G	8.2	7.5	8.2	8.2	8.3	7.3	8.1	8.2	8.2	8.2	8.2	7.2
		B	7.49	7.47	7.47	7.64	7.20	7.21	7.29	7.24	7.26	7.27	7.56	7.95
3.	Free CO_2	G	—	6.6	—	—	—	4.0	6.6	—	—	—	—	3.4
	(ppm)	B	0.53	0.42	1.45	1.63	0.98	1.12	1.03	1.37	1.20	2.15	0.36	0.42
4.	Carbonates	G	14.7	—	6.1	5.1	5.5	6.0	—	—	12.0	12.0	9.0	12.0
	(ppm)	B	—	—	—	—	—	—	—	—	—	—	—	2
5.	Bicarbonates	G	175.6	186.1	192.2	183.3	158.6	152.5	131.2	45.8	137.8	125.1	152.5	131.2
	(ppm)	B	51.0	45.83	50.33	35.0	28.66	31.8	29.80	30.76	28.10	29.75	32.32	42.88
6.	DO (ppm)	G	3.39	3.63	1.47	2.16	1.40	4.45	1.26	1.82	3.63	3.7	3.4	18.2
		B	10.55	9.25	7.51	9.55	8.72	9.09	8.71	8.97	9.29	9.39	10.15	10.22

* Chacko and Srinivasan 1955; ** Gautam 1990

Abbreviations: G — Godawari, B — Bhagirathi

Table 2

Course of major rivers through Garhwall region and their gradients

S. No.	Name of the river	Upper stretch		Lower stretch		Distance (approx.)	Fall (m)	Gradient (m/km)
		From	to	From	to			
1.	Alaknanda	Aikapuri glacier (3300 m)	Vishnuparyag (1372 m)	–	–	70	1928	27.54
		–	–	Vishnuparyag (1372 m)	Deoparyag (470 m)	130	902	6.93
2.	Nandakini	Nandadevi glacier (6000 m approx.)	Nandparyag (914 m)	–	–	47	5086	108.20
3.	Pinder	Pindari glacier (5500 m approx.)	Karanparyag (795 m)	–	–	74	4705	63.50
4.	Mandakini	Kedarnath (3700 m)	Rudraparyag (610 m)	–	–	95	3090	32.50
5.	Bhagirathi	Gomukh (3900 m)	Uttarkashi (1158 m)	–	–	120	1654	13.77
		–	–	Uttarkashi (1158 m)	Deoparyag (470 m)	145	686	4.73
6.	Bhilangna	Khatling glacier (3590 m)	Tehri (630 m)	–	–	135	2960	21.93
7.	Yamuna	Yamnotri (3300 m)	Dakpatthar (700 m)	–	–	150	2600	17.33
8.	Ganga	–	–	Deoparyag (470 m)	Hardwar (294 m)	80	175	2.19
9.	Nayar	–	–	Satpuli (680 m)	Byasghat (415 m)	30	265	8.33

Table 3

Physico-chemical and hydrobiological characteristics of the Alaknanda (A) and Nayar (N)

S. No.	Parameter(s)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Water Temp (0°)*	A	7.8	9.2	12.6	17.5	15.2	15.6	15.0	14.3	14.1	13.2	11.5	8.3
		N	8.9	10.2	14.9	20.7	20.7	22.5	18.1	18.0	17.8	16.6	14.2	10.5
2.	Turbidity (%)*	A	–	–	–	–	2.0	5.0	26.0	28.0	10.0	2.0	–	–
		N	–	–	–	–	–	–	26.0	30.0	28.0	2.0	–	–
3.	Transparency*	A	c	c	c	c	90.2	68.7	25.0	22.5	28.8	76.9	c	c
		N	c	c	c	c	c	c	19.8	15.2	12.2	c	c	c
4.	Colour*	A	g	g	g	g	b	b	m	m	b	cl	g	g
		N	cl	cl	cl	cl	cl	cl	r	r	b	cl	cl	cl
5.	pH*	A	7.6	7.9	7.9	8.0	8.2	8.2	7.0	7.6	8.0	8.2	7.6	7.6
		N	7.0	7.3	7.6	7.9	7.3	7.3	8.0	8.2	8.0	7.9	7.6	7.6
6.	DO (ppm)*	A	18.1	14.5	10.7	9.9	9.5	9.3	9.0	9.2	14.2	14.6	15.2	17.2
		N	16.8	12.6	10.9	10.2	10.0	9.5	7.0	6.8	6.2	8.9	11.6	14.6
7.	Free CO_2 *	A	3.2	4.6	9.1	11.0	15.5	16.9	17.6	17.7	12.0	11.6	18.8	3.9
		N	2.8	3.7	6.2	12.8	15.3	18.0	35.4	35.6	31.5	30.0	22.1	3.0
8.	Diatoms (units/ ml)**	A	7.0	4.45	4.59	1.90	1.00	0.55	0.72	0.80	0.70	0.60	1.40	2.65
		N	9.06	8.00	7.00	4.30	1.30	1.05	0.56	0.40	1.20	1.60	3.60	5.80
9.	Caddisfly larvae (no/m²)***	A	150	235	182	120	90	6	3	1	24	60	90	116
		N	508	640	680	440	265	190	10	6	13	45	60	150
10.	Mayfly larvae (no/m²)***	A	390	510	415	180	150	10	5	3	30	135	160	315
		N	492	635	660	428	130	112	15	8	65	70	96	215
11.	Stonefly nymphs (no/m²)***	A	45	96	90	30	21	15	3	6	18	36	45	51
		N	120	225	225	222	190	140	100	95	98	102	120	120
12.	Dragonfly nymphs (no/m²) ***	A	3	9	6	3	6	7	3	4	–	–	3	3
		N	78	100	115	115	100	94	80	15	10	52	60	65
13.	Water beetles (no/m²) ***	A	51	98	90	75	60	18	15	21	24	30	46	50
		N	60	88	115	108	100	66	40	40	42	50	55	60
14.	Damselfly nymphs (no/m²) ***	A	2	1	1	–	–	–	–	–	–	–	–	–
		N	60	76	102	100	83	47	1	1	1	6	8	10

* Badola 1979; ** Nautiyal 1984; *** Badola and Singh 1981a.

Abbreviations: b – brownish, c – complete, cl – clear, g – green, m – muddy upon spring and intermittent rainfall for maintaining the water supply which become minimal during lean months.

Characteristics of Hillstreams – The climatic and meteorological conditions are, by an large, affected by the location, physiography and topographic configuration which collectively causes certain striking attributes in the physio-chemical and hydrobiological parameters to the Garhwal hillstream ecosystem when compared with fluvial system of tropical India (Table 1).

Various physico-chemical characteristics – temperature, pH, free CO_2, carbonates, bicarbonates, DO (Table 1) make the differences quite understandable. Monthly variations indicate the higher values of temperature, pH, bicarbonates in a tropical river (Godawari, Chacko and Srinivasan 1955), than in the hillstreams, while the values of DO are more in the coldwater hillstreams of Garhwal region (Bhagirathi and Nayar; Nautiyal 1984, Gautam 1990). Carbonates have been observed practically absent in the hillstreams. No discrenible trends can be made out of the values of free CO_2. The aquatic biota (planktonic, nectonic, neustonic and benthic communities) differ quantitatively as well as qualitatively. The variation follows diurnal and seasonal cycles.

The gradient is extremely high in practically all the stream of the region (Table 2). High gradient combined with uneven river-bed (comprising rocks, boulders, stones, gravels etc.) accounts for high water velocity and high turbulence.

The differences in the physico-chemical and hydrobiological nature of the glacial-snow-fed (like Bhagirathi and Alaknanda) and spring-rain-fed (like Nayar) rivers are also obvious (Table 3; Badola 1979, Badola and Singh 1981a, Nautiyal 1984, Gautam 1990). The reasons reside in the sources of water supply in glacial-snow-fed and spring-rain-fed-streams. In the former, the water supply is perennial without much scarcity during lean months and these are richly supplied during summers because of melting of snow, while, the spring-rain-fed rivers face not too much regular supply especially during summers. Recently Nautiyal et al. (1991) statistically proved water temperature, and water velocity as most significant features as far as the characteristics of most of the hillstreams are concerned. They coined the terms – 'torrential stenothermal (for fast flowing glacial-fed streams with narrow range of temperature variation like the Bhagirathi, Alaknanda, Yamuna, Bhilangna etc.) and 'placid eurythermal' (for relatively slowly flowing spring-rain-fed rivers with wide range of temperature fluctuations like the Nayar, Gular, Badiyar, Khoh etc.). Obviously, these are related to the source of water supply, gradient and amount of total water discharge.

To elaborate more this fact, the comparison between the Bhagirathi and Nayar (Dobriyal 1991) is relevant. Glacial-snow-fed Bhagirathi with high water velocity (annual average 0.703 m/sec.) favours low growth of plankton (0.1–4.16 units/ml), epilithic phytobenthos (13 CPP), macrozoobenthos (14 CPP resulting in poor fish productivity while spring-fed and moderately warm Nayar (Table 3) with lower velocity (annual average 0.462 m/sec) favours good planktonic growth (0.4–9.06 units/ml), epilithic phytobenthos (22 CPP) macrozoobenthos (36 CPP) with resultant increase in the fish biomass production (34 CPP).

The glacial-snow-fed hillstreams of Garhwal region form the rhithron zone of Ganga basin (Illies and Botosaneanu 1963; Sharma 1991). The rhithron itself comprises –

a. Epi-rithron: from upper altitudes down to 2600 m. It is characterized by sharp gradient, narrow glaciated valleys, alternate water falls and sha shallow pools and river bed consisting of coarse large boulders. As a result of swift water flow in this zone which strikes with boulders forming a foamy white look; there is nearly complete absence of biotic components, 'therefore' not favourable for fishes.
b. Meta-rhithron: from 2600 m down to 450 m with moderate gradient, rapidcascades, low gradient riffles at many places, river bed of small boulders pebbles, gravels and cobble sized particles. It harbours a considerable diversity of biotic and hence fish components.
c. Hypo-rhithron from 450 m down to 300 m with an almost flattened gradient (2 m/km). Main features of this zone include the dominance of pools and glides, relatively straight run of water at several places especially in lower stretches, low gradient riffles with moderate water current, river bed of sand, gravels and smaller pebbles. It is rich in different planktonic, benthic and nektonic communities. Such conditions favours a higher growth of ichthyo-biomass (qualitatively as well as quantitatively) because food is amply available at right stage of fish life cycle.

The Spring-rain-fed rivers comprise the potamon zone of this classification and it lacks further zonation.

ECOLOGY OF HILLSTREAM FISHES

The district wise distribution of fish fauna of Garhwal region was described by Singh 1964, Badola, 1975, Badola and Pant 1973, Badola and Singh 1977a,b, and Sharma 1984a,b. 65 teleost species have been recorded so far from Garhwal hillstreams (Sing et al. 1987) (Table 6). *Schizothorax richardsonii, S. plagiostomus, Pseudecheneis sulcatus* are the species which mostly prefer glacial-fed larger rivers and streams like Bhagirathi, Alaknanda, Pinder, Mandakini, Nandakini etc. *Schizothoraichthys progastus* have been observed in the fish catch from glacial-fed hillstreams from upper to lower stretches but more abundant in the lower reaches of Ganga (between Rishikesh to Hardwar). *Tor* spp. and *Labeo dyocheilus* do not occur in the glacial-fed rivers through out the year but these begin migrating from foot hills of Shivaliks to glacial-fed streams during March-June for breeding and, later on, return to their native places. *Garra gotyla gotyla, G. lamta, Crossocheilus latius latius, Glyptothorax* spp. *Noemecheilus* spp. are common in the glacial-snow-fed as well as spring-rain-fed rivers from the Greater Himalayas to the foot hills of the region. *Balitora brucei* is especially high altitude hillstream fish species. *Mastacembelus armatus, Botia dario, Barilius bola, Clupisoma garua, Chagunius chagunio* inhabit frequently the lower stretches of glacial-fed rivers during rainy season whereas many *Barilius* spp. always prefer spring-fed rivers especially crystal-clear water but these also have been observed in the side-waters of glacial-fed rivers in the upper stretches. Many of the species (*Puntius sophore, P. ticto, P. chola, P. conchonius, Labeo boga, Rasbora daniconius, Amblyceps mangois, Xenentodon cancila, Esomus danricus, Channa gachua, Noemecheilus corica, N. botia* etc.) are less common in glacial-fed rivers but very common in the spring-fed rivers like Khoh, Rawson, Maln, Hinwal etc. of Shivalik ranges and vack-waters of river Ganga. A gradual transition of rom richness to poor of ichthyofauna from hypo-rhithron to meta-rhithron to epi-rhithron (in terms of total ichthyo biomass, population size as well as the number of species) is in conversant with prevailing circumstances and general ecological principles (low temperature, lesser food for adults and juveniles, lesser availability of suitable feeding and breeding grounds in the upper stretches). As usual, the hillstream waters, as a result of vertical stratification, offer various habitats for fishes inhabiting these lotic waters. Therefore, many fish species have their particular preferences for habitat types. The hillstream fishes are broadly categorised (Das and Moitra 1955a,b, 1963, 1965) on the basis of habitats, as –

a. Surface dwellers, i.e., fishes inhabiting surface or upper water columns mostly (*Barilius bola, B. bendelisis, B. barna, Puntius chola, Xenentodon cancila* etc.)
b. Column dwellers, i.e., prefering middle water columns (*Schizothorax richardsonni, S. plagiostomus, Puntius sophore, P. sarana* etc.)
c. Bottom dwellers, i.e., living on river beds and bottom substrata (*Garra gotyla gotyla, G. lamta, Glyptothorax* spp., *Pseudecheneis sulcatus, Mystus vittatus* etc.)

However, it is not clear-cut demarcation because there are many gradations depending upon individual needs for safety, food and reproduction, water quality parameters, weather conditions, diurnal and seasonal cyclicity. For example, *Schizothorax richardsonii* and *S. plagiostomus* chiefly live in the calmer middle and lower water columns but, while feeding during late night hours, come to the bottom surface so as to scrap the debris on the substratum *Noemecheilus montanus, N. rupicola, N. multifasciatus* are found below stones, burrows and even observed in the paddy field during rainy season. *Puntius chilinoides, Mastacembelus armatus* make use of the spaces avalble below rocks larger stones and boulders while *Channa gachua* actually dig burrows in the bottom mud and detritus.

FOOD AND FEEDING IN HILSTREAM FISHES

A. Availability of Food Materials

The differences in the physico-chemical and hydrobiological conditions of glacial-snow-fed and spring-fed rivers (Table 3; Badola 1979, Badola and Singh 1981a, Nautiyal 1984, Gautam 1990) exert their profound bearing on the qualitative and quantitative seasonal growth cycle of biota in the fluvial system of Garhwal region. In the upland waters of glacial-snow-fed rivers, the biota is poor in quality and quantity as the natural consequences of low water temperature, steep gradient, high turbulence as compared to those in the lower stretches of these rivers as well as spring-fed streams. There are the seasonal fluctuations in the occurrence of fauna and flora. Table 4 presents a wholesome view of all the organic matter that can be used as food materials by various hillstream fishes and their juveniles and, thus, occupy varios loci in the complex food web. However, variations on the basis of sources of water supply (diurnal and seasonal) in many communities planktonic, benthic, nektonic and neustonic life forms may be taken into consideration while describing the foods of hillstream ichthyofauna because these variations are very much striking (Tonepi 1980, Nautiyal 1984, 1985, 1986, Negi, 1990, 1991, Negi and Singh 1990, Sharma 1991). Besides, hillstream water is never still, therefore, fresh food supply in the particular habitat is ensured to the fish individuals in their microhabitats as a result of water turbulence and water flow.

B. Feeding Grounds

As evident from Table 4, feeding grounds and dwelling niches are similar in case of many hillstream teleosts; but it is not necessarily the same in other species. Depending upon the feeding stratifications, Das and Moitra (1955a, 1963, 1965) classified the fishes of Uttar Pradesh hills into three categories. While describing the food and feeding in teleost from Garhwal region, Badola (1979) also followed similar scheme. These categories are –

I. Surface feeders – Such fishes feed near water surface or upper water columns, e.g. *Barilius bendelisis, B. vagra, B. barila, B. barna, Esomus danricus, Xenentodon cancila* etc.

II. Column or mid feeder – They feed near upper, mid and lower water columns e.g., *Schizothoraichthys progastus, Puntius chola, P. sophore, P. sarana* etc.

III. Bottom feeder – e.g. *Schizothrax plagiostomus, S. richardsonii, Garra gotyla gotyla, G. lamta, Crossocheilus latius* etc. which scrap the surface of bottom stones, rocks near the river banks to collect the detritus. There are other fishes that, in fact, suck the bottom mud and debris (*Glyptothorax* spp., *Pseudecheneis sulcatus*). Most of the bottom feeders are benthophagous and detritophagous; others have special adaptations to feed upon the phytobenthos, zoobenthos and mobile foods.

Table 4

Types of various food matters available in the hill streams of Garhwal region

S. No. Major categories	Ecological groups	Taxonomic categories	Name of the genera etc.
1. PLANT MATERIALS	A. *Phyto-plankton*	a. *Chlorophyceae*	– *Euglena, Volvox, Chlamydomonas, Binularia, Closterium* etc. (these include 32% and 19% of total plankton in Alaknanda and Nayar respectively).
		b. *Bacillariophyceae*	– *Fragilaria, Cymbella, Navicula, Nitzschia, Gomphonema, Surirella, Synedra, Diatoma, Amphora, Hantzschia, Tabellaria, Stauroneis, Coconeis, Ceratoneis, Neidium, Rhoicosphenia* etc. (diatoms form 49% and 69% of total plankton in Alaknanda and Nayar respectively.
		c. *Myxophyceae*	– *Nostoc, Anabena, Oscillatoria, Rivularia* etc. (blue-green algae form 20% and 13% of total plankton in Alaknanda and Nayar respectively)
	B. *Phyto-benthos*	a. *Chlorophyceae* (green algae)	– *Spirogyra, Microspora, Ulothrix, Hydrodictyon, Cladophora, Stigeoclonium, Schizogonium* etc.
		b. Aquatic woods (*higher plants*)	– *Uticularia, Hydrilla, Vallisnaria*; aquatic ferns *mosses* and others.
	C. *Plants parts*	– *leaves, twing, wood*	pieces and particles, fibres of higher plants etc.
2. ANIMAL MATERIALS	A. *Zooplank-ton*	a. *Protozoans*	– *Zoothammium, Campanella, Centropyxis, Epistylis, Carachasium* etc.
		b. *Rotifera*	– *Ascomorpha, Asplanchna, Trichocera, Philodina, Lacane, Keratella, Brachionus* etc.
		c. *Copepoda*	– *Cyclops, Daphnia, Diaptomus, Cypris* and their larval forms.
		d. *Cladocera*	– *Ceriodaphnia* and larval forms
		c. eggs of various aquatic animals.	
	B. *Zoobenthos*	**Developmental stages** (nymphs and larvae of the orders) of the insects	
		Plecoptera (nymphe of stone flies)	– *Pereinella, Arcynopteryx, Isoperla, Allolapnia, Perla, Peltoperla, Classaonia, Aeronuria, Nemoura, Atoperla* etc.
		Odonata (nymphs of dragon flies)	– *Argia, Corixa, Octogomphus, Epicordula, Perogomphus, Symptrum, Ophiogomphus, Enallagma* etc.
		Epheneroptera (mayfly, mymphs)	– *Leptophleba, Baetis, Arthroplea, Chroterpes, Ecdyomurus, Heptagenia, Rhithrognea, Isonychia, Cloeon, Pseudocleon, Ephemerella, Cynigmula, Ameletus, Caenis, Cynigma* etc.
		Trichoptera (caddis larvae)	– *Polycentropus, Glossosoma, Hydrophilid, Hydrophila, Philopotamus, Leptocella, Rhyacophilla, Trianoedis, Brachycentrus, Phrygnema, Hydroptila, Mystacides, Limnephilus, Hydropsyche* etc.
		Diptera (larvae two winged flies)	– *Simulium, Atherix, Psychoda, Eristalsia, Corethra, Dixa, Tabanus, Hoxatoma, Magistocera, Bibiocephala, Antoch, Denterophleba, Chironomus* etc.
		Others	– nymphal stages of water beetles and waters bugs (see neuston)
	C. *Neuston:*	**Adult aquatic insects**	
		Cleoptera (water beetles)	– *Sternolophus, Dianous, Helochares, Promoresia, Lacobin, Paracymus, Gyramus, Prephynus, Psephanus, Coelostoma, Dysticus, Potamonectes, Hydracna* etc.
		Hemiptera (water bugs)	– *Micronocta, Helocoris, Lactotrephos, Corexia, Gerris* etc.
		Others	– some mollusce (*Neliosoma, Musculium, Physa* etc.), nouroptoran flios, water scorpions und water mites.
	D. Nekton:	small sized fishes, larvae, fry and fingerlings of fishes (during food stress may be used as food by the large sized specimens or as usual dien for piscivorous fishes), amphibian tadpolagae well as small sized higher vertebrates which find their way accidentally in the stroems.	
	E. Parts of animal body:	fins, scales, bona piocos and teeth of aquatic vertsbrates, parts of exoskeleton of arthropoda, pieces of molluscan shells.	
3. Organic matter of surface run off from land.			
4. Bottom mud, bottom scraps and bottom detritus			
5. Sand particles.			

Table 5

Feeding habits and basic foods of some hillstream teleosts

Feeding habits	Fish species	Basic foods	Special remarks
HERBI VOROUS	*Schizothorax richardsonii* *S. plagiostomus* *S. sinuatus* *Crossocheilus latius latius* *Garra gotyla gotyla* *G. lamta*	algae, diatoms and surface scraps of the bottom	bottom feeder benthophagous and detritophagous
	Labeo dyocheilus *L. dero*	diatoms and algae	bottom feeder
HERBI OMNI VOROUS	*Puntius chilinoides* *Tor spp.*	diatoms, algae aquatic weeds, insects and their larvae	"
OMNI VOROUS	*Puntius ticto* *P. chola* *Chaounius chaounio* *Barilius bendelisis* *B. barila* *B. barna*	–	–
CARNI-OMNI VOROUS	*Schizothoraichthys progastus* *B. vagra* *Noemecheilus multifasciatus* *N. rupicola* *N. montanus*	insect larvae, crustacens predominant but aquatic weeds and algae also	–
CARNI VOROUS	*Pseudecheneis sulcatus* *Glyptothorax telchitta* *G. pectinopterus* *G. conirostrus*	aquatic, insects, their larvae and nymphs	bottom feeder and monophagic
	B. bola	–	–
	Mastacembelus armatus	insects, larvae and nymphs; small sized fishes also	predator

However, the total depth of the water column in the rivers appears to be a deciding factor in such a classification and, obviously, the depth of the water column is a variable feature which may decrease or increase acoording to the season. In most of the cases (except in strictly bottom dwellers and bottom feeders, the fish come near the side waters for feeding because it is always richer in organic food matters and food items are less mobile hence easier to be taken in. During rainy season when many fish species migrate from large voluminous rivers (where food availability is not feasible owing to highly turbid water) to smaller rivulets especially for spawning, relatively lees turbid water improves the chances of easily available foods in smaller rivers.

C. Feeding Habits

Successful survival, optimum population density and population growth of fishes largely depend upon, among other factors, the type of food available in their surroundings (especially in their microhabitats) and they should have easy accessibility to the feeding grounds. Food and feeding in fishes continue to be a fascinating subject for fish ecologists since earlier times. On the basis of food consumed, Nikolsky (1963) classified fishes as – (i) herbivorous and detritophagous (ii) carnivorous and predators. Das and Moitra (1955b, 1963, 1965) have applied an improved scheme while making observations of food and feeding of fishes from Uttar Pradesh. Accordingly, the categories are –

a. Herbivorous (75% of foods are plant foods)
b. Omnivorous (plant and animal foods are approximately 50%–50%, neither is less than 10%–15%)
c. Carnivorous (animal foods constitute of about 75%)
(Two more categories have further been added)
d. Herbi-omnivorous (greater amount of plant foods)
e. Carni-omnivorous (greater amount of animal foods).

27 teleost species from Garhwal rivers have been classified according to their feeding habits (Table 5) (Badola 1979). Interestingly, many of these fishes from Garhwal hillstreams are benthophagous and detritophagous, e.g., *Crossocheilus latius latius, Garra gotyla gotyla, G. lamta, Schizothorax richardsonii, S. plagiostomus* etc.

There is an obvious relationship between fishes and their foods. The food materials have been divided into four categories (Nikolsky 1963) –

(a) Basic foods – comprising major parts of gut content.
(b) Secondary foods – are also frquent in alimentary canal but in lesser amount as compared with the basic foods.
(c) Obligatory foods – during scarcity and food stress conditions, the non-availability of basic foods, the fishes are forced to take in.
(d) Incidental foods – of rare occurrence in the gut.

For example, according to Badola (1979), Nautiyal (1990), Nautiyal and Lal (1984, 1985), *Tor* spp., during late winters and summers, feed upon aquatic insects, their nymphs and larvae and few algal materials and, thus, may be classified as herbi-omnivorous. But highly turbid water and similar such other conditions during monsoons, are not favourable for algal growth. Similarly, larval-pupal stages of aquatic insects (like caddis larvae, stone fly nymphs, dragon fly nymphs, dipterous larvae etc.) metamorphose into adult and sub-adult forms leaving poor animal foods during rainiy season (late June to early September). Under such conditions of food stress, larger specimens of *Tor* spp. invariably take the small sized fishes as food (obligatory food). Moreover, small-sized herbivorous, herbi-omnivorous or omnivorous fish species as well as their frys fingerlings (of practically all hillstream teleosts) may also be planktivorous with species based and developmental stage based preferences towards phytoplanktivorous or zooplanktivorous habits. The fingerlings and juveniles of *Tor putitora* have bee observed to be zooplanktivorous (Nautiyal and Lal 1985).

According to Nikolsky (1963)'s classification based on variation in the type of food materials consumed, Badola (1979) described most of the fishes of Garhwal rivers (out of 27 species studies by him) either as euryphagic (wide variety of food matters) or stenoghagic (few different types of foods) except *Pseudecheneis sulcatus, Glyptothorax pectinopters, G. conirostris, G. telchitta* which are monoghapic (feeding only on single category of food, i.e., aquatic insects and their larvae and nymphs).

Feeding status of particular fish depends upon the relative density of food available in the surroundings and nutrient requirement stage. Above all, the well being of total habitat is vitally significant for effective feeding since it directly affects quantitative and qualitative density of foods, growth rate of biomass, stimulus-response system of body, prey-predator relationships in the fish habitat.

D. Body Adaptations Associated with Feeding

Hillstream fishes of Garhwal region live under unique ecological conditions and many of these conditions prove to be less favourable for optimum feeding. For this, these fishes have developed, during the course of their evolution, numerous significant adaptations which are highly useful while feeding in their habitat. Badola (1979) described candidly such adaptations which are associated with food gathering and feeding. Such special adaptations are –

1. Cylindrical or nearly cylindrical body is one of such features observed in *Schizothorax* spp., *Schizothoraichthys progastus, Tor* spp., *Barilius* spp., *Puntius* spp. etc. It is extremely helpful to swim through the fast water current. Other body shapes to love and feed successfully in the lotic habitat are exhibited by *Noemecheilus multifasciatus, N. montanus, N. rupicola, Garra gotyla gotyla, G. lamta, Glyptothorax* spp., *Pseudecheneis sulcatus* wherein the anterior part of the body is dorso-ventrally flattened *Balitora brucei* displays maximum flattening of body with leaf like shape.

2. Mouth opening in *Pseudecheneis sulcatus, Glyptothorax* spp. and *Noemecheilus* spp. is wide and situated ventrally under surface behind the tip of snout. In strictly bottom feeders, bottom scrappers, detritophagous and mud suckers (*Schizothorax richardsonii, S. plagiostomus, Garra lamta, G. gotyla gotyla, Crossocheilus latius latius* etc.), mouth is specifically ventrally situated instead of being terminal as in other teleosts in general. A hard scrapping plate in the lower jaw posterior to the mouth helps in scrapping the detritus (debris from the surface of bottom). In *Tor tor, Schizothoraichthys progastus* mouth is suctorial and funnel shaped. *Mastacembelus armatus* has mouth suited for predation.

3. Adhesive apparatus (Singh and Agarwal 1991, Singh et al. 1991a), keeping in view the fast water current, steep gradient and turbulence, bottom dweller and bottom feeder teleosts have developed adhesive apparatus, e.g.,*Schizothorax richardsonii, S. plagiostomus* (as 'posterior labial fold' in the chin region), *Crossocheilus latius latius* (as tuberculated 'fringed anterior labial fold' in the pre-mouth opening part and 'posterior labial fold' in the chin region), *Garra gotyla gotyla, G. lamta* (as tuberculated 'fringed anterior labial fold' in the pre-mouth opening region; 'posterior labial fold' in chin region; 'callous portion of disc' and 'posterior free margin' in the thoracic region between opercular openings *Glyptothorax* spp. (in the thoracic region between opercular openings) (Bhatia 1950, Lal et al. 1966, Sinha et al. 1990), *Pseudecheneis sulcatus* (in the similar position as in *Glyptothorax* spp. but with thick, bread and transverse lamellae) (Saxena 1961). Similar lamellated adhesive structures have also been noticed in the outer bony fin rays of ventral and pelvic fins in *Glyptothorax* spp., *Gara* spp. and *P. sulcatus* (Saxena 1961). Such integumentary modifications help the subject to withstand the torrential water, turbulence and to attach to the substratum especially during feeding.

4. *Schizothorax richardsonii, S. plagiostomus, Labeo dero. Tor* spp. have both lips thick and highly muscular. In *Tor* spp., lower lip is modified as thick muscular tungue like structure – 'median postero-lateral free lobe' so that the fish may cling to the rocks or stones. According to Hora (1939), jaws of *Tor* spp. are protrusible so much so that lip remains attached to the substratum as sucker; there are also internally lined cupshaped papillae in the lower lip of *Labeo dero* which are, in fact, two muscular folds so as to help the fish to stick to the stones during feeding. Upper lips in *Crossocheilus latius latius* and *Garra* spp. are fringed and muscular to stick to the substratum while feeding. Both lips in *Noemecheilus multifasciatus* are thick and muscular structure with lower lip being a bilobed part. Both lips in *Glyptothorax* spp. and *P. sulcatus* are muscular and bear numerous papillae. Similarly, mandibular and maxillary barbel in *Glyptothorax* spp. and *P. sulcatus* show many spong papillated structures. These also support the clinging to the bottom substratum during feeding.

Various important aspects of the hillstream fishes from the Garhwal Himalaya have been summarized in Table 6.

FACTORS RESPONSIBLE FOR THE ENVIRONMENTAL DEGRADATION IN THE RIVERS OF GARHWAL HIMALAYAS

1. Multipurpose river valley projects: The riverine resources in the Garhwal hills, with all their qualities and attributes, are bestowed with numerous streams of various dimensions. Many of these perennial and perpetual streams owe this nature because of their origin from age-old glaciers which ensure the continuous water supply round the year. Moreover, the topography and the climatic conditions of the area are optimalls suitable for exploiting the numerous potentialities but with prudent planning. Among the various potentials, the exploitation of hydroelectricity seems to be of immense economic value requiring rational and economic technologies. This avenues appears to be significant in view of the multiplying energy resources (conventional and non-conventional) and demand, petroleum-deficient state of India, over dependence on petroleum imports with a number of riders, glooming prospects of population increased, and hazards in harnessing other energy resources and, above all, sudden changes in the global scenario (arising from the changes in ground realities in the Middle East, fastly moving and unstable scene in the former USSR).

Our policy planners, in the early decades of independence, might have foreseen such a grim scenario and they called for tapping the vast water resources available in the hilly regions of the country. Consequently, about 38 major or small scale river vally projects, mainly devoted to the cause of hydroelectricity generation are either under construction or have been proposed (Table 7, Figure 1) with a thrust on self reliance in energy sector. The perusal of data reveals that these multipurpose river valley projects are spread over the five districts of Garhwal region involving all the major glacial-fed rivers with the over all capacity of 8776.75 MW and total out lay of 8300.81 crores of rupees (Table 7, Figure 1) (these are the estimates of 1989 which have now multiplied many-fold as a result of recent rupee devaluation, inflationary tendencies as well as delay in the final approval from the concerned State or Central Government agencies).

The data only reflects a fraction of total existing potential which may further be harnessed with increased efficiency, rational planning, minimal ecological transformations etc. No proper estimate are available as far as the details and other relevant data regarding other stream are concerned (Asiganga, Jarganga, Bhilangna, Mandakini, Nandakini, Birahi among glacial-fed rivers; Western and Eastern Nayar, Nayar, Khandagad, Suswan, Malan, Khoh, Hinwal, Aswan, Lastar, Gular, Badiyar etc. a mon the spring-rain-fed hillstreams) which are fully pregnant with ample hydroelectricity potentialities. It requires indepth research work to know their actual potentials and other relevant informations.

However, such developmental activities in this geologically sensitive (as evident from the recent earth-quake on 20 October 1991 of the magnitude of over 6.1 on ritcher

Important aspects of feeding ecology of hillstream fishes in the streams of Garhwal Himalaya

Name of the species	Vernacular name	Nature of the stream	Ecological habit	Feeding grounds	Feeding habit	Special Adaptations related to feeding	References
Family *CYPRINIDAE*							
1. *Schizothorax richardsonii* Gray	Maseen	High altitude, glacial fed	column dweller (during day hours stay below rocks, large stones in relatively calmer columns of water; juveniles-surface dwellers	bottom-stone surface scrappers	H	hard scrapping plate in lower jaw; 'adhesive apparatus' in the chin region as modified posterior labial fold; mouth suctorial and ventrally situated	Badola 1979 Sharma 1984b
2. *S. plagiostomus* Heckel	Maseen or Dhibrua	"	"	"	"	"	Badola 1979, Sharma 1984c, Singh and Agarwal 1991
3. *S. sinuatus* Heckel	Maseen	"	"	"	"	"	Badola 1979
4. *S. niger* Heckel*	–	lakes	?	?	H	–	Malhorta 1967
5. *S. curvifrons* Heckel*	–	glacial fed	–	–	–	–	–
6. *S. intermedius* McClelland*	–	"	–	–	–	–	–
7. *S. micropogon* Heckel*	–	"	–	–	–	–	–
8. *Schizothoraichthys progastus* McClelland	Chongu or Chynetha	high altitude, glacial fed and larger streams at food-hills	middle and lower water columns; rest during day times	bottom and lower water columns during night hours	CO	mouth funnel shaped, highly muscular lips	Agarwal et al. 1990
9. *S. esocinus* Heckel*	"	"	"	–	–	"	–
10. *Tor tor* Hamilton	Dansulu and Mahaseer	glacial- and spring-fed rivers depending upon the amount of water	bottom and lower water columns; bigger pools; fry hide under large boulders near banks; fingerlings prefer mid streams	bottom and lower water columns	adults -HO juveniles-CO	protrusible; semiventral mouth with upper and lower lips everted, edentulous jaws	Desai 1970 Badola and Singh 1980 Jhingran 1983
11. *I. putitora* Hamilton	"	"	"	"	"	protrusible mouth	Das and Pathni 1978 Badola and Singh 1980 Jhingran 1983 Nautiyal and Lal 1984, 1985, Nautiyal 1990
12. *I. chilinoides* McClelland*	"	–	–	–	–	–	–
13. *Labeo dero* Hamilton	Kharont	spring fed and mixed streams	middle and upper water columns	bottom and middle water columns during evening and early morning hours	H (detritophagous)	mouth narrow and semiventral bounded by thick lips; both lips adorned with two papillated folds	Badola 1979 Saxena 1980
14. *L. dyocheilus* McClelland	"	"	middle columns	"	"	–	"
15. *L. boga* Hamilton*	Jabu	"	?	?	–	–	–
16. *Puntius chola* Hamilton*	?	spring fed	surface and upper columns	upper columns and surface	0	–	Badola and Singh 1980
17. *P. ticto* Hamilton	Damru	spring fed near foot hills	"	"	"	–	"
18. *P. conchonius* Hamilton*	"	"	?	?	?	?	"
19. *P. sophore* Hamilton*	"	"	?	?	0	?	"
20. *P. sarana* Hamilton	?	"	middle water columns	middle and upper columns	0	–	"
21. *P. chilinoides* McClelland	Dansulu	"	"	bottom crevices under rocks and larger stones	0	mouth crescentric semiventral and suctorial; scrap food material from rocks and stones with edentulous jaws	Badola and Singh 1980 Singh and Bahunguna 1983
22. *Garra gotyla gotyla* Gray	Gondal and Gunthela	glacial – and spring fed	bottom dweller under rocks and larger stones	bottom surface scrapper	H (detritophagous)	mouth ventral and suctorial; upper lips modofied as'fringed anterior labial fold'. Besides hard scrapping plate, lower lip modified as 'posterior labial fold', also found 'callous portion of disc' and 'posterior free margin of disc' in the chin and pharyngeal region.	Badola 1979 Singh et al.1991
23. *G. lamta* Hamilton*	?	"	"	"	"	"	–
24. *G. prashadi* Hora*	?	"	"	"	"	"	Somvanshi and Bapat 1979

25. *Chagunius chagunio* Hamilton	Kharont	glacial- and spring-fed; frequently seen during rainy season in the lower reaches of snow-fed rivers	bottom and middle water columns	bottom and middle water columns	0	mouth ventral, thick lips are supported by edentulous jaws	Badola 1979
26. *Barilius bola* Hamilton	?	abundant in spring fed streams but occasionally in lower reaches of snow fed rivers especially during rainy seasons	”	surface and upper water columns	C	–	Badola and Singh 1980
27. *B. bendelisis* Hamilton	Fulra and Chaal	abundant in spring fed but occasionally in snow fed streams; always prefer crystal clear water	surface and upper water columns	surface waters	0	mouth terminal and hard jaws	”
28. *B. barna* Hamilton	Fulra	”	”	”	”	”	”
29. *B. barila* Hamilton	”	”	”	?	”	”	”
30. *B. vagra* Hamilton	”	”	”	”	”	mouth terminal situated at the top of snout	Badola and Singh 1980 Bahuguna and Singh 1984 Singh and Bahuguna 1984a,b
31. *B. shacra* Hamilton*	”	”	?	?	?	?	–
32. *Danio (Danio) aequipinnatus* McClelland*	”	spring fed	?	?	?	–	–
33. *Danio (Brachydanio) rerio* Hamilton*	Dharidar	”	?	?	?	–	–
34. *Danio (Danio) devario* Hamilton	?	”	?	?	?	–	–
35. *Crossocheilus latius latius* McClelland	Sunhara	glacial- and spring fed	exclusively bottom dweller	bottom surface scrapper	H (dertito-phagous)	mouth ventral, 'fringed anterior labial fold' in the pre-mouth region; 'posterior labial fold' in the chin region; hard scrapping plate in lower jaw. With the help of fringed lips, scrap the detritus from the bottom surface	Singh and Bahuguna 1984b Singh and Agarwal 1991
36. *Rasbora daniconius* Hamilton*	?	spring fed	–	–	–	–	–
37. *Esomus danricus* Hamilton*	?	”	–	surface	C	–	Sen 1937
38. *Puntius phutunio* Hamilton*	?	spring fed (near foothills)	?	?	?	–	–
Family *HOMALOPTERIDAE* (hillstream loaches)							
39. *Balitora brucei* Gray	Patherchatta	high altitude, glacial fed	bottom, burrows	bottom burrows	C	body leaf like; pectoral and anal fins large so as to direct the food items to mouth	Badola 1979
Family *COBITIDAE* (loaches)							
40. *Botia geto* Hamilton*	?	spring fed but frequently seen in the lower reaches of snow-rivers	bottom	bottom and lower water columns	C	–	Malhotra 1967
41. *B. dario* Hamilton*	?	”	”	”	”	–	”
42. *Lepidocephalychthys guntea* Hamilton*	Gadiyal	spring fed, very common near foothills	?	?	?	?	?
43. *Noemacheilus montanus* McClelland	”	glacial- as well as spring fed, prefer smaller streams, sometimes also found in paddy fields	bottom (burrows below stones)	burrow, crevices at the bottom	CO	wide mouth supported by the edentulous jaws, suctorial disc formed by the lower lips	Badola 1979 Singh and Bahuguna 1983
44. *N. botia* Hamilton	”	common in smaller streams near foot hills	”	”	”	”	Badola 1979

45. *N. rupicola* Hamilton	”	smaller snow-fed streams	”	”	”	”	”
46. *N. bevani* Gunther*	”	smaller spring-fed streams	–	–	?	–	–
47. *N. savona* Hamilton*	”	”	?	?	?	?	–
48. *N. multifasciatus* Day	”	smaller high altitude streams	–	–	CO	as in *N. montanus*	Badola 1979
49. *N. zonatus* McClelland*	”	glacial- and spring fed streams	–	–	?	?	–
50. *N. scaturigina* McClelland*	”	”	–	?	?	?	–
51. *N. corica* Hamilton*	”	”	–	?	?	?	–
Family *AMBLYCIPIDIDAE*							
52. *Amblyceps mangois* Hamilton*	?	spring fed	–	?	?	?	–
Family *BAGARIDAE*							
53. *Mystus vittatus* Bloch	–	spring fed in the foothills near plains	bottom and lower water columns	bottom feeder	C	–	–
Family *SISORIDAE* (sucker catfishes)							
54. *Glyptothorax cavia* Hamilton*	Sipliya	high altitude glacial fed	bottom	bottom feeder	–	–	–
55. *G. pectinopterus* McClelland	Nau	high altitude glacial fed but in foot hills streams during rainy season	bottom and lower water columns	”	C	mouth ventral and wide, both jaws hard provided with minute teeth. Food items are captured by hard jaws	Badola 1979 Bahuguna and Singh 1981
56. *G. madraspatnam* Day*	–	”	”	”	?	?	–
57. *G. telchitta* Hamilton	Sipliya	spring fed, also in the stream near foot hills	”	”	C	as in *G. pectinopterus*	Badola 1979
58. *G. trilineatus* Blyth*	Nau	”	”	”	?	?	–
59. *G. brevipinnis* Hora*	”	”	”	?	?	?	–
60. *G. conirostris* Steindachner*	”	”	”	bottom feeder	C	as in *G. pectinopterus*	Badolá 1979
61. *Pseudecheneis sulcatus* McClelland	Mungerinau	high altitude glacial fed and spring fed	exclusively bottom dweller	exclusively bottom feeder	C	mouth ventral, wider jaws provided with minute teeth, highly muscular lips bear well developed papillae	Singh and Bahuguna 1984b
Family *OPHIOCEPHALIDAE*							
62. *Channa gachua* Hamilton	Sonal	spring fed (foot hill streams)	bottom, burrows and under stones	bottom and lower water columns	CO	body modified for burrowing	–
Family *SCHILBEIDAE*							
63. *Clupisoma garua* Hamilton*	–	high altitude glacial fed	?	?	?	?	–
Family *BELONIDAE* (Freshwater gars)							
64. *Xenentodon cancila* Hamilton	–	spring fed (near food hills)	calm surface	surface feeder	C	jaws elongated as beak	–
Family *MASTACEMBELIDAE*							
65. *Mastacembelus armatus* Lacepede	Gairee	spring fed (near foot hills), frequently seen during rainy season	bottom crevices, below rocks and larger stones	bottom, lower water columns	C	jaws elongated, upper jaw longer than the lower one	–

* = much description is not available

abbreviations : – = not avalable; ? = unknown; H = herbivorous; HO = herbi omnivorous; C = carnivorous; CO = carni omnivorous; O = omnivorous

Table 7

Profile of the important river valley projects in Garhwal region*

S. No.	Name of the project(s)	District(s)	River(s)	Height of dam (m)	Length of barrage (m)	Length of Tunnel (km)	Length of power channel (km)	Capacity MW	Tunnel diam. (m)	Estimated cost Crores Rs.
	A. Projects completed:									
1.	Yamuna HS Phase I	Dehradun	Yamuna	–	516.50	–	7.80	33.75	–	?
2.	Yamuna HS Phase I (Dhalipur PH)	"	"	–	515.50	–	5.80	51.00	–	16.83
3.	Yamuna HS Phase II	"	"	52.25	–	6.10	–	240.00	7.00	73.32
4.	Yamuna HS Phase IV (Kulhal PH)	"	"	–	288.00	–	4.00	30.00	–	14.10
5.	Yamuna HS Phase II – Part 2 (Khodri PH)	"	"	–	–	5.60	–	120.00	7.50	65.15
6.	Maneri-Bhali HS Phase I	Uttarkashi	Bhagirathi	39.00	127.00	8.631	–	90.00	4.75	79.34
7.	Garhwal-Rishikesh-Chila HS	Pauri	Ganga	–	312.00	–	14.30	144.00	–	97.76
	B. Projects – ongoing:									
8.	Lakhwar DP	Dehradun	Yamuna	192.00	–	–	–	300.00	–	?
9.	Byasi DP	"	"	80.00	–	2.70	–	120.00	7.00	276.42
10.	Kishau DP	"	Tons	253.00	–	–	–	600.00	–	460.00
11.	Khara HS	"	Yamuna	–	–	1.20	13.00	72.00	6.00	110.77
12.	Maneri-Bhali HS Phase II	Uttarkashi	Bhagirathi	–	81.00	16.00	–	304.00	6.00	212.66
13.	Pala-Maneri HS	"	"	74.00	–	12.70	–	372.00	6.00	253.07
14.	Tehri DP	Tehri	"	260.50	–	6.40	–	1000.00	11.00	1065.86**
15.	Vishnuparyag HS	Chamoli	Alaknanda	–	59.00	12.00	–	480.00	4.00	266.61
16.	Srinagar HS	Pauri	"	73.00	–	0.80	4.50	200.00	9.75	144.20
	C. Projects – proposed/conceived:									
17.	Arakot-Tyuni HS	Uttarkashi	Pawar	–	51.00	10.50	–	62.00	3.50	50.28
18.	Hanal-Tyuni HS	"	Tons	–	72.00	6.00	–	26.00	3.50	33.90
19.	Tyuni-Palasu HS	"	"	–	77.00	8.00	–	50.00	5.00	50.24
20.	Kuwan-Damta HS	"	"	200.00	–	12.00	–	126.00	4.00	119.08
21.	Barkot-Kuwan HS	"	Yamuna	–	30.00	17.00	–	25.00	2.50	29.82
22.	Kuthnore-Barkot HS	"	"	–	?	?	?	?	?	?
23.	Hanuman Chatti-Yamuna Chatti HS	"	"	–	26.00	6.00	–	33.00	2.50	25.25
24.	Katapatthar HS	Dehradun	"	–	196.00	–	5.95	19.00	–	27.58
25.	Rishiganga HS	Chamoli	Rishiganga	–	–	–	11.20	14.00	–	22.20
26.	Lata-Tapowan HS	"	Dhauliganga	–	–	5.00	–	89.00	2.50	40.00
27.	Markura-Lata HS	"	"	–	128.00	7.50	–	108.00	3.60	105.00
28.	Tapowan-Vishnugad HS	"	"	–	55.50	11.64	–	360.00	4.80	242.20
29.	Vishnugad-Pipalkoti HS	"	Alaknanda	202.00	–	–	–	340.00	–	344.00
30.	Bobala-Nandparyag HS	"	"	–	102.50	9.3	–	132.00	5.60	177.40
31.	Karanparyag DP	"	"	105.00	–	–	–	160.00	–	161.53
32.	Uttyasu DP	Pauri	"	175.00	–	–	–	1000.00	–	803.00
33.	Bhagoli & Padali DP	Chamoli	Pinder	170.00	–	–	–	80.00	–	175.00
34.	Bharonghati HS (Phase I)	Uttarkshi	Bhagirathi	–	57.00	5.30	–	324.00	–	186.28
35.	Bharonghati HS (Phase II)	"	"	232.00	–	–	–	240.00	–	959.00
36.	Lohari Nag HS	"	"	–	67.50	13.60	–	282.00	4.30	177.26
37.	Koteshwar DP	Tehri	"	87.50	–	–	–	150.00	–	250.25
38.	Kotli DP	Pauri	Ganga	210.00	–	–	–	1000.00	–	1186.00
								8776.75 $		8300.81 $$

* Source of data, U.P. Irrigation Office, Sprinagar Garhwal 1988 and Singh et al. 1991
** In July 1991, it was Rs 3800 crores

$ It excludes No.22
$$ It excludes No. 1 and 22. In view of the recent rupee devaluation, inflation and delay, the estimates will definitely increase many-fold.

Abbreviations: HS = hydroelectricity scheme, DP = dam project, – = not relavant, ? = not available
PH = power house

scale) and geographically smaller area are involving the large scale transformations in relatively short duration. These projects are seriously affecting the Garhwal hill environment (Singh 1987; Singh et al. 1991b). For example, the Maneri-Bhali Project – a three phased project with estimated annual power generation capacity of 94 MW, on completion of first phase, the reservoir at Maneri has the capacity of 1294.50 MT and height and length of the 'concrete gravity dam' are 39 XI 27 meters. Presently, only the first phase (Uttarkashi) is commissioned, and others, the second at Bhali and third at Dharasu, are under construction. But, the dam has already deteriorated the Bhagirathi ecology to a large extent. Tragically, The whole of the dam structure and considerable part of the reservoir got seriously damaged (perhaps beyond repairs) as a result of recent earthquake (reffered to as above).

As a corollary to such developmental activities, other activities have also added to the deterioration of the total quality of the hillstream ecology. These are –

2. Deforestation (Bhatt 1983, Singh 1987),
3. Over grazing by livestock,
4. Forest fires (Tewari 1983),
5. Creation of transport facilities,
6. Modern Tourism (Singh and Kaur 1985)
7. Over exploitation of fisheries and illegal fishing (Singh and Badola 1978).

DELETERIOUS CONSEQUENCES OF ENVIRONMENTAL DEGRADATION FOR FISHES

While changing the mountain belt from stable to unstable, deforestation causes most serious consequences. According to Masserli (1985), there are several stages of such changes – stability, vulnerability, fragility and finally unstability. The 'stability' means long term sustainability in the use and exploitation of natural resources of the ecological belt. The 'vulnerability' implies a stage of the system for which the stability is maintainable only by cereful management and by input of high energy quantum. The 'fragility' is characterized by irreversible change or damage that may be inflicted easily to the system while the 'unstability' is used for a situation wherein the damage or change is occurring not only in terms of the resource use but also through the interaction between belts or between highland and low land systems.

Keeping in view of the fact, the cumulative deteriorating impacts of these factors (mentioned above) on ichthyofauna are being experienced as –

a. Deforestation affects not only the biota of forests and neighbouring ecosystems the soil is eroded, land is degraded, gradual channels are altered and water becomes polluted and scarce.
b. Floods and flash floods as an environmental tragedy are second to none in creating havocs. The Garhwal region is flood prone zone and has a long history of floods

interlinked with several geo-morphological problems including deforestation. The recorded history of major floods in the Alaknanda recounts the important floods in 1894, 1924, 1970, 1978 which have inflicte irreparable damage to the Alaknanda ecology to the extent that fish population after 1970 flood was worst affected and has not recovered so far (Singh and Badola, 1978).

c. Land slides – The available data indicate that interesting varieties of land slodes-land slips and related phenomenon occur in Garhwal Himalaya at alarming pace. For example, most frequently described and reported 'Kaliasaur Land Slide' continues to be a burning questioon for the last 25 years. Land slides in the catchment area of a tributary may block its course and convert it into a lake (Nityanand and Prasad 1972).

d. Blockade formation as a result of multiple degrading environmental factors are significant as geo-morphological hazards. According to Sharma and Singh (1980), the blockade formed in August 1978 due to huge land slide into Bhagirathi near Ganganani, 45 km upstream from Uttarkashi, resulted in almost complete stoppage of onward flow of Bhagirathi for about 14 hours, ultimately led to the formation of huge lake of water and silt. It caused the washing off of many eroding rocks, thousands of trees, bridges, telephone poles, numerous huen settlements, damage and breach to 130 km long road stretch (between Dabrani-Uttarkashi-Tehri). Consequently, vast increase in the silt load led to the reduction of dissolved oxygen in water to 3.8 ppm and increase in the free CO_2 content upto 7.5 ppm. The fish population was also severely affected.

e. During tunneling and related dam construction activities, rocky materials of the dimensions of dust particles to huge boulders, continue to be added in the river. According to Singh (1987), in the process of Tehri Dam Construction, 38.42 Lac cubic meters of total rocky materials were thrown into Bhagirathi and 18.95 tons of explosives were used for blasting by the end of July 1981. Since then, such amount must have been incresed many-fold till today. The most drastically changed physico-chemical parameters of water quality, down stream the Tehri Dam site, are water temperature, turbidity, velocity, dissolved oxygen and free CO_2 are given in Table 8.

f. Increase in the town sewage which is ultimately thrown in the river (Gautam et al. 1989b), is one of the bane of modern tourist activities and changed relationships between nature and man kind.

g. Increased pollution – The factors mentioned earlier, have considerably damaged the riverine ecosystem during last few years, by adding a number of pollutants. Gautam (1990) listed six categories of pollutants in the Bhagirathi and other hillstreams. These pollutants are –

   i. Oxygen demanding wastes (sewage),
   ii. Disease causing agents (contamination due to ectoparasites, endoparasites, fungi, bacteria etc.),

Table 8

Physico-chemical characteristics of the river Bhagirathi at Tehri Dam *

S. No.	Place	Water Temp. (0°C)	Turbidity (NIV)	Velocity (m/sec.)	DO (ppm)	Free CO_2 (ppm)
1.	Tehri (before dam site)					
	Winter	11.25 ± 2.87	10.5 ± 7.51	1.44 ± 0.88	10.26 ± 0.69	2.15 ± 0.32
	Summer	15.75 ± 0.96	50.17± 76.07	1.7 ± 0.1	9.75 ± 1.55	2.87 ± 0.64
	Monsoon	16.75 ± 2.06	188.75 ±154.38	1.81 ± 0.17	9.55 ± 1.11	3.45 ± 1.11
2.	Tehri (after dam site)					
	Winter	12.33± 2.31	17.17± 15.69	0.89 ± 0.19	10.07 ± 0.85	2.45 ± 0.21
	Summer	16.25± 1.26	115.00±141.03	0.93 ± 0.27	9.48 ± 0.53	3.85 ± 1.51
	Monsoon	16.88± 2.02	241.75 ±136.06	0.99 ± 0.07	8.4 ± 0.97	3.58 ± 1.66

* Sinh 1987

iii. Sediments (dumping of soil, movement of debris downwards, soil erosion, by land slides-land slips and slop failures),

iv. Metal, viz., lead, cobalt, zinc, magnesium etc. (sewage and basic rocks of river bed),

v. Nutrients (emanating from sewage), and

vi. Others like pesticides, herbicides, insecticides, fungicides, detergents and natural toxins (ichthyotoxic plants parts).

ADVERSE IMPACTS ON FOOD AND FEEDING OF HILLSTREAM FISHES IN GARHWAL

Major sources of degrading riverine habitat cumulatively begin to assert by affecting the lotic biota qualitatively and quantitavely and, thus, addting to the miseries to the fishes especially as far as their food and feeding is concerned.

1. Continuous addition of silt, soil, sewage, explosives and other chemicals cause menacing changes in the physico-chemical and hydrobiological parameters of the water quality of hillstreams (Gautam 1990, Gautam et al., 1989a,b). The siltation and resultant turbidity of extremely higher levels lead to very weak or no penetration by sun rays (especially to the bottom), lower photosynthetic activities, decreased phytoplanktonic growth (Nautiyal 1985) and depleting primary productivity. Besides,

the gradual silt deposition over the river bed sevely affects the phytobenthic communities. The obvious consequences are observed in lesser availability of primary food items causing tremendous hardships to herbivorous and omnivorous fishes.

2. Because of rapid run off from surface during rainiy season (as a result of land clearance by deforestation) residues of fertilizers and pesticides (being inreasingly used in the agricultural practices) are ultimately added to the riverine ecosystem leading either loss to existing favourable fauna and flora or favouring the growth of nutritively unsuitable biota. Thus, abrupt alterations in the availability of food items to fishes are realized.
3. Qualitative and quantitative impacts on the growth of zooplanktonic and zoobenthic life forms are deleterious leading to severe hinderances in the food chain, energy cycle, cycling of nutrients in the early phase making it practically infeasible for omnivorous, herbiomnivorous, carniomnivorous and carnivorous fish species.
4. Changes in planktonic and benthic communities affect the availabilty of particular food materials, feeding spots in terms of particular fish species especially monophagous fishes like *Glyptothorax pectinoterus, G. conirostris, G. telchitta, Pseudecheneis sulcatus* etc. It also exerts tremendous pressure on feeding grounds, feeding behaviour and feeding intensity of juveniles as well as adults.
5. Recurrent flash floods and droughts have brought about the serious repercussions to riverine biota (Sharma and Singh 1980) especially to the developmental stages of fishes. Consequently, food matters become scarcely available to larvivorous and piscivorous hillstream fishes.
6. Dam construction, diversion of smaller stream etc. deteriorate the habitat of juveniles, adults and feeding-breeding-spawning grounds. Similarly, migratory patterns and migratory routes (e.g. of *Tor* spp., *Schizothorax* spp. etc. are choked, thus, altering/impeding the feeding-breeding cycles.
7. Creation of resevoirs due to dam construction and barrage making practically convert the large stretches of fast-running stream(s) into a huge body of standing water of which physico-chemical and hydrobiological characteristics markedly differ from the rapidly flowing streams. Under such circumstances, the food availability, nature of feeding grounds, feeding stimuli-feeding responses will certainly not be in coherence with the extream hillstream specializations/adaptations for torrential rapids (particularly in case of strictly bottom feeder and bottom dweller hillstream teleosts – *Schizothorax plagiostomus, S. richardsonii, Garra* spp., *Glyptothorax* spp., *Crossocheilus latius latius, Pseudecheneis sulcatus* etc.).

   Moreover, if other hard and exotic fishes (e.g., grass carp, Chinese carp, silver carp etc.) get introduced in such reservoirs to filfil the objectives of these multipurpose river valley projects, it will certainly result in severe competetion for food and feeding grounds between newly introduced hard fishes and indigenous hillstream fishes. Naturally, indigenous fishes (Table 6) will fail in the long run because many of these fishes are selective feeders while commercially cultivable fish specis mostly feed indiscriminately in terms of herbi-, omni- or carnivorous feeding habits.

8. Besides, the clandestine fishing methods have consolidated the degradation of hillstream ecology, feeding grounds and food matters. Most of the fishing devices cause large scale killing of fishes particularly their juveniles at the particular feeding spot, thus, causing scarcity of food to larvivorous and piscivorous fish species.

CONCLUSION

Keeping in view the profile of hillstreams of the Garhwal Himalaya and hillstream coldwater fishes therein, the hillstream fishes form one of the most successful groups inhabiting these rivers. Hillstream teleosts have made optimum use of resources available in their environs. By adapting themselves to different ecological habitats, veritable food matters, they have minimized the competeting so much so that large populations comprising many species in different developmental stages in a relatively small area become an interesting feature of Garhwal lotic environments, though ecological conditions like low water temperature, high tubulence, steep gradient, fast water velocity etc. are not condusive for high rate of biomass production.

It is also relevant to mention that practically all teleost species of Garhwal rivers are the descendents of ancestors from slow running waters from plains which, their pursuit of habitat exploitation, invaded and successfully occupied the different habitats and mobilized all the resources available ther in these riverine ecosystems. Such an invasion and occupation have not been singly or one time phenomenon but a continuous process. These rivers have continuously attracted many fish populations of different species at various geological times. Thus, few species like *Garra lamta, G. gotyla gotyla, Glyptothorax pectinopterus, G. telchitta, Pseudecheneis sulcatus* etc. are among the earliest invaders and occupiers of hillstream habitats available in glacial-snow-fed as well as non-glacial-fed or spring-fed river waters. There are other species (*Schizothorax plagiostomus, S. richardsonii, Crossocheilus latius latius* etc.) which appear to be in the process towards complete bottom dwelling and bottom feeding nature. After successfully occupying the riverine environment, these fishes have adjusted themselves in accordance with the local conditions and have undergone their own adaptive radiations independent of their counterparts in the waters of plains and peninsular India. None of the fish species could encroach so far the epi--rhithron riverine water, i.e., above the altitude of over 2600 m.

Since the time of immemorial, these fishes are living in almost absolute harmony to their surroundings and, in the process, cause no ill effects to the hillstream ecology.

But, the introduction of many deleterious factors as a result of man's greedy (so called developmental) activities, especially during last few decades, have compounded the sensitivity and fragility of geomorphology, physio-topography and climate of Garhwal hills. It, in turn, is seriously deteriorating the pristine wholesomeness of hillstreams of the region. Consequently, very existance of biota including ichthyofauna stands threatened. In the last few years, the population of many species (*Tor* spp., *Schizothoracids* etc.) have been observed to be gradually depleting because of the encroachment of and destruction to their feeding grounds, food matters, feeding behaviour, spawning grounds, migratory patterns and overall reproductive strategies. It is the responsibility of one and all to save this fragile environment and denizens herein.

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ZARYS RZECZNEGO EKOSYSTEMU, POKARM I ODŻYWIANIE SIĘ RYB Z POTOKÓW GÓRSKICH ORAZ SKUTKI DEGRADACJI ŚRODOWISKA W GAHRWAL HIMALAYA

STRESZCZENIE

Region Garhwal w Środkowych Himalajach (w Uttar Pradesh, India) charakteryzuje się unikalnymi warunkami topograficznymi, klimatycznymi i środowiskowymi. Rzeki, zasilane roztopionymi lodowcami lub strumieniami, tworzą górne dorzecze systemu rzeki Ganges w północnych Indiach. Niska temperatura wody, duże zawirowania, wysoki gradient szybko płynących wód, wywierają duży wpływ na żywe organizmy. Dotychczas stwierdzono obecność 65 gatunków ryb, należących do 9 rodzin (kostnoszkieletowych). Różne grupy biotyczne (jak: plankton, bentos, nekton, neuston), detrytus, cząstki piasku itp. występujące w poszczególnych strefach lotycznych wody służą jako pokarm dla ryb roślino- lub roślino-wszystkożernych, wszystkożernych, mięsożernych, mięso-wszystkożernych, larwo- oraz rybożernych. Wymienieni konsumenci, w zależności od strefy żerowania, dzielą się na grupy: przypowierzchniową, środkową i przydenną. Niektóre gatunki są euryfagami, inne steno- bądź monofagami. U wielu z nich występują wyraźne adaptacje do bardzo specyficznych warunków środowiska.

W ostatnich latach warunki środowiskowe potoków górskich uległy znacznemu pogorszeniu. Zostało to spowodowane przez nadmierne wycinanie i pożary lasów, nowoczesną turystykę, zbyt intensywny wypas bydła, rabunkową eksploatację naturalnych zasobów.

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