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Studies on Snow Trout *Schizothorax richardsonii* (Gray) in river Beas and its tributaries (Himachal Pradesh), India

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INTRODUCTION

The Himalayas is the youngest mountain chain in the world and extend for 2500 km in length in a series of parallel ridges or folds. The formation of the Himalayas took place slowly in three orogenic movements, of which the first upliftment took place in the Oligocene epoch (35 million years ago), second upliftment in the Miocene (15-25 million years back) and third one in the post-Pliocene period (10 million years back). The Indus-Ganga Brahamputra plain is situated between the Himalayas in the north and Peninsula in the south. The Himalayas are with a net work of dralnages fed with glaciers and streams.

The lion river, the Indus received its name from the Sanskrit word, Sindhu, which means a large water body, a sea or an ocean. In Greek, it is called "Sinthos" and in Latin, the "Sindus" The origin of the Indus River (Fig. 9) is in the Tibet at the confluence of the Sengge and Gar rivers. The Indus subsequently flow northwest through Ladakh and Baltistan into Gilgit, south of the Karakoram Range. The Indus River is fed by the snows and glaciers of the Himalayas, Karakoram and the Hindu Kush ranges of Tibet, the state of Jammu and Kashmir in India. The water of the Indus River system (Beas, Satluj, Ravi, Chenab and Jhelum) joins the Arbaian Sea near Karachi (West Pakistan).

The Drainage System of Himachal-Pradesh feeds to the five major rivers, *i.e.* Chenab, Ravi, Beas, Satluj and Yamuna (Fig. 2) which are the part of Indus River System and Ganga River System respectively. River Beas originates from the mighty Dhauladhar range of great Himalaya at an altitude of 4062 m asl near Rohtang Pass in District Kullu. On right of the Rohtang Pass lies the source of the river Beas known as Beas Rishi, where the Maharishi Vyas, meditated. To the South of this source lies another source known as Beas Kund. The tiny round stone hut shelter the Kund (Fig. 10). Near the source of the Kund, the River is narrow and water flows like a spring, transparent and icy. The terrain is rocky all around near the Beas Kund with scattered boulders, stones, pebbles and sparsely distributed vegetation. A few mules were observed grazing over here (Fig. 12). It becomes torrential and deep gorged downwards of Rohtang *i.e.* at Kothi. Both these mountain streams meet at Palachan village, 10 km north of Manali to form the river Beas. The world famous tourist place Manali is situated on the right banks of the river Beas.

Beas Drainage System in Himachal-Pradesh is spread over a length of 923 km which includes 297 km main River and 626 km of its tributaries (Sehgal, 1983). It traverses through district Kullu, Mandi and Kangra of Himachal Pradesh. The Beas River is a snow fed River and with its perennial tributaries forms major water resources of districts Kangra, Mandi and Kullu of Himachal-Pradesh (Fig. 3). During the course of its length various tributaries join and main streams are the Parbati, the Spin nala and Malana nala in the East; and the Solang, the Manalsu, the Sujoin, the Phojal and the Sarvati Streams in the West in district Kullu. In Mandi district, it is fed by Hansa, Tirthan, Bakhli, Jiuni, Suketi, Panddi, Son and

Bather. In Kangra, it is joined by Binwa, Neugal, Banganga, Gaj, Dehr and Chakki from North, and Kunah, Maseh, Khairan and Man from the South. The Northern and Eastern tributaries of the Beas are perennial and snow fed, while Southern are seasonal. Its flow is maximum during monsoon months.

Himachal-Pradesh has a vast potential for the development of cold-water fishery. The cold-water streams are characterized by high transparency and dissolved oxygen. The major coldwater fishes belong to families : Cyprinidae, Cobitidae, Salmonidae, Sisoridae and Homalopteridae. Most of the fishes inhabiting cold water are small in size. Most of the hill stream fishes live at the bottom or on the banks due to low water current than the main stream. Some commercially important coldwater species are *Tor putitora* (Hamilton-Buchanan), *Tor tor* (Hamilton-Buchanan), *Tor mosal* (Hamilton-Buchanan), *Neolissochilus hexagonolepis* (McClelland), *Schizothorax richardsonii* (Gray), *Schizothorax progastus* (McClelland), *Barilius bendelisis* (Hamilton-Buchanan), *Crossochielus latius latius* (Hamilton-Buchanan), *Labeo dero* (Hamilton-Buchanan) *Labeo dyocheilus* (McClelland) and *Garra gotyla* (Gray). The distribution of these fishes depends upon current velocity, nature of substratum and food availability. Schizothoracinae fishes are well adapted to such conditions. Fishes living in torrential streams have special organs for attachment. These fishes thrive in the hilly streams and have bottom dwelling habits. The presence of a row of enlarged and tiled scales on anal flaps distinguishes the Schizothoracids from Cyprinids.

The 'Snow Trout', *Schizothorax richardsonii* (Gray) (Fig. 6) belongs to subfamily Schizothoracinae, family Cyprinidae under a major order Cypriniformes of class Pisces. These fishes are also called 'Indian Trouts' because of its resemblance with family Salmonidae. This is one of the important food and game fish of the region.

Schizothoracinae are the specialized group of fishes which inhabit snow fed torrential streams of Himalayas in India. Out of the 19 Schizothoracinae species recorded from Indian upland, only *Lepidopygopsis typus* Raj is restricted to the Western Ghats and remaining are available from the Himalayas (Sunder and Joshi, 2002). These fishes were first discovered by Heckel (1838) from Kashmir. They have very small scales on their body. The reduction in size or absence of scales on the body is the distinguishing character of *Schizothorax richardsonii*. McClelland (1842) placed them under the subfamily 'Schizothoracinae' due to their specialized character of tiled row of enlarged scales along the anal flap.

Schizothorax sp. are characterized by inferior mouth; horny covering on the lower jaw; hard papillated band on chin; two pairs of barbels; three rows of pharyngeal teeth; last undivided ray of dorsal fin bony and posteriorly serrated. The scales are very small in size. The reduction or degeneration of scales in Schizothoracinae is a character shared by high altitude fishes of the family Cobitidae and Salmonidae. Smooth and soft skin is the requisite for hill stream fishes since it is helpful in cutaneous respiration. These fishes are herbivorous, and their horny jaws are helpful in scraping off algae from stones and rocks in fast running water.

A perusal of literature revealed that fish fauna of Himachal Pradesh has been described by several workers *viz*. McClelland, 1842; Steindachner, 1867; Prasad, 1919; Day, F. 1875-1878; Fowler, 1924; Hora, 1950; Menon, 1962; Bhatnagar, 1973; Tilak and Hussain, 1977;

Dhanze and Dhanze, 2004; Mehta and Uniyal, 2005 and Sharma and Mehta (2008).The work available on the hydrobiology in Beas River in Himachal Pradesh (Sehgal, 1983; Dhanze and Dhanze, 1999; Dhanze *et al.*, 1998; 2002; Chauhan, 2002 and Kumar & Saxena (2008). The systematic study on the Schizothoracinae has been undertaken by Talwar, 1978; Tilak and Sihna, 1975 and Menon, 1971. Ecological observation and breeding, development, culture prospective has been studied by Baloni and Tilak, 1983 and Raizada, 1982 respectively. Thus, pertinent literature revealed that work on the Schizothoracinae is very meager. The present studies of Schizothoracinae with relation to ecology will go a long way to conserve this fishery.

MATERIAL AND METHODS

The study was undertaken for three years *i.e.* from 2005 to 2008. The study was undertaken in the 44 streams of River Beas in district Kangra and Mandi of Himachal Pradesh. The geomorphologic features include general features of stream, number of channels at site, substratum type, bank stability, pollution and status of vegetation (Table-1) was undertaken. A stretch of two Kilometer of each stream site was selected for the study. Rosgen's (1996) classification with slight modification was followed to classify the streams. The altitudinal gradation of the sampling sites varies from 420 to 2015 m asl. Longitude, latitude and altitude (m asl) of the collection spot were determined with the help of GPS.

Abiotic Parameters : The water samples were collected seasonally from the six selected sites *viz.* Binwa, Poon, Neugal, Baner, Manuni and Gaj streams of district Kangra and from five sites of district Mandi *viz.* Beas River, Jauni stream, Sukhad stream, Uhl stream and Arnodi stream (Fig. 4 & 5) for the analysis of hydrobiological parameters which include Water velocity, Temperature, pH, Dissolved oxygen, Alkalinity, Chloride, Salinity, Hardness and Primary Productivity. The Temperature was recorded with the help of ordinary mercury thermometer, pH by standard pH meter, Dissolved oxygen by Winkler's method and other parameters were determined by Standard Methods (APHA, 1985).

Biotic Parameters : The planktons were collected by filtering fifty liters of water in plankton net and fixed in 4% formalin at the spot. For the collection of benthos, mud and stones were oollected by dredging of one square meter area and was sieved through a metallic gauge and transferred to enameled tray for sorting and separation of individuals from the debris and stones.

For the collection of fishes, cast net of mesh size 0.5cm, gill net, mosquito net, hand net and hook were employed. The catch per unit of effort (U) was also calculated for each site. The observation of feeding and breeding behavior was also made.

The fishes were collected in the field and preserved in 10% formalin. For the identification of the organisms Welch (1952), Talwar and Jhingran (1991), APHA (1985) and Jayaram (1999) were consulted. The classification is as per of website www.fishbase.org.

PHYSIOGRAPHY OF STUDY AREA

Himachal Pradesh (Fig. 1) is situated between 30°22' and 30°12' north latitude and between 75°47' and 79°4' east longitude in the heart of the western Himalaya. Its altitudes vary from 350 to 7000 m asl. Physiographically, it is divided into four zones of the Himalayan mountain ranges.

1. The outer Himalayas or the Shivaliks

The Shivaliks consist of lower hills. The Shivaliks include the districts of Hamirpur, Kangra, Una, Bilaspur, and the lower parts of Solan, Sirmaur and Mandi. The rainfall in this zone ranges between 150 cm to 175 cm.

2. The lesser Himalayas or the Central zone

The lesser Himalayas are distinct by a gradual elevation towards the Dhauladhar and the Pir Panjal ranges. In the south the rise is more abrupt in the Shimla hills. North of Satluj the rise is gradual. The Pir Panjal, the largest of the Lesser Himalayan ranges, branches off from the greater Himalayan range near the bank of the river Sutlej. Numerous glaciers exist and several passes lie across Pir Panjal. The middle region includes the parts of Sirmaur, Mandi and parts of Kangra, Shimla and Chamba and experiences rainfall between 75 cm to 100 cm. This zone remains under snow for almost five to six months.

3. The Inner or Great Himalayas

The Great Himalayan range runs along the eastern boundary and is cut across by the defile of the Satluj. The range separates the drainage of the Spiti from that of the Beas. This range comprises districts of Kinnaur and Lahaul and Spiti. A large number of glaciers are situated in this range and provide water throughout the year. The area receives less rain fall due to rain shadow zone created by other two ranges.

4. Trans-Himalayan Range

It is the eastern most range and separates Spiti and Kinnaur from Tibet. This is a thick snow covered range throughout the year. It comprises of the Kinnnaur (Kalpa) and Pangi tehsils of Chamba and some parts of Lahaul and Spiti district.

Climate : The climate varies from semi-tropical to semi-arctic from place to place depending on the altitude of the region. The months from April to June are pleasant and comfortable at higher altitude and humid in the lower hills. The months of July to September are the months of rainfall. Himachal-Pradesh experiences average annual rainfall of about 160 cm. The entire state becomes lush green and all the springs and streams are filled again. The winter season begins from October to February and is very severe. Heavy snowfall occurs during this season.

Forest : The 63.9% of the total area in the state is under the thick forest cover. The vegetation comprises of Ban Oak Forest, Moist Deodar Forest, Western Mixed Coniferous Forest, Moist Temperate Deciduous Forest, Himalayan Alpine Pastures and Rhododendron Scrub Forest.

There are several major rivers running through the state including the Beas River, Satluj, Chandra-Bhaga, Ravi and Yamuna (Fig. 2). During the present study, the Beas River and its tributaries (district Kangra and Mandi) has been extensively explored to know the status and threats to Snow trout fish.

District Kangra is situated between North latitude 31°20' and 32°58' and East longitude 75°39' and 78°35' The Beas enters district Kangra at Sandhol, tehsil Palampur and afterwards the river takes a southwardly course and enters the valley of Nadhaun. The important tributaries in the district are Baner, Awa, Binwa, Poon, Neugal, Mole, Gaj, Manuni, Dehari, Manjhi, Darini and Khaouli streams. Maharana Pratap Sagar (Pong reservoir) is an important reservoir of international importance in district Kangra of Himachal-Pradesh is impounded on this River. Several large tributaries of Beas *viz.* Baner, Dehar and Gaj drain into Pong Dam reservoir.

District Mandi is situated between 31° 13' 50" and 32° 04' 30" N latitude and 76° 37' 20" and 76° 37' 20" and 77° 23' 50" E longitude in Himachal- Pradesh. Its area is 1620 square miles. Its east, north and west sides are bounded by district Kangra and on the southwest by Bilaspur district. The district is entirely hilly except Balh area in Sundernagar tehsil and Chauntra in Jogindernagar tehsil. There are four main hill ranges in the district *i.e.* Dhauladhar, Ghogar Dhar, Sikandra Dhar and Dhar-Vairket. At Bajaura, Beas River enters Mandi district which is situated on its left bank. River Beas, which receives almost the entire drainage of the district, is the principal river. Here the Jaswan chain obstructs its further passage to south and river flows in the northwest direction almost parallel to the strike of the hills.

The major tributaries of Beas River in district Mandi on the north bank are Uhl, Luni and Rena while Suketi, Jaunini, Janjheli and Hansa join the river on the south bank. The water of Uhl is used to generate electricity near Jogindarnagar. The construction of dam at Pandoh has resulted in the formation of reservoir in the upstream of the river and it reduces the water flow in the downstream up to Mandi. Pandoh dam is an earth-cum-rock fill dam 76.20 m (250 feet) high above the deepest foundation. At Pandoh the water of the river Beas is diverted into river Satluj through a tunnel and this interlinking of two rivers is known, as Beas Satluj Link. Beas Satluj Link project is the largest tunneling project in the country. It constitutes 13.1 Km tunnel of 25 feet diameter. Thus the water of Beas and Satluj feeds the Gobind Sagar Dam.

RESULTS AND DISCUSSION

The systematic position of *Schizothorax richardsonii* (Gray) adaptation to hill streams, geomorphology of the streams, abiotic and biotic parameters, feeding, breeding, species association and potential sites for the breeding has been discussed during the present studies.

SYSTEMATIC POSITION OF *SCHIZOTHORAX RICHARDSONII* (GRAY)

The schizothoracid fishes had an uncertain taxonomical history; a brief account is discussed here.

The genus *Schizothorax* was documented by Heckel (1838) without any type designation. He grouped these fishes in three groups *viz.* A, B and C. In group "A" he placed those fishes which are characterized by the presence of a strip of hard papillated structure at the chin, mouth ventral and lower jaw with a fine cartilaginous horny structure. In this section he included *Schizothorax plagiostomus* and *Schizothorax sinuatus*. The strip of hard papillated structure behind the chin is absent in groups B & C. In section "B" he described *Schizothorax curvifrons*, *Schizothorax longipinnis*, *Schizothoras niger* and *Schizothorax esocinus* and in section "C" he put *Schizothorax huegelii*, *Schizothorax micropogon*, *Schizothorax planifrons* and *Schizothorax esocinus*. McClelland (1839) without knowing about Heckel's publication, in his monograph on *Indian Cyprinidae* described the fishes under a new genus *Oreinus* with the species, *Oreinus guttatus* McClelland, *Oreinus richardsonii* (Gray), *Oreinus maculatus* McClelland and *Oreinus progastus* McClelland and out of these, three were new species. Misra (1962) proposed the genus *Schizothoraichthys*, to accommodate the species without suctorial disc which were put under the genus *Schizothorax* by Heckel, 1838. Tilak and Sinha (1975) opined that *Schizothorax plagiostomus* and *Orienus guttatus* are the species with a sucker at the chin and the latter is the synonym of the former and also supported the view of Misra (1962) that the fishes without a hard strip of papillated structure at the chin are rightly accommodated under a new generic name, *Schizothoraichthys*. Many other authors (Misra, 1962, Menon, 1971, 1974, Jhingran, 1992) also recognized that the fishes with a strip of papillated structure at the chin under the genus *Schizothorax*. Menon (1971) reported two valid species of *Schizothorax*- *Schizothorax richardsonii* and a new species, *Schizothorax kumaonensis*. Talwar (1978) re-established the genus *Oreinus*, 1839 removing it from the synonymy of *Schizothorax* and also merged *Schizothoraichthys* under the genus *Schizothorax*. Tilak (1987), Talwar and Jhingran (1992) viewed that in India, there are two species under the genus *Schizothorax*, *viz. Schizothorax richardsonii* (Gray) and *Schizothorax kumaonensis* Menon. *Schizothorax kumaonensis* differs from *Schizothorax richardsonii* in having a smaller head, which is five times lesser than the standard length.

The other genera in snow trout fishes are *Diptychus*, *Ptychobarbus*, *Schizothoraichthys*, *Schizopygopsis* and *Lepidopygopsis*. Menon (1999) recorded 15 species under Schizothoracinae subfamily and put two species in genus *Oreinus i.e. Oreinus richardsonii* (Gray) and *Oreinus kumaonensis* Menon and other under genus *Schizothorax i.e. Schizothorax curvifrons* Heckel, *Schizothorax esocinus* Heckel, *Schizothorax hugelii* Heckel, *Schizothorax longipinnis* Heckel, *Schizothorax micropogon* Heckel, *Schizothorax niger* Heckel and thus submerged the genus Schizothoraichthys with Schizothorax. Jayram (1999) recorded 16 species under this subfamily. *viz. Schizothorax richardsonii* (Gray), *Schizothorax kumaonensis* (Menon), *Schizothoraichthys curvifrons* (Heckel), *Schizothoraichthys esocinus* (Heckel), *Schizothoraichthys hugelii* (Heckel), *Schizothoraichthys longipinnis* (Heckel), *Schizothoraichthys micropogon* Heckel, *Schizothoraichthys nasus* (Heckel), *Schizothoraichthys*

niger (Heckel), *Schizothoraichthys planifrons* (Heckel), *Schizothoraichthys progastus* (McClelland), *Schizopygopsis stoliczkae* Steindachner, *Diptychus maculatus* Steindachner, ***Ptychobarbus conirostris*** Steindachner, *Lepidopygopsis typus* Raj and thus added one more species in the list *i.e. Gymnocypris biswasi* Talwar. Sehgal (1994) has identified *Gymnocypris **biswasi*** Talwar as the Extinct (Ex) from Ladakh region of the country. Further, as per CAMP (1998) *Gymnocypris biswasi* Talwar is an extinct species. As per www.fishbase.org. there are 8 species under genus *Schizothorax* in India *i.e. Schizothorax hugelii, Schizothorax kumaonensis, Schizothorax labiatus, Schizothorax microcephalus, Schizothorax molesworthi, Schizothorax nasus, Schizothorax plagiostomus, Schizothorax progastus* and *Schizothorax richardsonii.*

SYSTEMATIC ACCOUNT

ORDER : CYPRINIFORMES

FAMILY : CYPRINIDAE

SUBFAMILY : SCHIZOTHORACINAE

Genus/Sp. ***Schizothorax richardsonii*** (Gray)

Synonymies

1830-1832. *Cyprinus richardsonii* (Gray), Ill. *Indian Zool.*, I, pl. 94, fig. 2 (Illustration only) (Type-locality : India).

1838. *Schizothorax plagiostomus* Heckel, *Fische Caschmir*, p. 16, pl. I (Type-locality : Kashmir).

1838. *Schizothorax sinuatus* Heckel, *Fische Caschmir*, p. 21, pl. 2. (Type-locality : Kashmir).

1839. *Oreinus richardsonii* McClelland, *Asiat. Res.*, 19, pp.281, 371, (Kumaon, Simla, Nepal).

1839. *Oreinus punctatus* McClelland, *Asiat. Res.*, 19, p. 256 (foot-note; new name for *Cyprinus richardsonii*).

1839. *Oreinus richardsonii* McClelland, *Asiat. Res.*, 19, p. 273, 335 (Simla).

1839. *Oreinus guttatus* McClelland, *Asiat. Res.* pp.273, 344, pl. 39, fig. I (Type-locality : Bhutan).

1839. *Gonorhynchus petrophilus* McClelland, *Asiat. Res.*, 19, pp. 281, 371 (Type-locality : Kumaon, Simla, Nepal).

1839. *Oreinus maculatus* McClelland, *Ibid*, 19, pp. 274, 245, pl.57, fig. 6 (Type-locality : Bhutan).

1868. *Oreinus sinuatus* Gunther, *Cat. Fish. Brit. Mus.*, **22**, p. 734.

1877. *Oreinus richardsonii* Day, *Fishes of India*, 530, pl. 125, fig. 4.

1889. *Oreinus richardsonii* Day, *Fauna Br. India, Fishes*, **1** : 250.

1907. *Diptychus annandalei* Regan, *Rec. Indian Mus.*, **1** : 157 (Type-locality : Nepal).

1913. *Oreinus molesworthi* Chaudhuri, *Rec.Indian Mus.*, **8**: 247, pl. 7, figs 2, 2a, 2b (Type locality : Yombong, Abor Hills, Assam).

1921. *Oreinus molesworthi* Hora, *Rec. Indian Mus.*, **39** : 734 (Darjeeling).

1924. *Oreinus sinuatus* Fowler, *Proc. Acad. Nat. Sci.* Philaadelphia, **76**, p. 91 (Kulu Valley, Beas river Basin, Sutluj River north of Bilaspur).

1937. *Oreinus richardsonii* Hora, *Rec. Indian Mus.*, **39**, p. 44.

1949. *Oreinus plagiosomus* Misra, *J. zool. Soc. India*, **1** (1): 39-40.

1960. *Oreinus plagiostomus plagiostomus* Silas, *J. Bombay nat. Hist. Soc.*, 57, pp. 67, 68, 71, 74 (Kashmir).

1964. *Oreinus plagiostomus* Das and Subla, *Kashmir Sci.*, **1** : 27-34 (description of oral valves).

1967. *Schizothorax plagiostomus* Bhatnagar, *Indian J. Fish.*, **11**, pp. 485, 492 (spawning and fecundity).

1971. *Schizothorax richardsonii* Menon, *Rec. zool. Surv.* India, **63**(1-4), p. 203, pl. 1, figs.1, 2, 4 (description and distribution).

1971. *Schizothorax plagiostomus* Tilak, *Rec. zool. Surv. India*, **65**(1-4), p. 192, pl. 1, figs. 5, 6 (Tawi river, J& K).

1972. *Oreinus richardsonii* Banarescu and Nalbant, *Khumbu Himal.*, **4**(2), p. 236 (Nepal).

1974. *Oreinus plagiostomus* Seghal, *J. Bombay nat. Hist. Soc.*, **70**(3), p. 466- 470 (Chamba, Mandi, Bilaspur, Sirmour).

1974. *Oreinus sinuatus* Seghal, *Ibid*, p.466 (Chamba, Mandi, Bilaspur, Sirmour).

1978. *Schizothorax skarduensis* Mirza and Awan, *Biologia*, **24**(2) : 199, fig. 1 (Type-locality : Indus River at Skardu, Pakistan).

1981. *Schizothorax richardsonii* Jayram, Handbook: *Freshwater Fishes of India*, p.67.

1984. *Schizothorax nepalensis* Terashima, *Jap. J. Ichthyol.*, **31**(3) : 131, figs 3c, 4c, 5c, 8 (Type-locality : Rara lake, Nepal).

1987. *Schizothorax richardsonii* Tilak, *Fauna of India*, Pisces : **50**, figs. 12-24.

1991. *Schizothorax richardsonii* Talwar and Jhingran, *Inland Fishes*, **1** : 411-412, fig. 145.

1999. *Oreinus richardsonii*, Menon, Checklist of fresh water fishes of India, *Occasional Paper No.* **175** : 106-107.

1999. *Schizothorax richardsonii* Jayram, *The Freshwater Fishes of the Indian Region*, p 551, pl. XVIII.

Diagnosis : Body streamlined; presence of a strip of hard papillated structure at chin; upper jaw longer than lower; head short and blunt; interorbital space broad and flat; two pair of barbels and smaller than diameter of eye; pharyngeal teeth arranged in three rows; dorsal fin inserted near the snout tip; dorsal spine bony, strong and serrated behind; pectoral fin shorter than head; origin of dorsal fin near to tip of snout, dorsal fin insertion anterior to that of pelvic fin; pelvic fin does not reach vent; tiled row of scales forming a sheath on either side of vent and anal fin, lateral line complete and arched; scales very small.

Fin Formula : D. III/8, P. I/15, V./ 9, A. III/5, C. 17

Local Name : Gugal, Talore, Swal

Distribution : Himachal Pradesh: Bhakra reservoir, district Bilaspur, Chamba, Kinnaur, Kangra, Mandi, Kullu, Shimla, Sirmour

India : Himachal Pradesh, Jammu and Kashmir, Assam, Sikkim, Bhutan

Elsewhere : Nepal, Afghanistan, Pakistan

Status : Vulnerable, CAMP (1998)

ADAPTATION OF *SCHIZOTHORAX* SP. IN HILL STREAMS

The Schizothoracinae fishes thrive well below the stones, rocks in the fast current of water. These fishes have acquired characters making them suitable for living in the fast flowing hill streams. The body of these fishes is streamlined and is helpful to move against the torrential flow of the hill streams. Tilak (1987) stated that the streamlined body offer least resistance to the fast current of water enabling movement against the current of the hill streams. It has been observed that the body is completely covered with scales in *Schizothorax richardsonii* (Gray). The scales are very minute and embedded in the skin. The fishes require to press themselves against the substratum for feeding and therefore lepidosis of the ventral side of the body is reduced or absent (Tilak, 1987). The lower lip is modified to a hard labial plate with sharp horny edge on the lower jaw (Fig.7) which is the adaptation for herbivorous mode of feeding of these fishes. Tilak *op cit.* reported that they need to scrape algal encrustation from the stones in fast running streams and therefore, the development of these characters is needed for the purpose.

The paired fins (pectoral and pelvic) are larger with their bases and outer rays thick and muscular. The position of the paired fins shifted to the sides and get horizontially placed, so ventral side is attached to the rocks and act as organ of adhesion. The distance between pectoral and pelvic fin is also comparatively less (Fig. 8). Thus, the fishes are able to resist fast current of water. The barbels are absent or short in Schizothoracinae fishes. However, in *Schizothorax richardsonii* (Gray) two pairs of barbels are present, which are comparatively smaller and shorter than the eye diameter. Short barbels are an adaptation to the fast current of water in hill streams.

GEOMORPHOLOGY OF HILL STREAMS

The Beas River was divided into four categories on the basis of general features, substratum and altitude of the stream to know the adequate habitat of the fish.

1. Type A[1] Stream (>1251 m asl) : These type of streams are dominated by large boulders and have steep gradient. Step pools are the main habitat of such streams. The streams are narrow with torrential flow of current and fairly thick vegetation. The ratio of the depth of the stream is more than that of the width.

2. Type A Stream (1250-951 m asl) : These types of streams are also narrow but comparatively broader than 'A' type streams. This type of streams is dominated by big boulders, small boulders followed by cobbles and gravel. Silt and sand is very rare. Rapids and riffles are the main habitats.

3. Type B Stream (950-751 m asl): These streams are wider than "A" stream. The width and the depth ratio are almost same in these streams. Pools are the habitat of these streams. Large and small boulders are almost equal followed by cobbles and gravel. Riffles are the main habitats followed by rapids and runs.

4. Type C (750-500 m asl) : These streams are mostly open type and the width of the streams is comparatively more than that of the depth. The streams are dominated by cobbles and gravels. Boulders are scattered along the bank and in the stream. Runs and riffles are the main habitat of the streams.

5. Type F Stream (<500 m asl) : These stream sites are wide and also of open type and mostly located in the meadows and urban areas. The streams are dominated by sand and cobbles while small stones are scattered. The streams are shallow and water flows smoothly in the stream.

The general features (Table-1) of the stream are detailed for each stream site:

Rapids : It is a section of the river, where river bed has a relatively steep gradient causing an increase in water flow and turbulence.

Riffle : It is a shallow stretch of river or stream, where the current is above the average stream velocity. It consists of a rocky bed of gravels or small stones. This portion of a stream is an important habitat for aquatic invertebrates and juvenile fish.

Cascade : It is a type of water fall or a series of waterfalls.

Run : It is smoothly flowing water on the river bed.

GEOMORPHOLOGY VERSUS FISH RICHNESS

The studies on the geomorphology of the streams (Table-1) depict that no snow trout fishery could be recorded below 500 m asl (Type F stream) as the stream sites are shallow and substratum of the streams are mainly occupied by sand, cobbles and gravels. At 500-600 m asl, the snow trout fishery is also nil except one exception *i.e.* at Gaj stream at an altitude of 510 m asl, where 3 examples were recorded during winter season. Above 600 m asl, at Baner (630 m asl), Chambi (720 m asl), Beas River (730 m asl), Uhl (720 m asl), few examples were recorded. Thus, in the Type C streams in the altitude range of 500-750 m asl also, the *Schizothorax ricardsonii* (Gray) was negligible and only occasionally recorded (Table-2-6). It infers that the altitude range of <500 m asl (Type F Stream) and 500-750 m asl (Type C Stream), exhibit insignificant snow trout fishery, which was earlier recorded (Talwar (1978), Tilak (1987). Thus, the rare recording of fish under the present studies at Type C and Type F streams is attributed to the degradation of stream habitat due to anthropogenic stresses.

The type B streams (750-950 m asl) represents good number of fishery. The stream sites A[1] (1250 m asl) and A (950-1250 m asl) harbour comparatively very good number of fishes. The population of *Schizothorax richardsonii* (Gray) was good between altitude 850-1500 m asl at Neugal, Binwa, Poon, Sansal, Khoti, Arnodi, Uhl and Laghed stream of the Beas drainage system. Further, at elevation of 1500 m asl *i.e.* at Tiakkan, Barot fairly good number of fishes were recorded during the present studies. Any pollution and human interference was not observed at this site. However, above 2000 m asl, the snow trout fishes were not recorded.

Thus, it can be inferred that A[1], A and B stream sites are the preferable habitats for the snow trout fishery.

However, as per the altitude range it is difficult to categorize fishes as the geomorphology of the streams changes at the same altitude (Table-1). Since, extraction of stones, gravel, sand etc. is a common feature of these hill streams, results in a change of the stream bottom, the water current slows down, adversely affecting the abundance of fish. Boulders, rapids, and riffles are the preferable habitat of snow trout fishes. Thus, the topography of the stream gets changed in the stream sites located at the same elevation. With the change of the seasons, specially during rainy seasons the water get polluted more as over flood stream also changes the original path and entire ecology of the stream get affected, which also affects the fish fauna. According to Power (1973), the presence of cover in the form of boulders and large stones greatly enhances the holding capacity of the river for fish. Hence, it is inferred that the topography of the sites play a prime role in the abundance of this fishery. Neophitous (1986) also opined that not only physicochemical parameters affect the total catch but the topography of the site also plays an important role in supporting the fish faunal resources.

10 streams are without any type of pollution while 34 streams receive domestic waste, insecticides and also subjected to extraction of stones, etc. Most of the streams have fairly uniform vegetation. The streams with thick vegetation exhibit good population of snow trout. The vegetation serves an important purpose in relation to the physical nature of the stream *e.g.* peak flow, sediment load, runoff that occurs from rainfall or snow melt events (Dymeres, 1963). Plant communities along the streams are dynamic species which can be correlated with the productivity and biomass (Cummins *et al.* 1984). Nilsson *et al.* (1993) reported those riparian ecosystems are the sieves or filters through which information from upland area passes before entering the aquatic ecosystem. The present investigation also infers that cold, transparent, clear and oxygenated water is the prerequisite of this fishery.

Table-1 : Geomorphology of the Streams

S. No.	Stream	Altitude m asl) & Origin	Substratum	Channel	General Features	Pollution	Vegetation
1.	Binwa (Majherana), dist. Kangra	810, Kharli Village, Jamada Valley	*LB, SB, C, G, J.	Two	Gradient moderate, Predominated by rapids followed by runs, Cascades, banks stable, Two pools.	Channalization, Degradation of pebbles, Cobbles and sand.	Fairly thick vegetation
2.	Binwa (Kandanala), dist. Kangra	964, Do	LB=SB, C, G, J	One	Runs and rapids are the main habitats followed by riffles, Banks stable, Three pools.	Hydroelectric project, Bleaching powder.	Fairly uniform
3.	Sansal, dist. Kangra	1275, Sathi village	LB=SB, C, G, J	One	Rapids are the main habitat followed by riffles, One pool.	Domestic	Fairly uniform
4.	Poon (Tharu), dist. Kangra	970, Near Neelkanth	*C,G, SB, LB, K, J	One	Runs are the main habitats followed by riffles, Two pools, Banks unstable, Ditches along bank have algal growth and inhabited by fry.	Unscientific method of catch, Domestic, Extraction of cobbles, pebbles and sand.	Scattered
5.	Poon (Sarsowa),	990, Do dist. Kangra	LB=SB, C, G, S, K	One	Gradient moderate Riffles and rapids are predominant, Banks stable.	No	Thick vegetation
6.	Awa (Banodu), dist. Kangra	1190, Satjaliya	SB=LB,C G, J, K	One	Gradient moderate, Riffles, rapids and runs are the habitat of stream, Banks stable, Two pools.	Channalization for agriculture.	Fairly thick
7.	Neugal (Latwala), dist. Kangra	970, Thathari (Kandi)	*SB, C, G, LB, J	One	Riffle, Runs and rapids are the habitat of stream, Banks unstable.	Extraction of stones, on going Construction of new bridge.	Thick
8.	Neugal (Chimbalhar), dist. Kangra	1070,Do	*SB, LB, C, G, J	One	Gradient moderate, Predominated by riffles followed by run and rapids, Banks stable.	Extraction of stones, pebbles and stones, Domestic.	Uniform

S. No.	Stream	Altitude m asl) & Origin	Substratum	Channel	General Features	Pollution	Vegetation
9.	Neugal (Kandi), dist. Kangra	1295 Do	SB=LB, C, G, J	One	Gradient high, Pre-dominated by rapids and runs, Banks stable, Two pools, Bridge was coming up to connect the village.	Extracting stones and sand from right bank of stream.	Fairly uniform
10.	Mole (Malnu), dist. Kangra	770, Bandla	*G, J, C, K	One	Very shallow water.	Domestic	Scattered
11.	Baner (Pong Dam)	450, Near Mallha	*C, J, K, SB	One	Runs are the main habitat, One pool.	Domestic	Scattered
12.	Baner (Saddar), dist. Kangra	630, Do	*C,J, SB, LB	One	Runs are the main habitat of the stream, Banks unstable, One pool, Banks shallow and with water plants.	Domestic, Extraction of stones, Upstream is less polluted than down stream.	Uniform
13.	Baner (Mallha), Uniform	1280, Do	*C, LB, SB, G,J	One	Rapids and riffles are the main habitats.	Mining, Power House work going on.	Uniform
14.	Manuni (Gurkadi), dist. Kangra	670, Yol	*C, SB, J, G, LB	Two	Runs are main habitat of stream, Banks unstable; Three streams Manuni, Manjhi and Baner join at Kanyar village and are known as Sangam.	Domestic, Eutrophication of stream at one patch of stream, Channalization of stream at three sites.	Uniform
15.	Manjhi (Sanora, near Gaggal), dist. Kangra	690	*SB, LB, C, G, J	One	Predominated by runs and riffles, Two pools.	Domestic, One traditional Gharat.	Scattered
16.	Gaj Stream (Sukanada), dist. Kangra	420	*C, G, J, SB	One	Site open, Shallow water.	Extraction of stones, Domestic.	Scattered
17.	Gaj (Jerbala), dist. Kangra	510	*SB, LB, C, G, J	One	Rapids and runs are main habitat, Several ditches along bank having algal growth and inhabited by fish fry, Banks stable.	No	Uniform

S. No.	Stream	Altitude m asl) & Origin	Substratum	Channel	General Features	Pollution	Vegetation
18.	Khaouli (Rait), dist. Kangra	520	*C, SB, G, J, LB	One	Runs and riffles are major habitats.	Channalization	Uniform
19.	Khaouli (Darini), dist. Kangra	1160	*LB, SB, G, C, J	One	High gradient, Closed site, Rapids and riffles are main habitats, One pool, Banks stable.	No	Thick vegetation
20.	Baharal (Trilokpur), dist. Kangra	520	*SB, LB, J,G, C		Open site, Runs and rapids are the main habitat, Two pools.	Domestic	Scattered
21.	Bhaid (Kotla), dist. Kangra	530	*C, G, J, K	One	Smooth flowing shallow water and some patches of stream were dry and some isolated patches of stream with polluted water.	Domestic	Scattered
22.	Jabbar near Chakki, dist. Kangra	650, Ahar Khajan	*C,G, J, K	One	Stream is wide and open, with large hillock on one side of stream, One pool, Banks unstable.	Domestic	Scattered
23.	Chambi, dist. Knagra	720, Rajol	*J, C, G, SB	No	Site open with shallow water, Two pools, Banks stable.	Domestic	Scattered
24.	Dehar (Haar, Pong Dam), dist. Knagra	470	*C, G, J, SB	One	Site open, shallow water.	Extraction of stones	Uniform
25.	Dehari (Pong Dam), dist. Knagra	460	*C. J, K, SB	Two	Site open, Shallow water.	Extraction of stones, Domestic.	Scattered
26.	Beas River (Badanu) dist. Mandi	710, Beas Kund,	*LB, SB,C, G, J	One	Gradient moderate, Site open and predominated by runs and riffles.	Illegal poaching	Fairly uniform
27.	Beas River (Nine Mile), dist. Mandi	750, Do	*SB, J, C, LB, G,	One	Gradient moderate, Site open and predominated by runs and riffles and one pool.	Domestic	Scattered

S. No.	Stream	Altitude m asl) & Origin	Substratum	Channel	General Features	Pollution	Vegetation
28.	Jauni (Gada Nala), dist. Mandi	810, Devi Dad, Near Kamaru Nag	LB=SB, J, C, G	One	Site Closed, riffle, runs and rapids are the main habitat of stream, Several ditches on the left bank were occupied by sand and aquatic plants.	No	Thick vegetation
29.	Khoti Nalla, dist. Mandi	990, Parshar Lake	*LB, SB, C, G	One	High gradient, Site closed, sites dominated by runs and rapids, step pools.	Mining	Thick vegetation
30.	Uhl (Sat Mile), dist. Mandi	720, Near Lohari, Barot	*LB, SB, C, G, J	One	Site open, Runs and rapids are the main habitats.	Illegal poaching	Uniform
31.	Uhl (Tikkan), dist. Mandi	1500, Do	*LB, SB, C, G, J,	One	Rapids are the predominant habits of the stream, One pool inhabited by snow trout fishes.	No	Fairly uniform
32.	Uhl (Lahori), dist. Mandi	1650, Do	*LB, C, G, SB, J	One	Rapids are the predominant habits of the stream.	No	Thick vegetation
33.	Bakhali, dist. Mnadi	870, Janghali	*SB, C, G, LB,J	One	Gradient moderate, Site open and predominated by runs and riffles in upstream and water shallow in lower stream.	Illegal poaching, Fisherman community live on the bank of stream, Extraction of stones.	Uniform
34.	Rena (Tikru), dist. Mandi	860, Near Tikru	LB=SB, G, J, C	One	Gradient moderate, Predominated by rapids and riffles, Three tributaries Sukhad, Bajgar and Gugali join here and known as triveni.	No	Thick vegetation
35.	Rena (Makrodi), dist. Mandi	970, Do	*SB, C, G, J, LB	Two	Gradient high, Open and runs and rapids are the main habitats of stream, One Pool.	No	Fairly uniform

S. No.	Stream	Altitude m asl) & Origin	Substratum	Channel	General Features	Pollution	Vegetation
36.	Suhkad, dist. Mandi	Chattar Nallah	*SB, G, J, C, LB	One	Rapids and runs are main habitats, One pool.	Domestic	Fairly uniform
37.	Bajgar, dist. Mandii	870, Marol	*LB, SB, C, G, J	One	Runs and rapids are main habitats, Open site, Ditches along the stream with good number of fry.	Channalization, Extraction of stones etc.	Fairly uniform
38.	Gugali, dist. Mandi	1090, Dulab Nllah	*SB, C, G, LB, J	One	Gradient moderate, Runs are the main habitat of the stream.	Domestic (Polythene Bags).	Fairly uniform
39.	Nari, dist. Mandi	845, Harra Bag	*SB, C, G, J, LB	One	Gradient low Runs and riffles are the main habitats.	Tunnel has been raised for Bassi Power House.	Uniform
40.	Laghed (Jauni), dist. Mnadi	980, Jattir Dhar	*LB, SB, C, G, J,	One	Gradient moderate, Runs, Rapids and riffles are the main habitat of the stream.	Illegal (Bleaching Powder)	Fairly uniform
41.	Sohan, dist. Mandi	Risha	*J, C, G, K	One	Open site, shallow water and one pool was there.	Domestic, Extraction of stones.	Scattered
42.	Aronodi, dist. Mandi	1050, Jubaldhar	*SB, LB, C, G, J	One	Gradient moderate, Open site Runs and riffles are the main habitats, One pool.	No	Fairly uniform
43.	Tirthan, dist.Kullu	950, Dathar	*SB, LB, C, G, J	One	Deep pools and site is dominated by rapids and riffles.	Water is polluted due to crashing of boulders, widening of road etc.	Fairly uniform
44	Choki, dist. Mnandi	1050	*LB, SB, J, G	One	Gradient high, Runs, riffles and rapids are the habitats of the stream.	No	Fairly uniform

LB = Large Boulder, SB = Small Boulder, C = Cobble, G = Gravel, J = Sand, K = Silt, = Equal Ratio, *= Dominant Material

CATCH COMPOSITION AND CATCH PER UNIT EFFORT

The catch composition of *Schizothorax richardsonii* (Gray) in different stream sites depicts its abundance mostly in the winter months followed by Post-Monsoon and least in summer (Table 2-6). The maximum fish population was recorded in Binwa, Poon, Baner, Gaj and Khaouli during winter months while in Sansal and Awa streams it was observed during Post-Monsoon. The snow trout fauna in district Kangra was recorded from different tributaries in the order of :

Binwa > Neugal> Sansal> Poon> Awa> Khaouli> Baner> Manuni> Gaj

Schizothorax richardsonii (Gray) was recorded in maximum numbers at all the stream sites in winter in district Mandi (Table-4, 5) and least in summer. During summer, the streams at higher elevations remarkably showed good fauna *i.e.* at Uhl and Arnodi stream while at lower reaches it could not be noticed. It infers that fish migrates to higher elevation when the temperature rises. The maximum fishery was also correlated with the deep pools in the vicinity of the site. The maximum fauna was recorded from Arnodi. The fauna recorded is in order of :

Arnodi> Khoti> Uhl> Basgar> Rena> Gugali> Nari> Sukhad

At Nari stream near Bassi Power House during summer months water are used for hydroelectric project and stream get dried, huge mortality of snow trout fingerlings was noticed. Likewise, at Baner stream also due to Shannon Hydroelectric Project the fish is loosing its habitat. Due to the impoundment of the Beas River at district Kangra (Pong Reservoir) and district Mandi (Pandoh Reservoir), the fishery is adversely affected. The migratory routes of the fish have been influenced. It was once the predominant fish in the River (Kumar, 1999), but during the study period no snow trout fish could be collected from the reservoir as well as upstream of Pong Dam. Further, in Beas River, downward of Pandoh Reservoir, district Mandi it was rarely recorded. However, before the construction of the Pong and Pandoh Dam, Beas River was considered as the paradise for the anglers.

The catch composition was found directly correlated with catch per unit effort. The catch per unit effort varies from Nil to 0.72. These data depict that still there are good number of *Schizothorax richardsonii* (Gray) exist in the tributaries and in the main river. However, over fishing in the main river has led to decline in its stock.

Table-2 : Catch Composition and Catch per unit efforts of *Schizothorax richardsonii* (Gray) from tributaries of Beas River, dist. Kangra during winter

Site	Stream	Altitude (m)	Coordinates	*Schizothorax richardsonii*	CPUE	Others
1	Binwa stream (Majherana)	810	N 32° 02' 33.7" E 076° 37' 36.7"	18	0.57	-
2	Binwa stream (Kandanallha)	964	N 32° 03' 13.5" E 076° 38' 53.4"	02	0.024	-
3	Sansal stream (Sal)	1275	N 32° 03' 58.0"E E 076° 41' 42.9"	01	0.024	-
4	Poon stream (Tharu)	970	N 32° 03' 35.2" E 076° 37' 33.6"	03	0.031	10
5	Poon stream (Sarsowa, Near Neelkanth)	990	N 32° 05' 17.4" E 076° 35' 34.9"	12	0.66	-
6	Neugal stream (Chimbalhar)	1070	N 32° 06' 54.4" E 076° 30' 26.8"	07	0.42	-
7	Baner stream (Mallha, Near Jiya Power house)	1280	N 32° 09' 59.5" E 076° 28' 08.6"	03	0.27	-
8	Baner stream (Saddar)	630	N 32° 05' 55.6" E 076° 17' 16.1"	02	0.03	11
9	Manuni stream (Gurkadi)	670	N 32° 07' 39.4" E 076° 17' 13.0"	05	0.22	16
10	Manjhi stream (Sanora, Near Gaggal)	690	N 32° 09' 18.9" E 076° 16' 05.2"	-	-	14
11	Gaj stream (Jerbala)	510	N 32° 08' 44.4" E 076° 11' 47.0"	03	0.45	18
12	Khaouli stream (Near Rait)	520	N 32° 08' 50.6" E 076° 11' 17.7"	02	0.21	03
13	Khaouli stream (Drini)	1160	N 32° 16' 42.2" E 076° 12' 28.0"	13	0.6	-
14	Baharal stream (Near Trilokpur)	520	N 32° 13' 49.6" E 076° 05' 01.8"	-	-	-
15	Bhaid stream (Near Kotla)	530	N 32° 15' 42.0" E 076° 01' 33.8"	-		22
16	Barahal stream (Battis Meal)	520	-			08

Table-3 : Catch Composition and Catch per unit efforts of *Schizothorax richardsonii* (Gray) from Beas River, dist. Kangra during Post-Monsoon

Site	Stream	Altitude (m)	Coordinates	*Schizothorax richardsonii*	CPUE	Others
1.	Poon stream (Sarsowa, Near Neelkhanth)	990	N 32° 05' 17.4" E 076° 35' 34.9"	05	0.34	0.34
2.	Awa stream (Banodu)	1190	N 32° 05' 28.0" E 076° 34' 41.1"	16	0.57	0.57
3.	Neugal stream (Kandi)	1295	N 32° 08' 08.9" E 076° 32' 01.7"	21	0.61	0.61
4.	Neugal stream (Latwala)		N 32° 06' 32.7" E 076° 29' 15.6"	04	0.21	0.21
5.	Binwa stream (Rainwari)	750	N 32° 00' 56.1" E 076° 37' 04.7"			-
6	Binwa stream (Majherana)	810	N 32° 02' 33.7" E 076° 37' 36.7"	16	0.61	0.61
7.	Binwa stream (Raid)	860	N 32° 02' 55.5" E 076° 39' 18.0"	01	0.002	0.002
8.	Sansal stream (Sansal)	1275	N 32° 03' 58.0" E 076° 41' 42.9"	22	0.67	0.67
9.	Mole stream (Malanu)	770	N 32° 01' 50.8" E 076° 31' 02.7"			
10.	Baner stream (Saddar)	630	N 32° 05' 55.6" E 076° 17' 16.1"		-	
11.	Munani stream (Gurkadi)	670	N 32° 07' 39.4" E 076° 17' 13.0"	-	-	-
12.	Baner stream (Upstream)	690		02	0.16	0.16
13.	Manjhi stream (Smeerpur)	690	N 32° 09' 18.9" E 076° 16' 05.2"	-	-	-
14.	Kahaouli stream (Darini)	1160	N 32° 16' 42.2" E 076° 12' 28.0"	02	0.06	-
15.	Jabbar stream (Near Chakki)	650	N 32° 18' 13.4" E 075° 53' 22.9"	-	-	08
16.	Chambi stream (Chambi)	720	N 32° 11' 28.3" E 076° 13' 16.7"	01	0.025	19

Table-4 : Catch Composition and Catch per unit efforts of *Schizothorax richardsonii* (Gray) Beas River, dist. Mandi during winter.

S. N.	Stream	Altitude (m)	Coordinates	*Schizothorax richardsonii*	CPUE	Others
1.	Beas River (Nine Mile)	750	N 31° 42' 23.4" E 077° 02' 01.3"	-	-	-
2.	Beas River (Teen Peepal)	730		03	0.07	5
3.	Jauni Khud (Gada Nala)	790	N 31° 39' 27.5" E 077° 02' 52.0"	04	0.019	-
4.	Khoti stream	990	N 31° 41' 36.0" E 077° 06' 32.9"	28	0.61	4
5.	Uhl stream (Sat Mile)	720		03	0.12	-
6.	Beas River (Badanu)	710	N 31° 42' 23.4" E 077° 02' 01.3"	-	-	-
7.	Bakhali stream	870		07	0.28	8
8.	Rena stream	860	N 31° 52' 31.3" E 076° 47' 58.7"	24	0.67	-
9.	Sukhad stream (Sainthal)	990	N 31° 59' 13.1" E 076° 44' 52.0"	07	0.42	-
10.	Bajgar stream	870	N 31° 58' 35.7" E 076° 45' 54.0"	14	0.51	-
11.	Gugali stream	1090	-	21	0.62	-
12.	Nari Khud (Near Basi Power House)	845	-	20	0.52	5

Table-5 : Catch Composition and Catch per unit efforts of *Schizothorax richardsonii* (Gray) from Beas River, and tributries dist. Mandi during Post-Monsoon

S. N.	Stream	Altitude (m)	Coordinates	*Schizothorax richardsonii*	CPUE	Others
1.	Tirthan stream	950	N 31° 42' 43.3" E 077° 15' 11.5"	08	0.31	02
2.	Beas River	750	N 31° 42' 23.4" E 077° 02' 01.3"	02	0.06	-
3.	Jauni stream (Gada Nala)	790	N 31° 39' 27.4" E 077° 02' 52.0"	-	-	03
4.	Khoti stream	990	N 31° 41' 36.0" E 077° 06' 32.9"	16	0.72	02
5.	Sukhad stream	990	N 31° 59' 13.1" E 076° 44' 52.0"	05	0.48	-
6.	Bajgar stream	870	N 31° 58' 35.7" E 076° 45' 54.0"	18	0.54	08
7.	Uhl stream	1500	N 31° 58' 06.0" E 076° 53' 19.5"	25	0.59	03
8.	Choki stream	1050	N 31° 44' 53.7" E 076° 47' 42.3"	25	0.58	03
9.	Arnodi stream	1050	N 31° 44' 52.9" E 076° 52' 00.4"	23	0.61	05

Table-6 : Catch Composition of *Schizothorax richardsonii* (Gray) from tributries of Beas River dist. Kangra, Mandi and Kullu during summer

S.N.	Stream	Altitude (m)	Coordinates	*Schizothorax richardsonii*	CPUE	Others
1. 30	Gaj stream (Pong Dam)	420	N 32° 03' 21.9" E 076° 05' 42.6"			-
2.	Dehar stream (Pong Dam)	470	N 32° 08' 39.1" E 076° 01' 23.3"	-	-	10
3.	Dehari stream (Pong Dam)	460	N 32° 05' 49.51" E 076° 03' 38.2"			17
4.	Baner stream (Pong))	450	N 32° 00' 15.6" E 076° 09' 28.7"	-		09
5.	Sukhad stream (Mandi)	990	N 31° 59' 13.1" E 076° 44' 52.0"	2	-	19
6.	Barot stream (Kangra)	1807	N 32° 01' 59.8" E 076° 50' 56.6"	2		02
7.	Uhl stream (Lohari)	2015	N 32° 04' 35.8" E 076° 51' 32.8"	-	-	05
8.	Uhl stream (Tikkani)	1500	N 31° 58' 06.0" E 076° 53' 19.5"	12	0.41	12
9.	Arnodi stream	1050	N 31° 44' 52.9" E 076° 52' 00.4"	21	0.50	41
10.	Gyun stream (Dharmpur)	1150	N 31° 46' 22.7" E 076° 48' 09.3"	04	0.067	23

SPECIES ASSOCIATION

The species association of *Schizothorax richardsonii* (Gray) was mainly observed with *Barilius bendelisis* (Hamilton-Buchanan) and *Barilius barila* (Hamilton-Buchanan) at Poon, Awa, Binwa, Sukad and Jauni stream in pools and torrential streams. At stream sites *viz.* Sukhad, Poon, Jauni *Puntius ticto* (Hamilton-Buchanan), *Tor putitora* (Hamilton-Buchanan), *Acanthocobitis botia* (Hamilton-Buchanan), *Schistura horai* (Menon) were observed with snow trout association in the down streams in deep pools and undertones. However, its association was also recorded with *Crossocheilus latius latius* (Hamilton-Buchanan), *Puntius sarana sarana* (Hamilton-Buchanan) and *Garra gotyla gotyla* (Gray) (Table-7).

Only *Salmo trutta fario* (Smith and Stearby) could be recorded above the altitude of 2000 m asl in the Lahori stream (Barot).The *Schizothorax richardsonii* (Gray) was observed with *Oncorhynchus mykiss* (Linnaeus) and *Salmo trutta fario* (Smith and Stearby) from Beas River, Khoti, Uhl, Tirthan and Sainj streams with altitude ranging from 800-1500 m above msl. Generally, the trouts are mainly recorded above 1500 m above msl. These trout fishes have also intruded into the snow trout Fish Zone. Since the trout fishes are carnivorous and feed upon the fries and fingerlings of *Schizothorax richardsonii* (Gray) and it is only the native fish of commercial importance in these streams. Thus, in the near future the population of

this fishery may decline in these streams. However, other species associated with this fishery are found to live in harmony. The association of *Schizothorax richardsonii* (Gray) and altitude wise distribution of fish fauna has been documented in (Table-7).

Table-7 : Association of *Schizothorax richardsonii* (Gray) and altitude wise distribution of Fish Fauna from Beas River

S. N.	Altitude (m asl)	Streams	Fishes
1.	>2000m	Uhl (Lohari)	*Salmo trutta fario* Linnaeus
2.	> 1251	Uhl (Tikkan), Uhl (Barot) Sansal (Sal), Baner (Mallha), Neugal (Kandi)	*Schizothorax richardsonii* (Gray) *Salmo trutta fario* Linnaeus *Schizothorax richardsonii* (Gray)
3.	1250-951	Khoti Binwa (Kandanallha), Poon (Tharu, Sarsowa), Khaouli (Darini), Awa (Banodu), Gugali, Sukhad, Arnodi, Gyun	*Schizothorax richardsonii* (Gray) *Salmo trutta fario* Linnaeus *Onchorhynchus mykiss* Smith & Stearby *Schizothorax richardsonii* (Gray)
4.	950-751	Binwa (Majherana, Raid), Jauni (Gada Nallha), Bakhali, Rena, Bajgar, Nari (Near Basi).	*Schizothorax richardsonii* (Gray) *Tor putitora* (Hamilton-Buchanan) *Crossocheilus latius latius* (Hamilton-Buchanan) *Garra gotyla gotyla* (Gray) *Schistura horai* (Menon) *Acanthocobitis botia* (Hamilton-Buchanan) *Barilius bendelisis* (Hamilton-Buchanan) *Barilius vagra vagra* (Hamilton-Buchanan) *Barilius barila* (Hamilton-Buchanan)
5	750-500	Baner (Sadder), Manuni (Gurkadi), Manjhi (Sanora), Gaj (Jerbala), Khaouli (Rait), Bahral (Trilokpur, Battis Meal), Bhaid (Battis Meal), Gaj Stream (Jeervala).	*Schizothorax richardsonii* (Gray) *Barilius bendelisis* (Hamilton-Buchanan) *Barilius vagra vagra* (Hamilton-Buchanan) *Barilius barila* (Hamilton-Buchanan) *Tor putitora* (Hamilton-Buchanan) *Schistura horai* (Menon) *Acanthocobitis botia* (Hamilton-Buchanan) *Crossochielus latius latius* (Hamilton-Buchanan) *Puntius sarana sarana* (Hamilton-Buchanan) *Garra gotyla gotyla* (Gray) *Glyptothorax pectinopterus* (McClelland)
6.	<500	Gaj, Dehar, Dehari, Baner	*Barilius bendelisis* (Hamilton-Buchanan) *Barilius vagra vagra* (Hamilton-Buchanan) *Barilius barila* (Hamilton-Buchanan) *Puntius ticto* (Hamilton-Buchanan) *Puntius sophore* (Hamilton-Buchanan) *Tor putitora* (Hamilton-Buchanan) *Acanthocobitis botia* (Hamilton-Buchanan) *Mastacembalus armatus* (Lacepede) *Brachydanio rerio* (Hamilton-Buchanan) *Rasbora daniconius* (Hamilton-Buchanan) *Channa marulius* (Hamilton-Buchanan) *Channa punctatus* (Bloch) *Xenentodon cancilia* (Hamilton-Buchanan)

CLIMATIC CHANGE VERSUS FISH RICHNESS

The present studies showed that snow trout inhabit in the altitude range of above 750 m asl. Further, its population is more in the higher elevations. However by the previous workers *viz.* Talwar (1978), Tilak (1987), it has been recorded at an altitude of 670 m asl. It seems that in the recent years its altitude range has changed and it is correlated with the slow rate of change of climate. This slow rate of climatic change may be due to urbanization, industrialization *etc.* Kulkarni *et al.* (2002) working on the Beas River, reported that there is substantially increasing trend of average degree days from 6.2 to 8.4 between 1983 & 2001 and linked this with overall increase in average global temperature. The snow trout fishes have the tolerance range of temperature from 8-22°C in Himachal Pradesh (Baloni and Tilak, 1983).Temperature more than that of the tolerance range has been recorded during the present investigation at the altitude range, where already fauna was recorded (Table-8, & 9). Due to change of temperature both abiotic and biotic components get distorted.

ABIOTIC COMPONENT

Climate

The climate includes mainly three seasons *i.e.* summer, monsoon and winter. The summer comprises the months (March to June), Monsoon (July-August) and winter (November-February). The temperature decreases with the increase in altitude.

Water Colour

All the stream sites being snow fed remained clear and transparent in the study period except during rain fall when accumulation of allochthonus material; increases the siltation rate and results in a dirty colour (turbid). However, water imparts green tinge due to algal deposition at the bottom.

Temperature

Temperature is one of the important components which affect biota and all other parameters. Feeding, breeding, respiration and all other physiological parameters are influenced by it. The temperature is generally regarded as one of the important factor in the aquatic ecology and no other single factor has such profound influence (Ruttner, 1953).

The altitudinal gradation of different stream sites varies from 510 to 1160 m asl in district Kangra. The air temperature in different stream sites in district Kangra varies from 19-37.4°C. The mean of maximum was recorded at Poon followed by Khaouli, Gaj, Binwa, Neugal and Baner. The water temperature varies from 12 to 26.7°C at different stream sites. The peak values were recorded at Baner followed by Poon, Gaj, Binwa and Neugal and least in Khaouli stream. The maximum values were recorded during summer months at all the stream sites. The amplitude of variation is less in winter and it is more pronounced in summer months.

The altitudinal gradation in different stream sites in district Mandi varies from 750-1500 m asl. The air temperature in the stream sites varies from 10-36°C and water temperature

varies from 7-25.8°C. The mean of maxima of water temperature was recorded at Sukhad followed by Jauni, Arnodi, Beas River and Uhl. It is not in accordance with the air temperature. It has been found that in the streams in both the districts during summer the difference between atmospheric and water temperature is about 10°C or more. This variation may be due to the topography of the stream sites since high gradients, water current, presence of big boulders and stony bed *etc.* minimize the water temperature in comparison to air temperature.

Water Velocity

The volume of water in a stream moving down a slope at a given time is known as stream flow or stream discharge. The water velocity is affected by three factors, namely the steepness of the gradient of the stream, the width of the channel and depth of water.

The water velocity under study period in dist. Kangra varied from 0.42 to 1.2 m/sec. The highest velocity was recorded in Binwa and Kahouli 1.2 and 1.05 respectively in winter season and is positively correlated with the abundance of *Schizothorax richardsonii* (Gray). The mean values were also highest at these stream sites. It was comparatively less in the Poon, Baner and Neugal stream throughout the study period and average values recorded were 0.47, 0.56 and 0.63 m/sec. respectively. Dhanze *et al.* (1998) has recorded water velocity in Poon, Baner and Neugal stream to be 0.49, 0.61 and 1.21 m/sec. respectively. Thus, the water velocity recorded at these sites has reduced over the years, which has adversely affected the snow trout fishery.

The water current in selected stream sites in district Mandi varied from 0.45 to 1.2 m/ sec., (Table-9) which is comparatively more than that of the tributaries of the district Kangra. The highest of mean values were recorded at Uhl followed by Beas River, Arnodi, Sukhad and Jauni and is positively correlated with the abundance of the snow trout fishery.

In the present investigations, the velocity and turbidity showed a direct relationship. The turbidity was observed to be nil when the velocity of the streams was least in winter season. Similar observations have been recorded by Dobriyal (1981) and Nautiyal (1985) in the snow fed rivers of Garhwal Himalaya.

pH

It is the negative logarithm of hydrogen ion concentration. Pure water is neutral and its pH is 7. Water with pH less than 7 is acidic and greater than 7 is basic or alkaline.

The pH remained alkaline through out the study period, however it fluctuated between 6.5 to 7.5 at site-I, 7.1 to 8.0 at site-II, 6.8 to 7.7 at site-III, 6.5-7.5 at site-IV, 6.5 to 7.0 at site V and 7.0 to 7.9 at site –VI (Table-8) in district Kangra and in the tributaries of district Mandi its range varies from 7.2 to 8.0 at site-I, 6.5- 7.8 at site-II, 7.0-7.8 at site-III, 7.0 to 7.8 at site-IV and 6.8 to 8.0 at site-V (Table-9). The narrow range of variation in pH at all the sites was recorded. The range from 5.0 to 6.6 and 9.1-11.0 results in the low productivity (Sreenivasan, 1978). Ellis (1937) had observed that pH range of 6.7 to 8.4 is suitable for the growth of the fish. Thus, the pH recorded at all the stream sites is conducive for the fish.

Dissolved Oxygen

Dissolved oxygen is an essential parameter to assess the health of water body. Oxygen enters in the water from atmosphere and through aquatic plant and phytoplankton photosynthesis. The overload of the nutrients from overgrowth of plankton and human activities ultimately settle at the bottom and decompose by using up oxygen. Venkateswarulu (1969) was of the opinion that dissolved oxygen is inversely related to the quantity of the oxidisable matter in water.

The dissolved oxygen at different stream sites varies from 6.5 to 11.25 mg/l at district Kangra and 7.0 to 12.5 mg/l at district Mandi. The dissolved oxygen content was recorded highest in winter months and its peak values were recorded at Neugal (9.2 mg/l), 8.9 mg/l at Binwa and baner in the month of November at district Kangra and 12.0 mg/l at Arnodei, 10.5 mg/l at Uhl and Beas River in month of December at district Mandi. The altitude of these stream sites is comparatively more and colder water bodies have more oxygen holding capacity. Verma *et al.* (1984) reported that the tendency of the dissolved oxygen to increase during winter months might be due to low temperature and confirmed the present findings. Further, the dissolved oxygen concentrations showed an inverse relationship with temperature during the present studies. Sreenivasan (1969) reported that in low productive waters, the dissolved oxygen curve is governed by temperature but in productive waters it is actually parallel to the primary productive curve. During summers the value of dissolved oxygen were found least and the values fluctuated between 6.5 to 7.9 mg/l at district Kangra and between 7.0 to 10.8 mg/l in district Mandi. According to Banerjee (1967) for average and good productivity water bodies should have dissolved oxygen concentration above 5.00 mg/l. The streams under present study have dissolved oxygen above 6.9 mg/l and are conducive for fish. A minimum concentration of 5 mg/l of dissolved oxygen has been considered necessary to maintain the fish fauna of a water body (Trivedy *et al.* 1990). The depletion of the dissolved oxygen during summer might be due to the higher metabolic rate of lentic forms and also due to low solubility of this gas at higher temperature (Verma *et al.* 1984).

During the present studies it was found that in the summer months when the temperature increases and dissolved oxygen decreases, no snow trout fish could be collected at lower elevations while in winter they were recorded from the same stream sites. Further, at higher elevations *i.e.* Uhl (1500 m), Arnodi (1050 m), Neugal (1295 m), Kahouli (1160 m), during summer also good population of snow trout fishes was recorded, which depict that fishes migrates in the upstream during summer months. Sehgal (1990) reported that in stenothermal fish species like Schizothoracids and trouts, the rate of metabolism rises rapidly with increase in temperature and confirms with the present studies. Sehgal (*opcit*) also reported that *Schizothorax richardsonii* (Gray) undertake long distance migration in rivers like Beas and Satluj from Greater Himalayas to Siwalik regions.

Alkalinity

In natural waters (streams), the dissolved carbondioxide/bicarbonate/carbonate system forms a reservoir of carbon for photosynthesis of aquatic plant life.

The value of alkalinity varies from 42-58 mg/l at district Kangra. The maximum value at Binwa and Khaouli was 58 mg/l (March) and 57 mg/l (November) respectively was recorded during the study period. The values of alkalinity at the different stream sites in district Mandi varies from 30-88 mg/l at site-I, 36-65 mg/l at site-II, 38-74 mg/l at site-III, 66-105 mg/l at site-IV and 64-94 mg/l at site-V. The mean of maxima was recorded at Uhl followed by Arnodi, Beas, Sukhad and Jauni stream (Table-9). The higher values of alkalinity were well correlated with the abundance of the snow trout fishery. The values of alkalinity were found directly related with dissolved oxygen concentration. Spence (1964) classified streams into three categories as: a) 1-15 mg/l- nutrient poor, b) 16-60 mg/l-moderately rich c) >60 mg/l-nutrient rich. On this basis the streams studied comes under the category of moderately rich nutrient.

Free Carbondioxide

Carbon dioxide is essential for the photosynthesis and its concentration affects the fish, especially when the dissolved oxygen is low.

Their value varies from 06 mg/l to 16 mg/l at site-I, 06 mg/l to 10 mg/l at site-II, 05 mg/l to 6.5 mg/l at site-III, 05 mg/l to 15 mg/l at site-IV, 7 mg/l to 10 mg/l at site-V and 5.0 mg/l to 12 mg/l at site-VI (Table-8). The comparatively higher values were recorded at Poon (16 mg/l) and Baner (15 mg/l) during summer and are attributed to the anthropogenic stresses.

The fluctuation of values in the tributaries of district Mandi were recorded from 2.0 mg/l to 18.0 mg/l at site-I, 2.0 mg/l to 12 mg/l at site-II, 2 mg/l to 15 mg/l at site-III, 4 mg/l to 6.0 mg/l at site-IV and 5.8 mg/l to 10.0 mg/l at site-V (Table-9). The lowest values were recorded during the winter. An inverse relation between carbon dioxide and dissolved oxygen was observed during the study period which is in concurrence with Ganpati (1943); Gonzalves and Joshi (1946); Rao (1955); Saha *et al.* (1959); Mandal and Hakim (1975) and Khan and Siddiqui (1971). However, Singh (1960); Munawar (1970 a, b); Mehra (1976) and Zutshi and Vass (1978) obtained a direct relation between the two. The mean value varies from 3.9 mg/l to 8.33 mg/l in district Kangra and 5-11.67 mg/l in district Mandi. The values remained low and therefore can be attributed to the medium productivity of the streams.

Chloride

The chloride concentration at different sites varies from 8-14 mg/l at site-I, 5-9 mg/l at site-II, 6-11 mg/l at site-III, 8-15 mg/l at site-IV, 5-10 mg/l at site-V and 6 to 15 mg/l at site-VI (Table-8) in district Kangra. The maximum value was recorded at Baner and Gaj (15 mg/l) in the month of November and May respectively. The minimum values were recorded during winter month at all the stream sites.

The fluctuation in the value of the chloride in different stream sites in district Mandi vary from 10-14 mg/l at site-I, 5-13 mg/l at site-II, 10-15 mg/lat site-III, 5-7 mg/l at site-IV and 6-10 mg/l at site-V (Table-9). The highest value was recorded during the month of January in Beas River (14 mg/l) and during the month of November and May 12 mg/l and 15 mg/l respectively were recorded at Sukhad stream. The higher values are indicative of the organic pollution of animal and human origin.

The mean lowest values were recorded at Neugal, Khaouli and Binwa in the streams of the district Kangra. The mean lowest values were recorded at Uhl and Arnodi stream in the streams of district Mandi. The values of the chloride were inversely related with the abundance of the *Schizothorax richardsonii* (Gray) during the study period. No uniformity in minimum and maximum values was recorded at different stream sites in different season. Verma *et al.* (1984) reported that there is a gradual increase in the chloride concentration from January-June. Precipitation and evaporation were the main factors governing this change. Chauhan (2002) reported the Chloride contents 18 to 28 mg/l as an integral part of eutrophication.

Thus, the higher value of chloride contents in the present study may be treated as index of pollution of animal origin, human interference and sewage wastes. Further, the increasing chloride concentration may be due to progressive eutrophication of aquatic ecosystem and a threat to snow trout fishery.

Salinity

The salinity in the different stream sites in district Kangra varies from 14.7 to 25.69 mg/l at sit-I, 9.2 to 16.52 mg/l at site-II, 10.86 to 20.18 mg/l at site-III, 14.68 to 27.75 mg/l at site-IV, 9.2 to 18.35 mg/l at site V and 11.0 to 27.52 mg/l at site-VI (Table-8). The mean of maxima was recorded at Gaj followed by Poon, Baner, Binwa, Khaouli and Neugal.

The fluctuation in the district Mandi was recorded from 18.35 to 25.69 mg/l at site-I, 9.03 to 23.85 mg/l at site-II, 18.35 to 27.52 mg/l at site-III, 9.17 to 12.84 mg /l at site-IV and 11.01 to 18.35 mg/l at site-V (Table-9). The mean of maxima was recorded at Sukhad followed by Beas River, Arnodi, Jauni and Uhl. The values of salinity are directly related to the chloride concentration.

Hardness

The hardness is a measure of calcium, magnesium and other metals in the fresh water. The range of variation at different stream sites recorded vary from 40-48 mg/l at site-I, 32-45 mg/l at site-II, 42-48 mg/l at site-III, 34-54 mg/l at site-IV, 36-47 mg/l at site-V and 38-49 mg/l at site-VI (Table-8) in district Kangra. Their maximum was recorded in the winter at site-II, III and IV and in the summer at site-IV, V and VI. The values of hardness in district Mandi varies from 45-60 mg/l at site-I, 50-62 mg/l at site-II, 48-68 mg/l at site-III, 50-58 mg/l at site-IV and 48-56 mg/l at site V (Table-9). The maxima here are recorded in summer at all the stream sites. It revealed that values of hardness are more in water of district Mandi than of district Kangra. Moyle (1946) has given 40 mg/l alkalinity as the separation point between soft and hard water. During the study period the values of alkalinity were more than 42 mg/l. Thus, it is revealed that water of all the stream sites is hard. Barrett (1953) and Verma *et al.* (1984) stated that hard waters are more productive than soft water. Therefore, it is inferred that the water of the streams are productive and conducive for the abundance of the snow trout fishery.

Productivity

The primary production of a water body is an important component for the estimation of the fish production potential. Biological production from any water body can be used as indices

of trophic status and fisheries potential (Jhingran, 1992). Productivity is influenced by water temperature and the amount of nutrients.

The gross productivity in district Kangra varies from 20.18 to 98.125 mgC/m^3/hr at site-I, 11.0 to 66.25 mgC/m^3/hr at site-II, 31.24 to 86.35 mgC/m^3/hr at site-III, 146.25 to 273.435 mgC/m^3/hr at site-IV, 26.06 to 39.065 mgC/m^3/hr at site-V and 93.75 to 156.25 mgC/m^3/hr at site-VI and the net productivity varies from 36.2 to 354.14 mgC/m^3/hr at site-I, 15.63 to 93.755 mgC/m^3/hr at site-II, traces to 156.35 mgC/m^3/hr at site-III, traces to 234.375 mgC/m^3/hr at site-IV, traces to 156.255 mgC/m^3/hr at site-V and 31.5 to 312.5 mgC/m^3/hr at site-VI (Table-8) under the study period at the different stream site. The maximum values of gross productivity were recorded during the month of March except at site-II and site-III where it was recorded during the month of May. As at site II and III being at higher elevation the population of snow trout fishes were recorded during the summer month also.

The range of the fluctuation in the gross productivity in district Mandi varies from 132.5 to 158.35 mgC/m^3/hr at site-I, 98.6 to 117.18 5 mgC/m^3/hr at site-II, 125 to 312.5 5 mgC/m^3/hr at site-III, 108 to 125 5 mgC/m^3/hr at site-IV and 68.13 to 97.5 mgC/m^3/hr at site-V. The fluctuation in the values of net productivity were recorded from traces to 68.35 mgC/m^3/hr at site-I, 36.2to 156.25 5 mgC/m^3/hr at site-II, traces to 117.185 mgC/m^3/hr at site-III, traces to 59.8 at site-IV and traces to 25.7 mgC/m^3/hr at site-V (Table-9). The peak values of gross primary productivity were recorded during the month of November except at site-II and site-V where it was recorded during the month of the January and May respectively.

The peak values of the primary productivity were associated with the moderate water velocity and the fairly good concentration of the dissolved oxygen. Sreenivasan (1964) recorded higher production during the poor lighting conditions and Khan *et al.* (1988) observed a decline in production when turbidity was high. The average value at the streams in the district Kangra recorded was 65.475 mgC/m^3/hr at site-I, 45.307 mgC/m^3/hr at site-II, 52.2 mg C/m^3/hr at site-III, 216.06 mgC/m^3/hr at site-IV, 31.49mgC/m^3/hr at site-V and 145.75 mgC/m^3/hr at site-VI. The average values recorded at district Mandi was 144.1 mgC/m^3/hr at site-I, 107.49 mgC/m^3/hr at site-II, 205.6 mgC/m^3/hr at site-III, 116 mgC/m^3/hr at site-IV and 81.25 mgC/m^3/hr at site-V. Therefore, mean of maximum of productivity were recorded in the streams at lower elevation than at higher altitude.

Lieth and Whittakar (1975) reported the trophic status on the basis of the primary productivity and opined that streams with 50-300 mgC/m^3/hr and 250-1000 mgC/m^3/hr comes under Oligotrophic and Mesotrophic nature respectively. Thus, most of the streams under study are Oligotrophic in nature. In general, the nutrients in the hill streams are generally in short supply. Though, the photic zone is up to bottom, even then the primary productivity is low due to the low temperature and fast current of water. The low productivity is directly correlated with higher elevations.

ABIOTIC COMPONENT VERSUS FISH RICHNESS

The study of ecology of the streams in relation to the abundance of fish is of chief importance in the development of the fishery resource in the hilly streams. Many of the abiotic factors like temperature; dissolved oxygen and substratum interact with one another and affect the distribution and abundance of the fish species. During the survey it was observed that *Schizothorax richardsonii* (Gray) was found only in the stony bottom. Temperature is one of the important ecological factor for hill stream fishes. It has been found that in stenothermal fish species *i.e.* in Schizothoracids the rate of metabolism rises fastly with increase in temperature. During the survey, good numbers of *Schizothorax richardsonii* (Gray) were collected between the temperatures 10 to 19°C. These fishes are found more active at low temperature. Sehgal (1990) reported that the Schizothoracids have an upper limit of tolerance around 20°C and undertake long distance migration in the rivers of Beas and Satluj from the great Himalayas to Shiwalik regions. In the present survey it was observed that the Snow trouts found in the up streams during the summer months.

During the survey of Beas Drainage System in district Mandi in winter season, it has been analysed that the population of *Schizothorax richardsonii* (Gray) is more abundant in the streams than the main river. The hydrobiological parameter ranges *i.e.* water temperature 7 to 13°C; pH 6.5 to 7.6; dissolved oxygen 8.75 to 12.5 mg/l and alkalinity 30 to 90 mg/l are conducive for the growth of the fish.

It has been explored that higher elevation, water velocity, low water temperature, alkalinity have the positive correlation while pH, hardness and chloride have the moderate correlation with the species richness. The productivity was negatively correlated.

Table-8 : Physico-Chemical Parameters of Selected Tributaries of Beas River (dist. Kangra), H.P.

	Site-I Poon stream	Site-II Neugal stream	Site-III Binwa stream	Site-IV Baner stream	Site-V Khaouli stream	Site-VI Gaj stream
Air Temperature (°C)	21-37.4 (28.8)	23-32.4 (27.13)	23-34 (28.33)	24-33.0 (26.33)	19-36.4 (28.47)	24-33 (28.33)
Water Temperature (°C)	17-25.5 (19.83)	13-20.2 (16.4)	16-24.2 (18.73)	18-26.7 (21.23)	12-22.2 (15.4)	16-25.7 (19.57)
Water Velocity (ms^{-1})	0.42-0.5 (0.47)	0.62-0.66 (0.63)	0.55-1.2 (0.82)	0.48-0.62 (0.56)	0.53-1.05 (0.77)	0.5-0.63 (0.58)
pH	6.5-7.5 (7.17)	7.1-8.0 (7.4)	6.8-7.7 (7.3)	6.5-7.5 (7.07)	6.5-7.0 (6.83)	7.0-7.9 (7.37)
DO (mg/l)	6.5-8.5 (7.75)	7.5-10.6 (9.2)	7.9-9.8 (8.9)	7.8-11.25 (8.9)	7.25-10.0 (8.35)	7.5-9.5 (8.42)
Alkalinity (mg/l)	42-56 (47.6)	44-54 (48.67)	51-58 (55.26)	42-50 (46)	46-57 (52.9)	45.6-55 (50.2)
Free CO_2 (mg/l)	06-16 (8.33	06-10 (5.67)	05-6.5 (3.9)	05-15 (5.7)	7.0-10 (7.33)	5.0-12 (7.1)
Total Hardness (mg/l)	40-48 (43.33)	32-45 (40.33)	42-48 (45.33)	34-54 (42.33)	36-47 (40.33)	38-49 (45)

	Site-I Poon stream	Site-II Neugal stream	Site-III Binwa stream	Site-IV Baner stream	Site-V Khaouli stream	Site-VI Gaj stream
Chloride (mg/l)	8.0-14 (10.73)	5.0-9.0 (7.0)	6.0-11 (9.0)	8-15 (10.3)	5.0-10.0 (7.6)	6-15 (11)
Salinity (mg/l)	14.7-25.69 (19.76)	9.2-16.52 (12.85)	10.86-20.18 (16.48)	14.68-27.75 (19.04)	9.2-18.35 (13.95)	11-27.52 (20.18)
GPP (mgC/m³/hr)	20.18-98.12 (65.47)	11.0-66.2 (45.31)	31.24-86.3 (52.2)	146.25-273.43 (216.06)	26.06-39.06 (31.49)	93.75-156.25 (145.75)
NPP (mg C/m³/hr)	36.2-354.14 (129.13)	15.63-93.75 (62.50)	Traces-156.3 (55.57)	Traces-234.37 (119.79)	Traces-156.25 (55.21)	31.5-312.5 (135.50)

Table-9 : Physico-Chemical parameters of Selected Tributaries of the Beas River (dist. Mandi), H.P.

	Site-I Beas River	Site-II Jauni stream	Site-III Sukhad stream	Site-IV Uhl stream	Site-V Arnodi stream
Air Temperature (°C)	16-32.4 (25.47)	13-34.8 (24.93)	10-36 (24)	17-30 (23)	19-29.4 (25.8)
Water Temperature (°C)	9-22.2 (16.4)	7-25.8 (17.27)	12-24 (18.67)	11-18.2 (15.07)	13-20 (17.13)
Water Velocity (ms^{-1})	0.63-0.82 (0.72)	0.45-0.65 (0.55)	0.50-0.61 (0.56)	0.52-1.2 (0.84)	0.58-0.72 (0.66)
pH	7.2-8.0 (7.57)	6.5-7.8 (7.27)	7.0-7.8 (7.37)	7.0-7.8 (7.5)	6.8-8.0 (7.50)
DO (mg/l)	7.5-12.5 (10.5)	7.0-12.0 (9.2)	7.5-8.75 (8.7)	10.5-12.5 (10.5)	7.8-12.0 (12.0)
Alkalinity (mg/l)	30-88 (57.67)	36-65 (51.67)	38-74 (56.33)	66-105 (87)	64-94 (74.33)
Free CO_2 (mg/l)	2-18 (11.67)	2-12 (8.0)	2-15 (9.67)	4-6 (5.0)	5.8-10 (7.93)
Total Hardness (mg/l)	45-60 (53.33)	50-62 (55.33)	48-68 (57)	50-58 (53.33)	48-56 (53.33)
Chloride (mg/l)	10-14 (12)	5-13 (8.17)	10-15 (12.33)	5.0-7.0 (5.67)	6.0-10.0 (8.57)
Salinity (mg/l)	18.35-25.69 (22.02)	9.03-23.85 (14.93)	18.35-27.52 (22.63)	9.17-12.84 (10.39)	11.01-18.35 (15.72)
GPP (mgC/m³/hr)	132.5-158.3 (144.1)	98.6-117.18 (107.49)	125.3-312.5 (205.6)	108-125 (116)	68.13-97.5 (81.25)
NPP (mg C/m³/hr)	Traces-68.3 (44.67)	36.2-156.25 (90.22)	Traces-117.18 (60.1)	Traces-59.8 (19.93)	25.7-273.4 (99.7)

BIOTIC COMPONENT

Plankton

Among the biotic community phytoplankton constitute the Ist stage in the trophic level. Phytoplankton plays an important role as food for herbivores and is biological indicators of water quality in pollution studies.

The variation of plankton at different stream sites is computed in the (Table-10, 11). Bascillariophyceae, Chlorophyceae, Cyanophyceae are the representatives of phytoplankton

groups. A total of 23 phytoplankton genera were encountered with most the dominant group being diatoms. The zooplanktons were represented by 11 genera.

During the studies the following phytoplankton and zooplanktons were identified from the different tributaries of the Beas River.

1. **Chlorophyceae** (Green algae) : *Spirogyra, Ulothrix, Tetraspora, Scenedesmus, Cosmarium, Mougeotia, Pediastrum, Zygnema, Closterium*

2. **Bascillariophyceae** (Diatoms): *Navicula, Cymbella, Fragillaria, Synedra, Coconeis, Gomphonema, Pinnularia, Nitzschia.*

3. **Cyanophyceae (Blue Green Algae) :** *Anabaena, Oscillatoria, Ankistrodesmus, Nostoc, Gyrosigma, Surirella.*

The zooplanktons are represented by four groups :

1. **Copepoda** : *Cyclops, Diaptomus, Nauplius*

2. **Cladocera** : *Daphnia, Moina*

3. **Rotifera** : *Keratella, Branchionus, Euchlanis, Fillinia*

4. **Protozoa** : *Euglena, Gonium*

Phytoplankton

The analysis of data revealed that phytoplankton dominates at all the sites throughout the period under study.

The **Bacillariophyceae** was the most dominant group among the phytoplankton. The annual standing crop of phytoplankton reveals that range of variation in district Kangra and Mandi is 10.1 to 32.2 u/l and 15.6 to 33.7 u/l. The peak values of diatoms in district Kangra and Mandi were recorded in the winter followed by post monsoon and summer. Hence, the highest values are recorded during the winter months in the present studies. Ojja (1986) recorded dominance of Bacillariophyceae 60-70% during the winter. Cyanophyceae during monsoon and Chlorophyceae during summer as the season progress. Pahwa and Mehrotra (1966) reported Bacillariophyceae preferred a temperature ranging from 15 to 26°C and 18 to 26° C respectively. During the present study the average temperature recorded varies from 15.07 to 21.23°C and thus is favorable for the growth of diatoms. The abundance of the diatoms in winter months is directly correlated with fairly good amount of dissolved oxygen and alkalinity and low water velocity. Diatoms species do not favor polluted water. The growth forms like *Fragillaria* species and *Gomphonema* species are regarded as the forms avoiding polluted conditions (Munawar, 1970b). Thus, the predominance of the bacillariophyceae is the indicator of the clean water and also supported by the abundance of the *Schizothorax richardsonii* (Gray). As the Snow trout fishes prefers clean and oxygenated water. Welch (1952) and Rao *et al.* (1993) accounted that diatoms are the characteristics feature of the lotic and clean water.

Chlorophyceae is the second group in the abundance and exhibited dominance in summer months in both the districts. The summer peak of Chlorohyceae was higher than other months. However, Dhanze *et a*l. (2001) recorded the winter peak of Bacillariophyceae, Chlorophyceae and Myxophyceae. The present findings are in concurrence with Verma *et al.* (1984), who reported that the abundance of the Chlorophyceae is more during the summer months due to high temperature.

The **Cyanophyceae** is recorded scantily and sometimes also absent at different stream sites in both the districts (Table-10, 11).

Zooplankton

Zooplankton is a very important food source for fry and fingerlings. Turbidity caused by phytoplankton (microscopic plants) and zooplankton (microscopic animals) is not directly harmful to fish. Phytoplankton (green algae) not only produces oxygen, but also provides a food source for zooplankton and fishes.

The zooplankton comprising Protozoa, Copepoda, Cladocera were sparsely distributed in the study period (Table -10, 11). Trisal (1987) stated that in general population of zooplankton is low, presumably due to lower phytoplankton density and confirms with the present investigation as the density of phytoplankton is comparatively very less. Dhanze *et al.* (2001) found that zooplankton exhibit inverse relation with the phytoplankton and the function of the planktons are taken by the periphyton in the hill streams.

Benthos

The benthic fauna plays a significant role in the trophic status, as they utilize all forms of food and form an important link in the transfer of energy. The part played by benthic organism as a link in the food chain and transfer of energy has been stressed by Oomachan and Belsare (1984).

8 orders of Phylum Arthropoda, Mollusca and Annelida were recognized (Table-12, 13). Ephemeroptera was the dominant group throughout the study period. Among the 8 orders, only two exhibit their abundance throughout the study period. The orders Ephemeroptera and Trichoptera constituted the major benthic fauna while others Coleoptera, Diptera, Hemiptera, Plecoptera and Neuroptera were sparsely distributed (Table-12, 13).

BIOTIC COMPONENT VERSUS FISH RICHNESS

Biotic community plays an important role in the production process of the water and fishes are mostly dependent on these communities (Saltan *et al.* 2003). Ephemeroptera and Trichoptera were recorded maximum at site-I in district Kangra while in district Mandi its maximum were recorded at site-III in winter months. The higher values were correlated with comparatively less water velocity, transparency and temperature in winter months (Table-8, 9). The planktonic and benthic fauna was reported maximum during winter month and correlated with the abundance of snow trout fishery in the present study and negatively correlated with the diversity of fishes. However, Dobriyal *et al.* (2002) reported that maximum

Table-10 : Variations in Plankton abundance at Selected Stream Sites of Beas River (dist. Kangra).

	Winter						**Post-Monsoon**						**Summer**					
Site No	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Phytoplankton	**28.5**	**31.2**	**27.9**	**31.9**	**26.4**	**24.6**	**21.6**	**9..9**	**11.7**	**18.9**	**25.9**	**24**	**25.7**	**15.4**	**15.0**	**19.4**	**11.8**	**23.9**
Bacillariophyceae	24.8	29.7	26.7	31.2	23.1	19.7	21.5	6.7	10.3	18.2	20.1	15.2	19.5	10.3	8.5	6.2	9.5	9.7
Chlorophyceae	3.7	1.3	-	6.7	3.2	4.7	-	3.2	1.2	0.7	5.6	7.8	5.7	4.8	5.3	13.2	2.3	14.2
Cyanophyceae	-	0.2	1.2	-	0.1	0.2	0.1	-	0.21	-	0.2	1.0	0.5	0.3	1.2	-	-	-
Zooplankton		1.3	0.2	-	0.7	-	0.73	0.2	0.2	0.3	0.5	0.5	-	0.7	0.2	0.5	-	0.5
Copepoda	-	1.0	0.2	-	-	-	0.5	-	-	-	0.2	0.3	-	0.5	0.2	0.5	-	0.5
Cladocera	-	-	-	-	0.5	-	0.23	-	-	0.2	-	-	-	0.2	-	-	-	-
Rotifera	-	-	-	-	0.2	-	-	0.2	0.21	0.1	-	-	-		-	-	-	
Protozoa	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-
Total Plankton (no/l)	**28.5**	**32.2**	**30.1**	**31.9**	**27.1**	**24.6**	**22.33**	**10.1**	**11.91**	**19.2**	**26.4**	**24.5**	**25.71**	**16.1**	**15.2**	**19.9**	**11.8**	**24.4**

Table-11. Variations in Plankton abundance at Selected Stream Sites of Beas River (dist. Mandi)

	Winter					Post-Monsoon					Summer				
Site No	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Phytoplankton	**22.0**	**17.2**	**19.9**	**20.3**	**20.4**	**24.5**	**25.4**	**30.2**	**31.4**	**33.2**	**20.7**	**15.3**	**16.9**	**20.2**	**21.0**
Bacillariophyceae	20.5	17.2	16.5	17.5	20.2	21.5	24.8	26.7	28.7	28.5	16.2	9.8	8.7	13.2	14.8
Chlorophyceae	1.4	-	3.2	2.5	0.2	2.7	0.2	3.2	2.7	4.7	4.3	5.2	7.8	6.7	5.6
Cyanophyceae	0.1	-	0.2	0.3	-	0.3	0.4	0.3	-	-	0.2	-	0.2	0.3	-
Zooplankton	0.2	0.1	0.2	-	0.1	0.7	1.2	0.7	-	-	-	0.3	0.8	-	0.6
Copepoda	0.2	0.1	-	-	-	0.2	1.2	0.5	-	-	-	0.3	0.8	-	0.3
Cladocera	-	-	0.2	-	-	-	-	0.2	-	-	-	-	-	-	0.2
Rotifera	-	-	-	-	0.5	0.5	-	-	-	-	-	-	-	-	-
Protozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Total Plankton (no/l)	**22.2**	**17.3**	**20.1**	**20.3**	**20.5**	**25.2**	**26.6**	**30.9**	**31.4**	**33.7**	**20.7**	**15.6**	**17.7**	**20.2**	**21.6**

Table-12. Variations in Benthos abundance at Selected Stream Sites of Beas River (dist. Kangra)

	Winter						**Post-Monsoon**						**Summer**					
Site No	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Arthropoda																		
Ephemeroptera	102	58	68	97	48	90	85	44	61	83	37	82	60	35	52	65	38	45
Trichoptera	35	13	12	35	15	2	13	15	12	22	10	8	12	8	5	6	7	12
Coleoptera	8	1	-	2	-	1.5	5	-	-	-	-	1.0	2.0	3.0	2.0	2.0	1.0	1.2
Diptera	-	-	-	2.3	-	1.5	2.0	-	-	1.5	-	-	1.0	1.5	-	-	-	-
Odonata	-	-	-	-	-	-	-	1.0	-	0.5	-	-	2.0	-	3.0	1.0	2.0	-
Plecoptera	1.0	-	-		1.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera	3.0	1.0	-	2.0-	2.5	1.0	-	-	-	-	-	1.0	1.0	2.0	3.0	1.5	-	-
Neuroptera	1.0	-	-	—	0.5	2.2	—	-	-	-	-	-	-	-	-	-	-	-
Mollusca	-	2.0				4.0												
Annelida (Hirudinea)	2.0	-	-	2.5	1.0	-	1.5	-	-	-	-	-	2.7	0.2	-	3.5	-	2.0
Total Benthos (no m^{-2})	**152**	**75**	**80**	**142**	**64**	**120**	**105**	**60**	**73**	**107**	**47**	**92**	**80.7**	**49.7**	**65**	**79**	**48**	**60.2**

Table-13. Variations in Benthos abundance at Selected Stream Sites of Beas River (dist. Mandi)

	Winter					**Post-Monsoon**					**Summer**				
Site No	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**	**I**	**II**	**III**	**IV**	**V**
Arthropoda															
Ephemeroptera	87	85	93	57	90	67	58	75	48	85	57	54	45	55	45
Trichoptera	23	25	25	20	7	10	12	12	10	12	8	10	12	12	10
Coleoptera	2	-	1	2	1	1	2	-	-	-	1	1.5	1	-	-
Diptera	4.5	1.2	2.0	1.0	-	1.2	1.0	-	-	-	1.0	1.2	1.2	-	-
Odonata	2.3	1.2	1.5	2.3	-	1.5	1.2	1.5	-	-	1.2	1.0	-	-	-
Plecoptera	-	-	-	1.0	-	1.0	0.5	-	-	-	-	-	0.5	-	-
Hemiptera	1.0	0.5	1.5	2.5	-	2.0	1.5	0.5	4.0	-	0.5	-	1.5	1.2	-
Neuroptera	-	-	2.0-	3.0	-	-		-	-	-	-	2.0	5.0	-	-
Mollusca	-	-	2.0	-	3.0	-	-	-	-	-	-	2.0	5.0	-	-
Annelida (Hirudinea)	1.5	1.0	0.5	-	1.2	-	-	1.0	-	-	2.5	4.0	3.0	2.0	-
Total Benthos	**121.3**	**11 4.4**	**128**	**87.3**	**102.2**	**83.7**	**76.2**	**90**	**64**	**97**	**71. 2**	**74.2**	**69.2**	**70.2**	**55**

fish diversity in the river corroborates with the maximum macrozoobenthic density and comparatively less fish diversity with low macro zoobenthic density. The present studies are in concurrences with that of Dhanze *et al.* 2001, who stated that, the maximum of planktonic and benthic density occur during winter months in the sub mountain regions.

During the present studies, chironomids (Diptera) and Oligochaetes (Annelida) were poorly represented (Table -12, 13). Wiederholm (1980) suggested that in heavily polluted waters the oligochaetes are more abundant than the chironomids. Seather (1979) stated that the change from a chironomid dominated to an oligocheate dominated community often is the first stage of eutrophication. The water of streams under study depicts no sign of eutrophication.

FEEDING

Schizothorax richardsonii (Gray) is a bottom feeder and predominantly herbivorous. The true stomach is absent. The oesophagus is followed by an intestinal bulb. The intestinal bulb compensates for the absence of the stomach in herbivorous fishes. The intestinal valve is large and spacious that leads into the intestine, which is long, thin walled and highly coiled in several loops (Chatterji *et al.*, 1978). The juveniles feed upon aquatic insects, their larvae and nymph, as the relative length of the gut is less than the adults. The more length of the gut in adults indicates that the fish is totally herbivorous in the adult stage. Further, scraping mechanism in the jaws is absent in the young stage and thus fish feed upon insect larvae. Its food mainly consists of diatoms (Bacillariophyceae) *i.e. Navicula, Synedra, Cymbella, Fragillaria, Diatoma, Gyrosigma, Nitzschia, Amphora, Tabellaria.* Algae (Chlorophyceae) found in the gut contents are *Ulothrix, Spirogyra, Chara, Claadophora, Hydrodictyon, Zygnema* and *Chlamydomonas*. The macrophyte recorded was mainly *Potamogeton* and *Polygonum*. The average of the gut content annually constitutes 61.5% plankton (51% diatoms and 10.50% algae), 19.5% digestive material and 19% sand in the yearlings of fish. The bottom feeding habit of the fish is correlated with the ventral position of the mouth as the significant amount of sand was also recorded in the gut contents. This ventral position of the mouth with hard papillated plate is helpful for the scraping of algae and diatoms from the surface of rocks in torrential streams. Tilak (1972) opined that it rasps off algae in small instalments making a series of cresentic impressions on the rock.

BREEDING BEHAVIOUR

The fishes migrate upstream during breeding, where the temperature is less. It breeds twice, in the summer (May-June) and in (July-October), in the shallow water along the bank of the streams (Personal Observation), as the fry of this fish were observed up to November month in the Beas water. Raizada (1982) reported that the fish breed once at the approach of summer and second during the rains which flood the streams of Beas River. It breeds in the upstream in water temperature of 15-19°C. Fairly good number of *Schizothorax richardsonii* (Gray) was also recorded between temperatures 10 to 19° C during the study period. The range of the hydrobiological parameters *viz.* pH-7-8.5, Dissolved Oxygen 7.5-10.5 mg/l, Alkalinity-52-90 mg/l were recorded as conducive for breeding. However, Raizada *op cit.*

observed good survivability of fry in the temperature from 12 to 14.5°C in the snow-fed Beas River.

The mature male and female can be distinguished by the following characters :

1. The mature males are lighter in color than the female and have straight ventral profile and mature females have enlarged and distended bellies.
2. The males are smaller than the females.
3. In the male, the snout is blunt and in the female it is pointed.
4. The snout is tuberculated in the mature male and non-tuberculated in the female.

The ovaries are paired, elongated structure and fused with one another at the hind end. During the initial stage of growth, they are flaccid and translucent structure of dirty colour and become distended during the breeding season. In the winter month it is in the resting phase and fish undergoes hibernation. From May onwards the final stage of maturation of ova occurs. The diameter of the mature ova varies from 2.56 to 4.3mm and sticky in nature.

POTENTIAL SITES FOR BREEDING IN BEAS RIVER

The following sites were recognized as the potential sites for the breeding of the snow trout fishery :

1. Poon Stream (990 m asl) : The site is 10 Km from Baijnath towards the right side of the main National high way. This stream site is located at Sarsowa near Neelkanth Mahdev, district Kangra. The stream site is surrounded by hillock and by dense vegetation. The bottom bed is irregular, stony and dominated by boulders. There is a pool locally called Machyal of snow trout fishes in the vicinity of the site. The *Schizothorax richardsonii* (Gray) fishes with size ranging from 1-3 Kg were recorded in this pool. Fries and fingerlings of all size were recorded in the upstream and downstream of the pool throughout the sampling period. The fries of 20-60 no/m^2 were seen in the ditches below the mat of filamentous algae. Due to the presence of this pool, also the stream site provides an amiable environment for the breeding of snow trout.

2. Binwa (810 m asl) : Binwa Khud is located at a distance of 7 Kilometers from Baijnath on the way to Panchrukhi. The stream site is open and the bottom is irregular with big boulders, stones and pebbles. The fingerlings in the main stream and fries at the shallow ditches formed along the bank of the stream (15-50 no/m^2) were observed throughout the study period. Thus, it is one of the potential breeding ground of snow trout.

3. Kahouli (1160 m asl) : The site is located near Darini village and 14 Km north to Shahpur, district Kangra. The site is closed having dense trees of Pines on the hillocks. A pool was formed under the bridge. The fingerlings were observed in this pool and the downstream of the site. The site was dominated by big boulders. The density of the snow trout fries recorded was 20-40 no/m^2 in summer months.

4. Rena Khud (860 m asl) : The Rena khud is locted about 15 Km from Chautra near village Tikru, district Mandi. Three tributaries of the Beas River *i.e.* Sukhad, Bajgar, and Gugali Known as Trivani join in the vicinity of this site. The site is dominated by riffles and rapids and thick vegetation along the bank of the stream. The fingerlings were recorded in fairly good number in this stream and in shallow water fries were noticed (10-40 no/m^2) in the month of May.

5. Sukhad Khud (975 m asl) : The stream is 7 Km from Chauntra, district Mandi near village Sainthal. The stream site is open and wide. There is Pool (Machyal) in the vicinity of the stream site. The snow trout of 2-2.5 Kg were observed in this pool. The fishes were protected in this pool due to religious aesthetics. Therefore, the site provides a congenial environment for the snow trout breeding. The fries (10-50 no/m^2) and fingerlings were recorded throughout the sampling period due to the pool at the stream site.

6. Khoti Nalha (990 m asl) : The stream site is 9 kilometer from Pandoh (district Mandi). This is a closed site as both the sides of the stream are bordered by large hills. The site is deep gorge with stony bottom. The good numbers of fingerlings were recorded in the upstream. Step pool habitats were sighted at the stream site.

7. Arnodi Khud (1090 m asl) : The stream site is 40 Km far from Dharmpur, Kotli village, district Mnadi. The site is open and wide. There is Pool (Machyal) of snow trout and thus the fishes of different size in the stream and brooders of 2-4 Kg were recorded in the Pool throughout the sampling period. In the shallow water the density of the fries were about 20-60 no/m^2. This is a good site for the breeding of the fish.

8. Uhl Khud (1500 m asl) : The Uhl stream is near village Tikkan, which is 13 Km from Ghatasni, district Mandi. The site has large hillocks on the left side and right side is open having terrestrial vegetation. The bottom of the stream is irregular with big boulders, stones and pebbles. Different sizes of *Schizothorax richardsonii* (Gray) was observed in this stream. There are small pools formed at interval of half kilometer and fingerlings of 20-40 no/m^2 and fries and small fingerlings 100-250 no/m^2 are present along the banks of the stream and in shallow ditches partially covered with algae. This site is more potential than other stream sites, as a very good number of snow trout fishes were noticed and no human interference was recorded at this stream site.

On the basis of present studies in the Beas River the aforesaid stream sites were selected as the potential sites for the breeding of fish. It was analyzed that the topography, abiotic and biotic component have a great role. The closed sites, shady area with thick vegetation mostly were found favorable for the breeding of this fish. Highly oxygenated water and rapid current are prerequisite for the fish. It has been found that an alkaline pH, oxygenated water with water velocity more than 1.8 m/sec is the most suitable habitats for snow trout.

THREATS

1. Two dams have been constructed on the Beas River *i.e.* Pong Dam in district Kangra and Pandoh Dam in district Mandi, which has resulted in reduced down stream outflow.

The change of lotic into lentic environment has adversely affected the migration of fishes.

2. The exotic species introduced in the reservoir has influenced the snow trout fishery. No *Schizothorax richardsonii* (Gray) could be collected during the studies in the Pong Dam Reservoir. Raina and Peter (1999) reported that the impact of damming on Schizothoracines has been why serious.

3. *Schizothorax richardsonii* (Gray) was observed in association with *Salmo trutta fario* (Smith and Stearby) and *Oncorhynchus mykiss* (Linnaeus) in altitude range from 800 to 1200m in some of the streams of the Beas in district Mandi. The trout fishes are carnivores and feeds upon the fingerlings of the Snow trout; therefore, in the near future the introduction of these exotic fishes could be a serious threat to the Snow trout population.

4. The unscientific methods used for the fishing *i.e.* bleaching powder, insecticides, dynamiting, hammering and electric current are responsible for the mass mortality of all sort of fishes (all sizes). In fact, all the aquatic biota in a long stretch of the stream get destroyed, which disrupt the aquatic chain.

5. It has been observed that the heavy floods and landslide during monsoon and post monsoon in River Beas affect the diversity and population of fishes, as it changes the geomorphology of the area and increases the siltation in the river bed. The water current slows down and isolated pools are formed, which are not preferable habitat of snow trout fishes and are responsible for decline of snow trout population.

6. The channalization of water for irrigation and drinking purpose has been observed, which affect the stream habitat as cold water fishes prefer the torrential current of water.

7. Deforestation on the bank of the streams has led to soil erosion and thus siltation load is increasing in the hill streams. The extraction of boulders, cobbles, gravels and sand from the river bed alters the stream morphology as the breeding ground of fishes get disturbed.

8. Consequently, anthropogenic stresses such as human activities, removal of stones and sand, urbanization and channalization of water from the streams and deforestation along the river bed have disturbed the ecological balance of the hill streams. These factors are responsible for the degradation of hill stream ecology, resulting in decreased biodiversity.

CONSERVATION MEASURES

1. During the studies, it has been found that in the streams which have plants along the bank has comparatively more alkaline water. The alkaline water is an indicator of the good productivity of the water. The ecological parameters are thus more congenial in such habitats and comparatively the abundance of fish is more in these streams. Thus, riparian vegetation should be encouraged along the banks of the streams.

2. The exotic species should be introduced only after extensive research. As these species grow faster than the native species and affect their abundance, these snow trout fishes can not compete with the exotic species for food and space.
3. It has been observed that fish fauna is protected in Pools called Machyal. Like wise some patches in the streams can be declared as sanctuaries and will be helpful for *in situ* conservation of fish fauna.
4. In Himachal-Pradesh fishing is banned in certain stretches of stream in pool (Machyal) by Panchyat Pradhan or by temple authorities due to religious sanctity (Personal Observation). Like wise, some more patches can be declared as sanctuaries by Fishery Department to protect the fauna.
5. The closed seasons should be strictly observed, so that brooders and fries can be protected. The unscientific methods of fishing should be prohibited.
6. The mass awareness of the people by educating the local people at village, school, colleges etc. through seminars, videos, posters and slogans is important for coldwater fishery.

Hence, it is observed during the studies that several features such as substratum, stream morphology, water current, abiotic and biotic component, stream habitat, riparian vegetation, altitude, anthropogenic stresses, natural calamities, season etc. have the cumulative impact on the abundance and assemblages of the fish. Thus, a single component in the water cannot regulate fish life in the streams.

SUMMARY

The snow trout comprises one of the cold water commercial important fisheries. The ecological studies, feeding and breeding behavior of *Schizothorax richardsonii* (Gray) were undertaken. The abundance of these fishes has been correlated with the ecological parameters. These studies in relation to abundance had been undertaken for the first time. The studies in 44 streams of Beas River have been conducted w.e.f. 2005-2008. The geomorphology of the streams showed that 10 streams are without pollution and all other are under anthropogenic stresses. The hydobiological studies revealed that temperature is one of the important parameter and good number of *Schizothorax richardsonii* (Gray) are collected between temperatures 10 to 19°C. The range of limnological parameters *i.e.* water temperature 7 to 13°C, pH 6.5-7.6, dissolved oxygen 8.75 to 12.5 mg/l and alkalinity 30 to 90 mg/l were found conducive for the fish. Biotic components (Planktons and Benthos) are positively correlated with the abundance of *Schizothorax richardsonii* (Gray) during winter season. It has been observed that there is an impact of climate change on snow trout fishery as it is not recorded in the altitude range of 650-750 m asl, which was recorded by earlier authors. The data of fish composition at different tributaries showed that good number of snow trout fishes exist in the tributaries of Beas River. However, over fishing has led to decline in its stock. These fishes have bottom dwelling habitat and prefer stony bottom with rapid flow of water. The inadequate water and disturbance of the bottom of the tributaries are the factors responsible

for the abundance of Schizothoricids. The *ex situ* conservation can go a long way in conserving this fishery in the hill streams.

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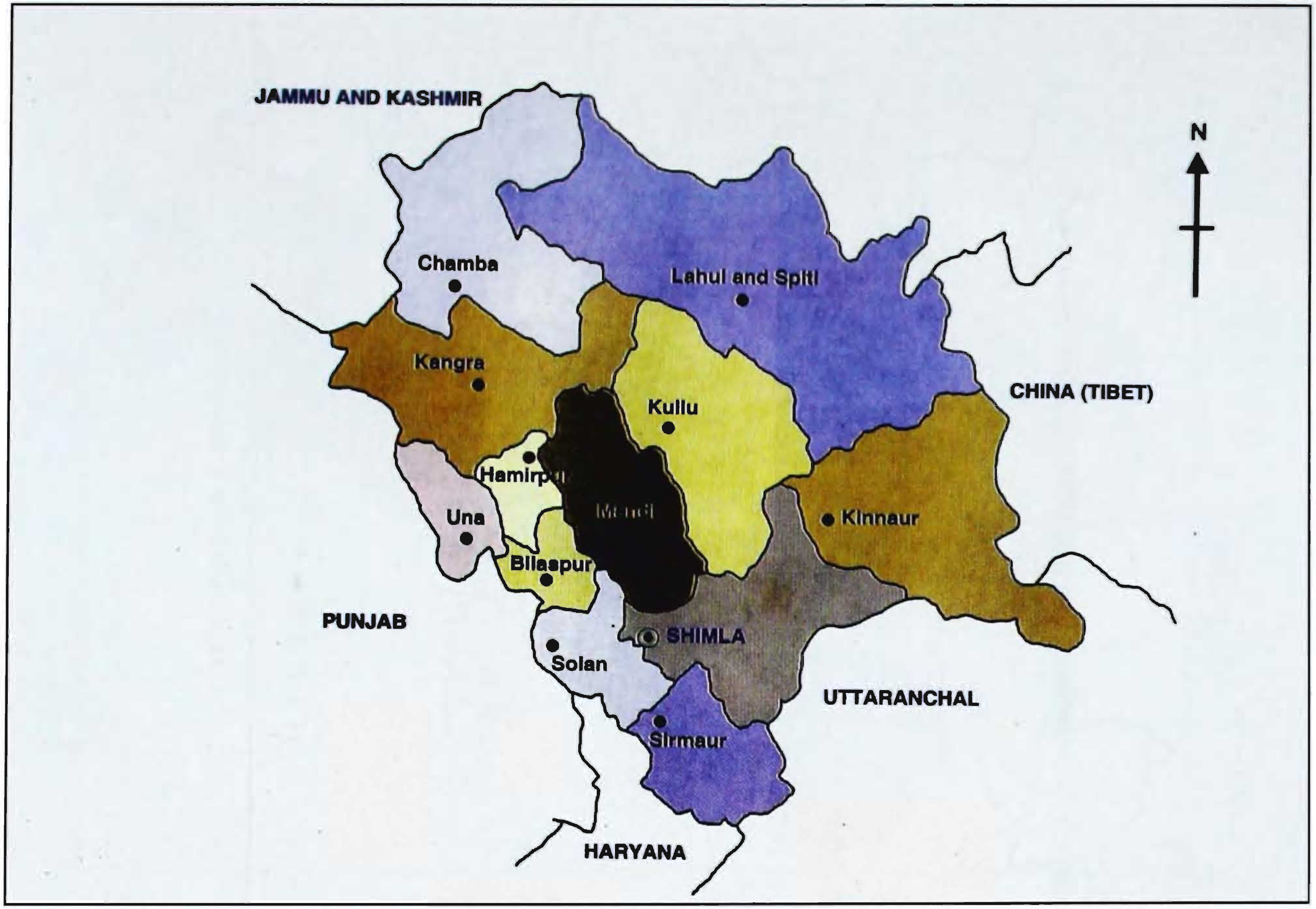

Fig. 1. Map of Himachal-Pradesh

Fig. 2. Main Rivers in Himachal-Pradesh

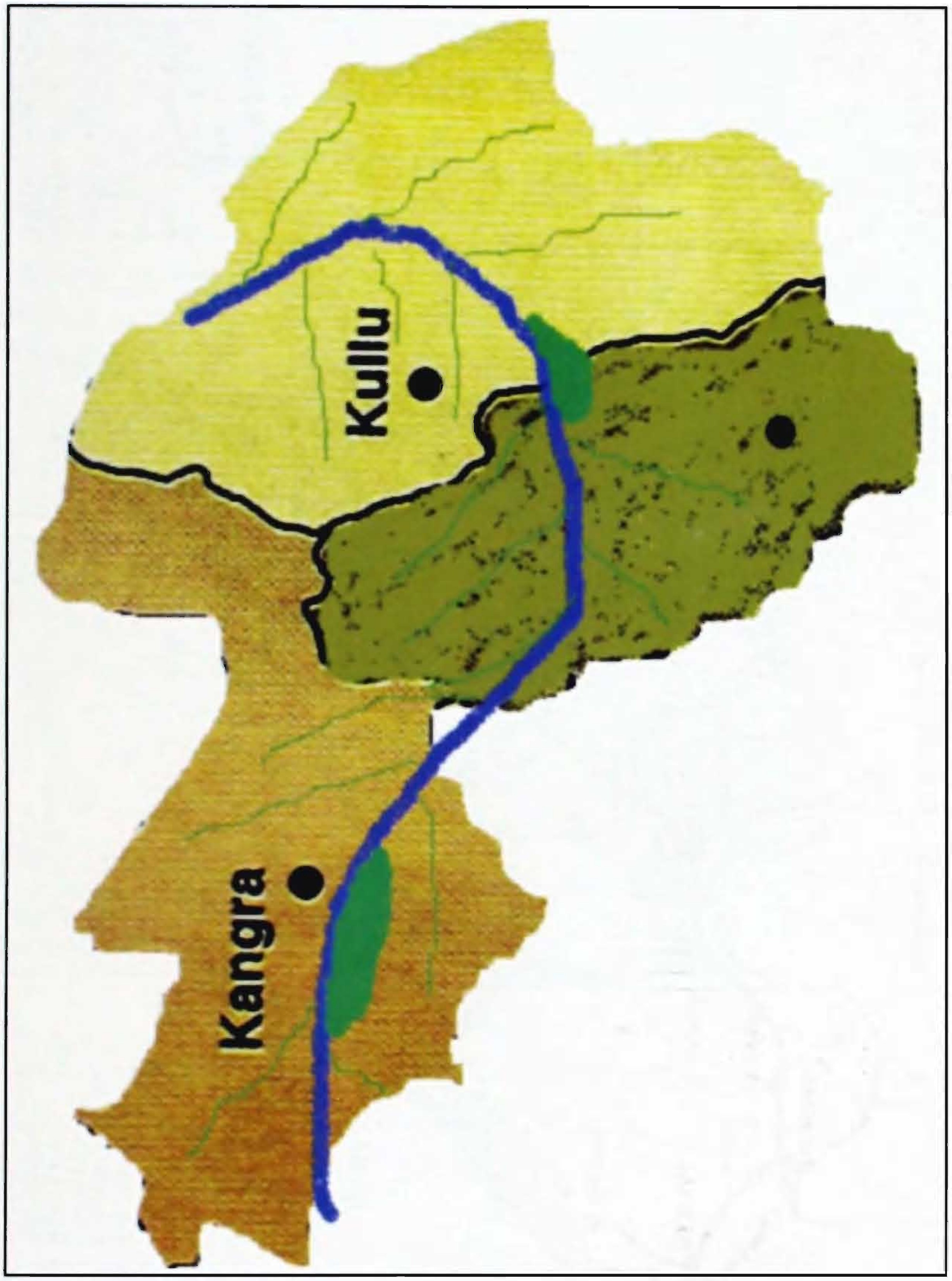

Fig. 3. Diagrammatic Map of Beas River in three districts of Himachal-Pradesh

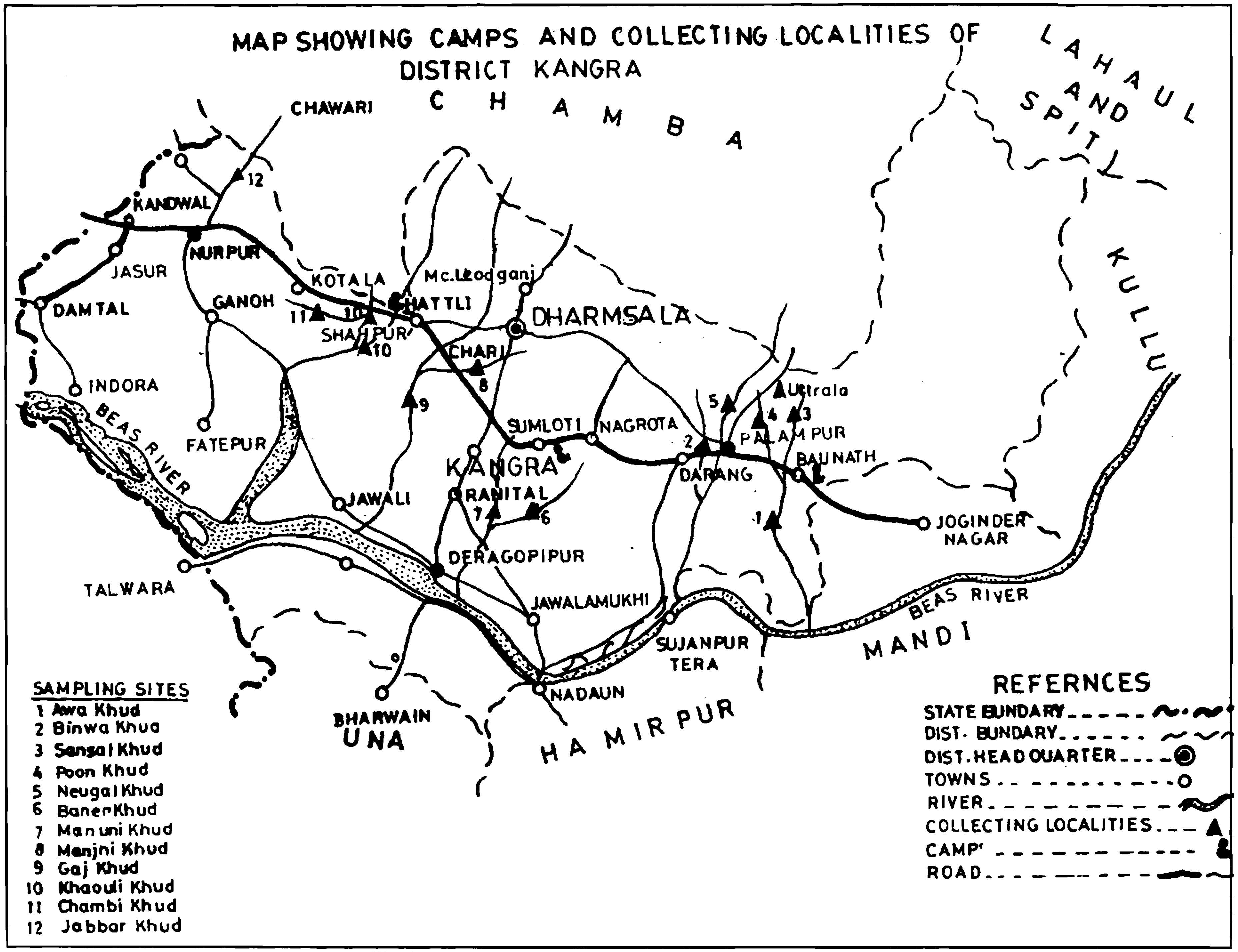

Fig.4. Sampling sites of Beas River dist. Kangra (H.P.)

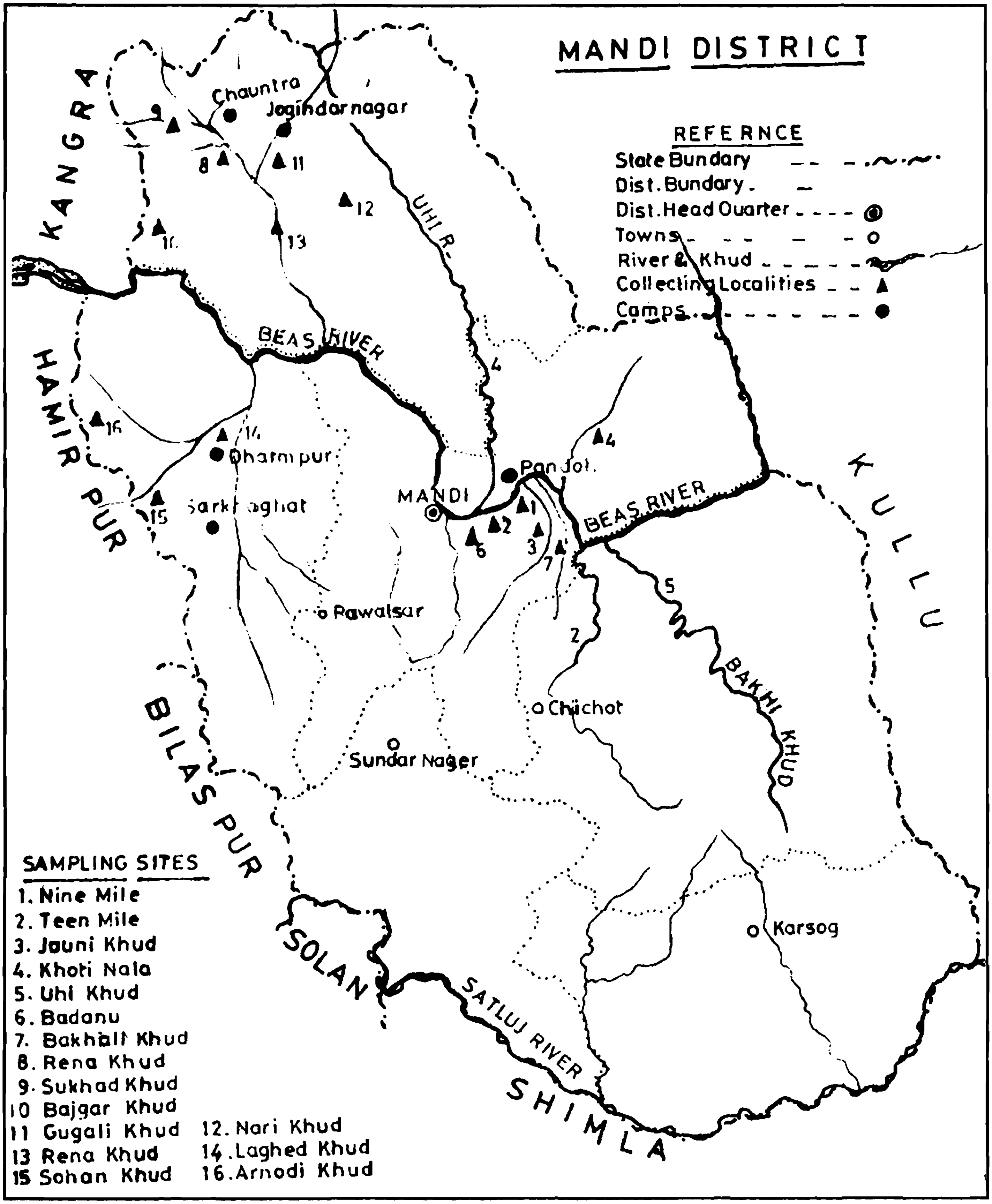

Fig. 5. Sampling sites of Beas River, dist. Mandi (H.P.)

Fig. 6. Lateral-view of *Schizothorax richardsonii* (Gray)

Fig. 7. Ventral view of Head and anterior part of *Schizothorax richardsonii* (Gray)

Fig. 8. Hill stream adaptation in *Schizothorax richardsonii* (Gray)

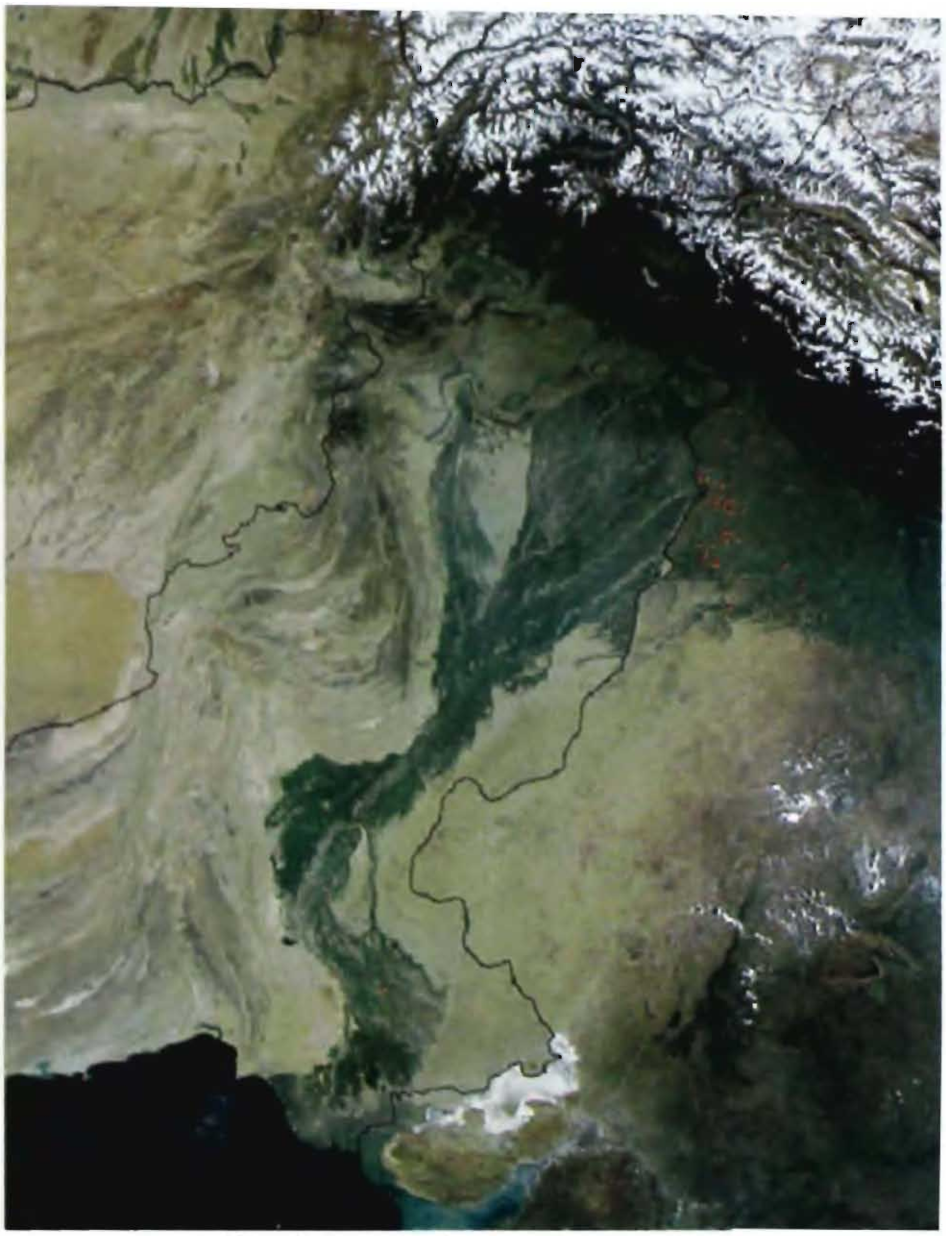

Fig. 9. Satellite image of Indus River

Fig. 10. Origin of Beas River (Beas Kund) near Rohtang

Fig. 11. View of Beas Kund (Inside)

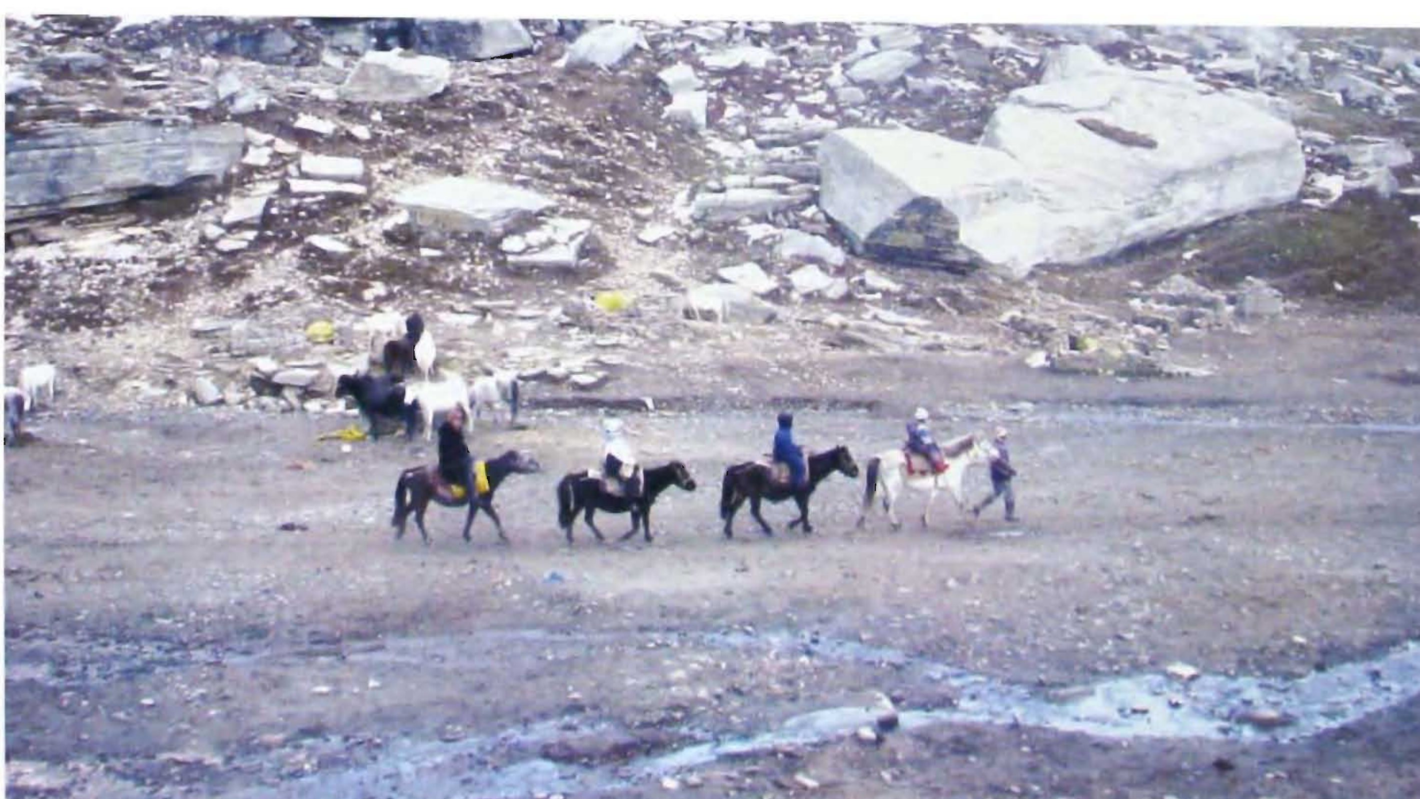

Fig. 12. Beas River near Beas Kund

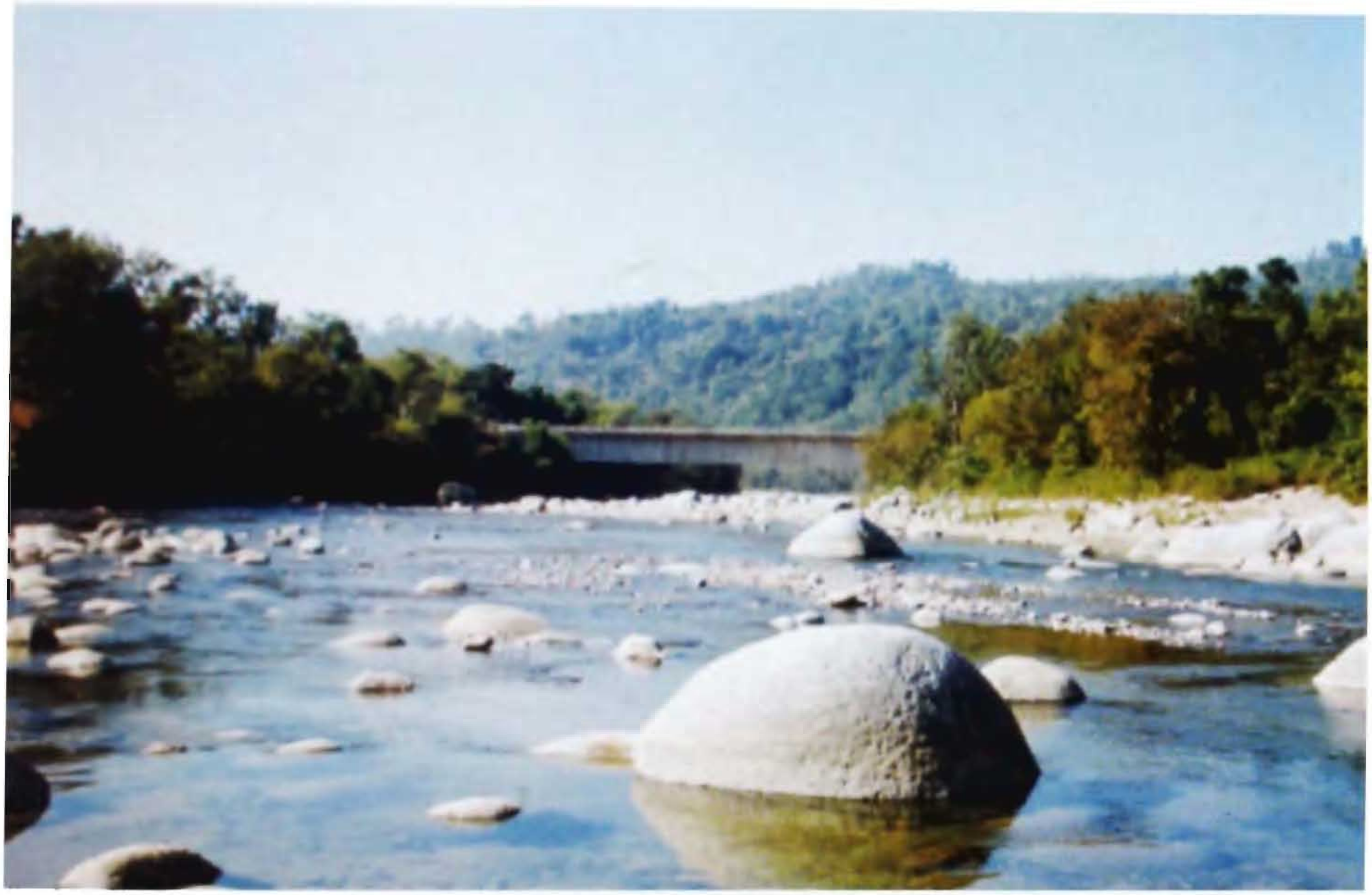

Fig. 13. View of Poon Stream (Sampling Site in dist. Kangra, Himachal Pradesh)

Fig. 14. *Schizothorax richardsonii* in Pool at Poon Stream (Sampling Site in dist. Kangra, H.P)

Fig. 15. Neugal Stream showing irregular bottom (Sampling Site in dist. Kangra, Himachal Pradesh)

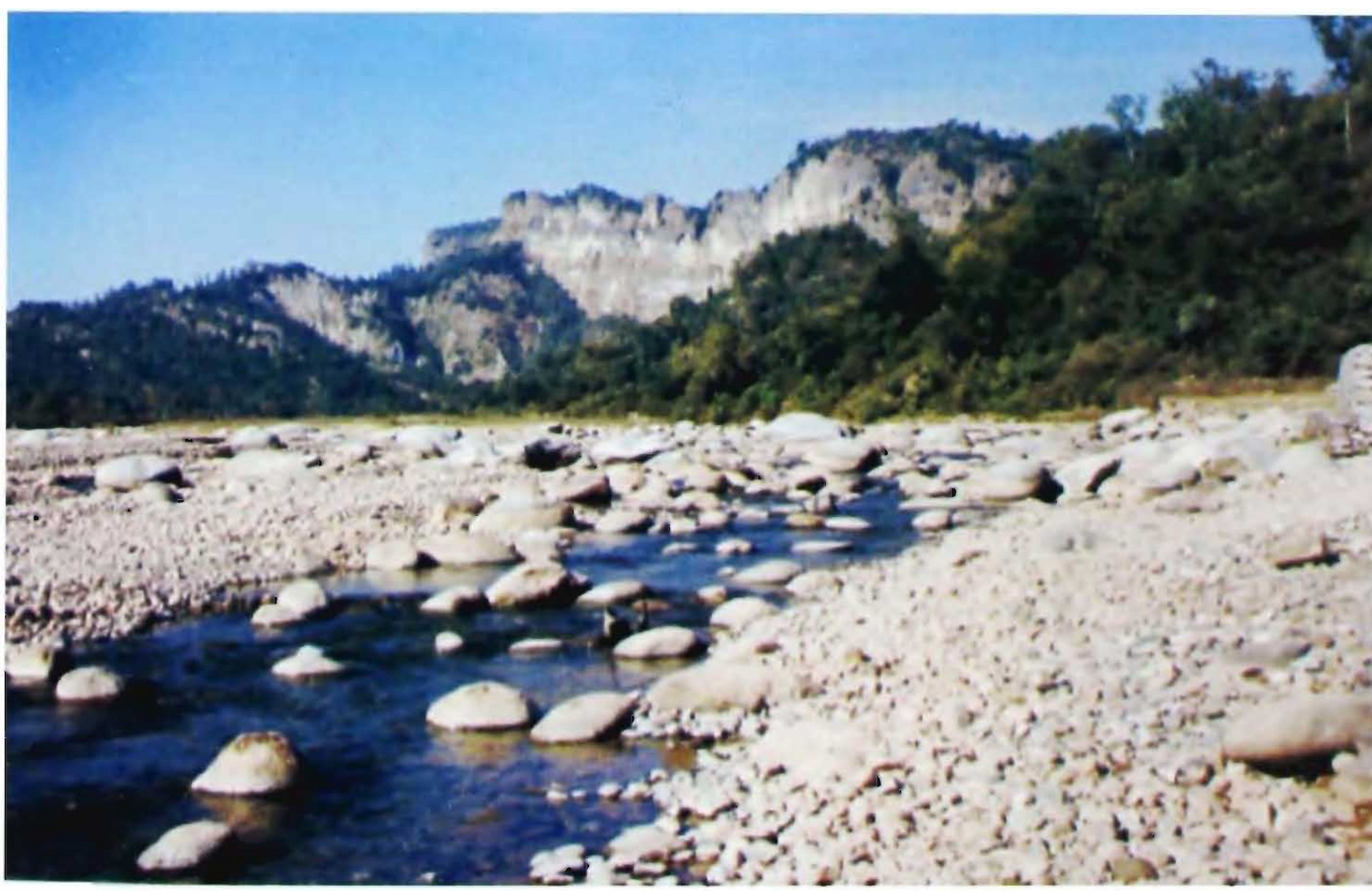

Fig. 16. Binwa stream at Majherana (Sampling Site in dist. Kangra, Himachal Pradesh)

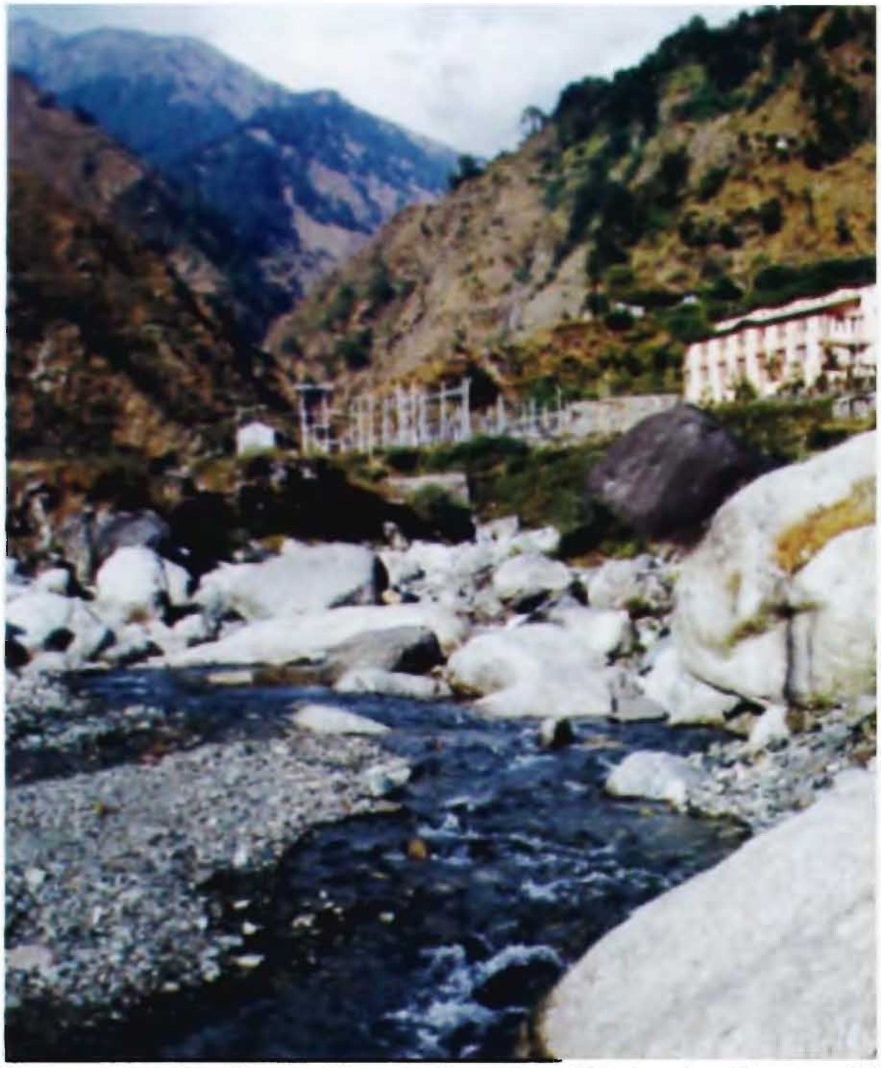

Fig. 17. Baner Stream near Jiya Power House (Sampling Site in dist. Kangra, Himachal Pradesh)

Fig. 18. Khaouli Stream at Darini (Shahpur) (Sampling Site in dist. Kangra, Himachal Pradesh)

Fig. 19. Fish fries at Gaj Stream (Sampling Site in dist. Kangra, Himachal Pradesh)

Fig. 20. Cast net operation at Gaj Stream (Sampling Site in dist. Kangra, Himachal Pradesh)

Fig. 21. View of Beas River, dist Mandi (Sampling Site in dist. Mandi, Himachal Pradesh)

Fig. 22. Jauni Stream near Pandoh (Sampling Site in dist. Mandi, Himachal Pradesh)

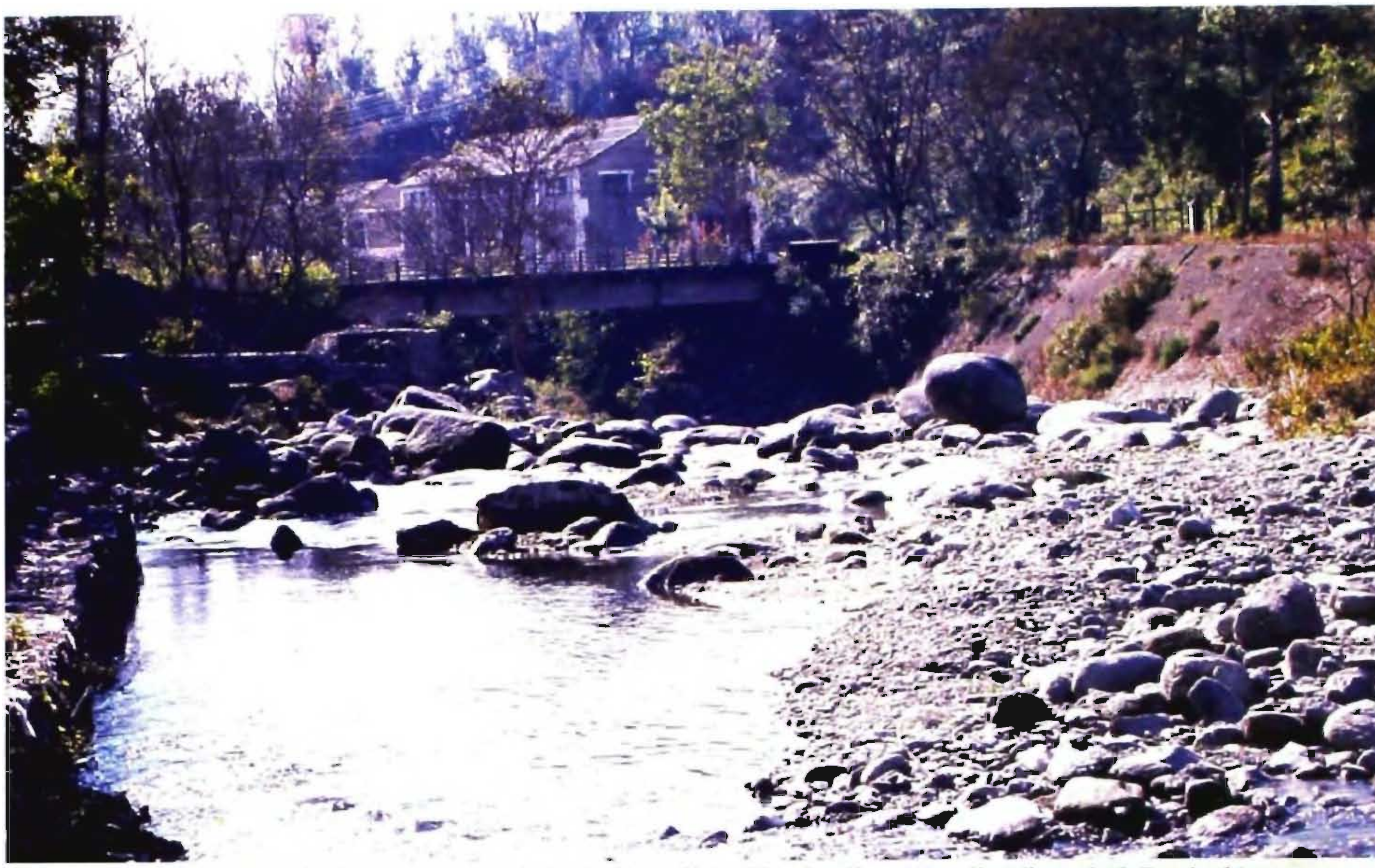

Fig. 23. Sukhad stream at Sainthal (Sampling Site in dist. Mandi, Himachal Pradesh)

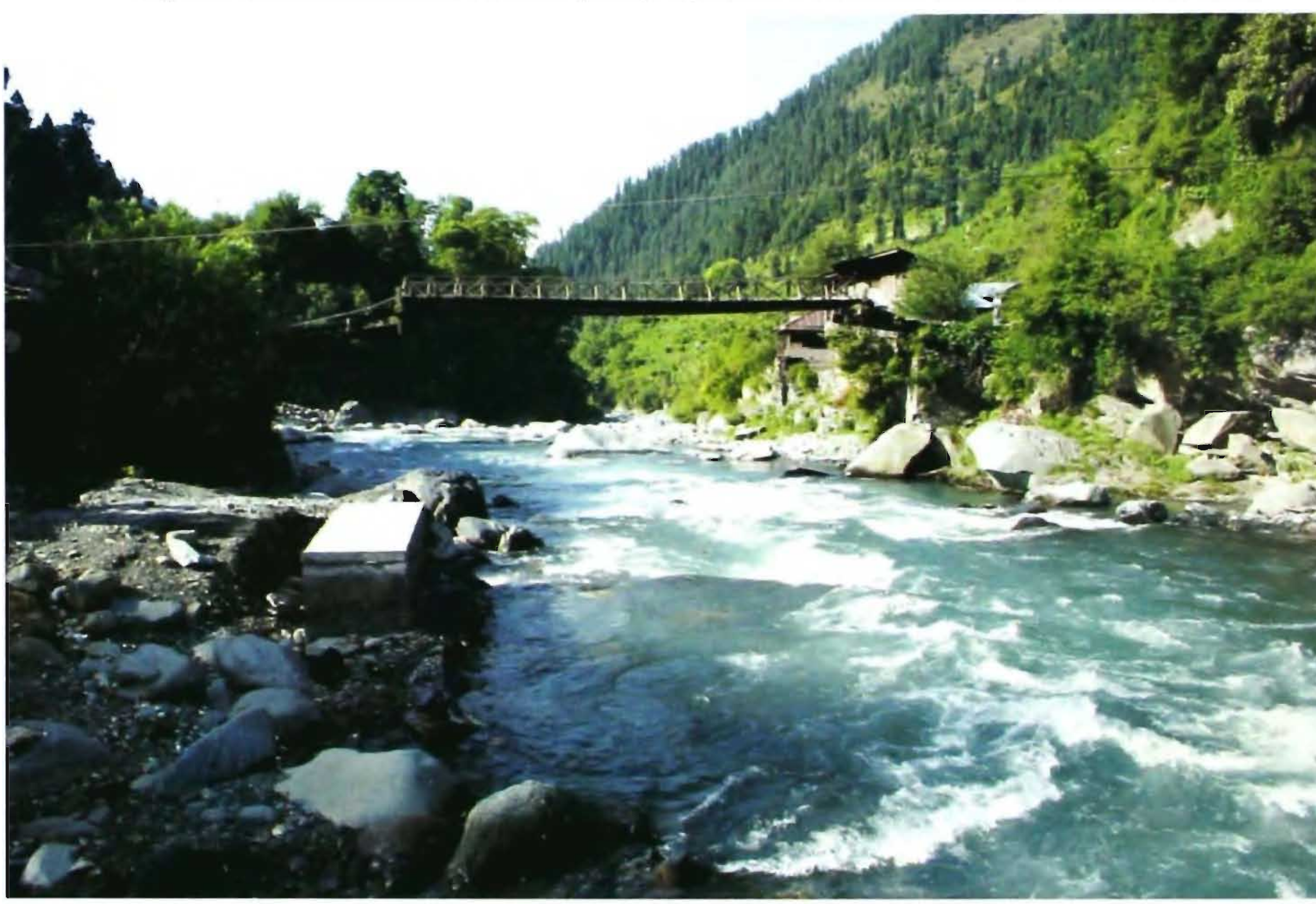

Fig. 24. Uhl stream at Barot (Sampling Site in dist. Mandi, Himachal Pradesh)

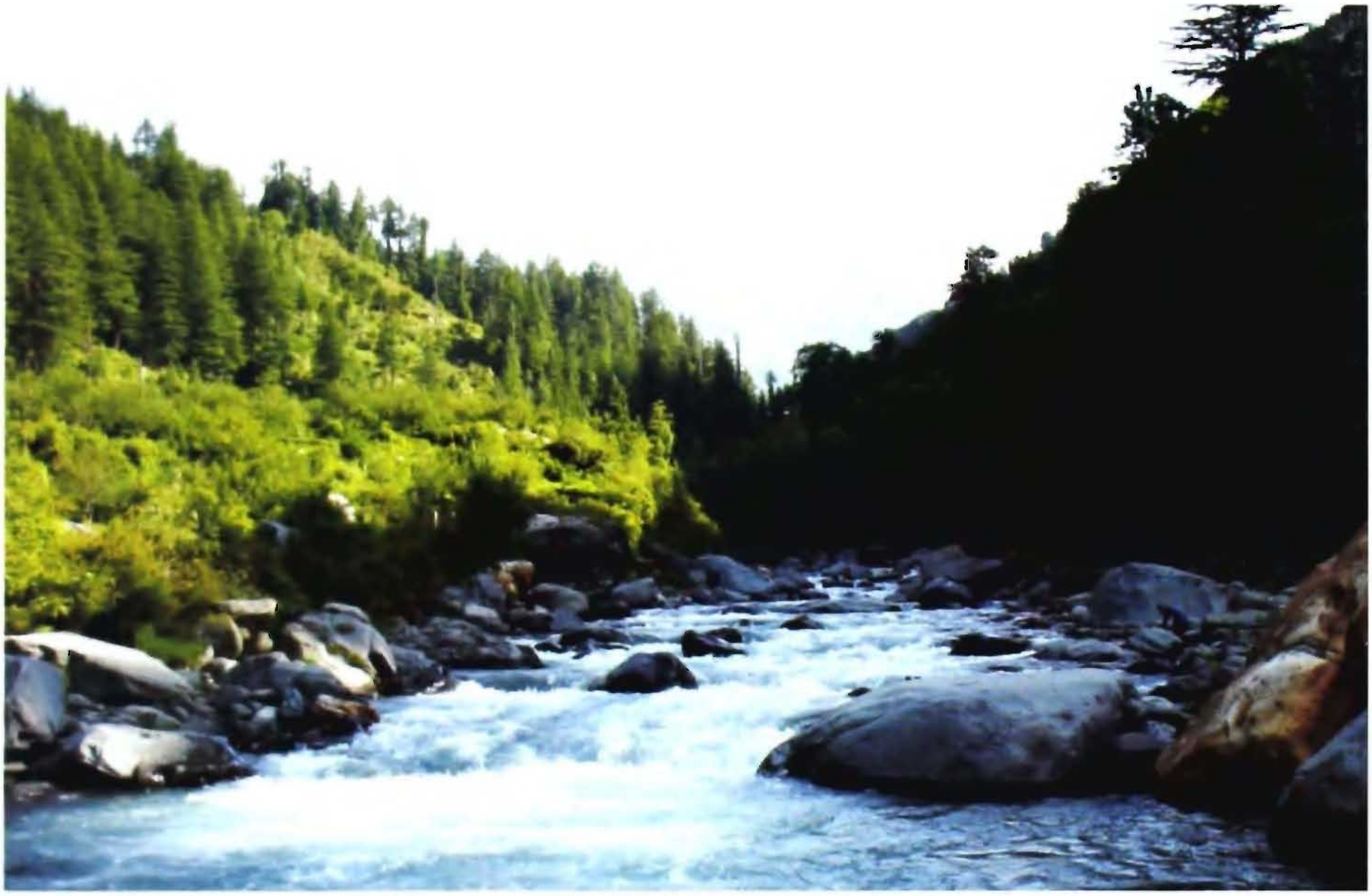

Fig. 25. Lohari stream near Barot (Sampling Site in dist. Mandi, Himachal Pradesh)

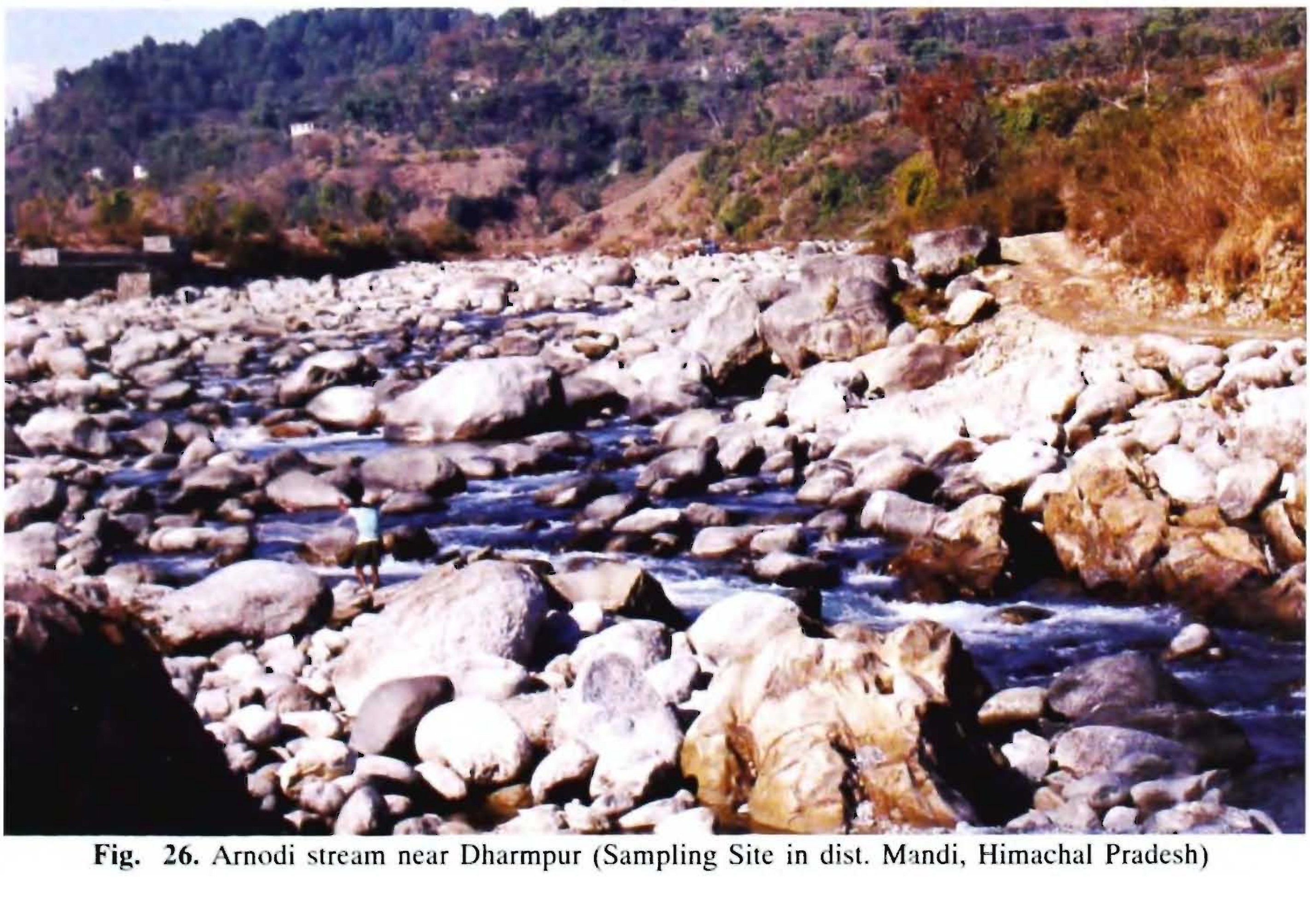

Fig. 26. Arnodi stream near Dharmpur (Sampling Site in dist. Mandi, Himachal Pradesh)

Fig. 27. Snow trout in Pool (Machyal) near Arnodi stream (Sampling Site in dist. Mandi, H.P.)

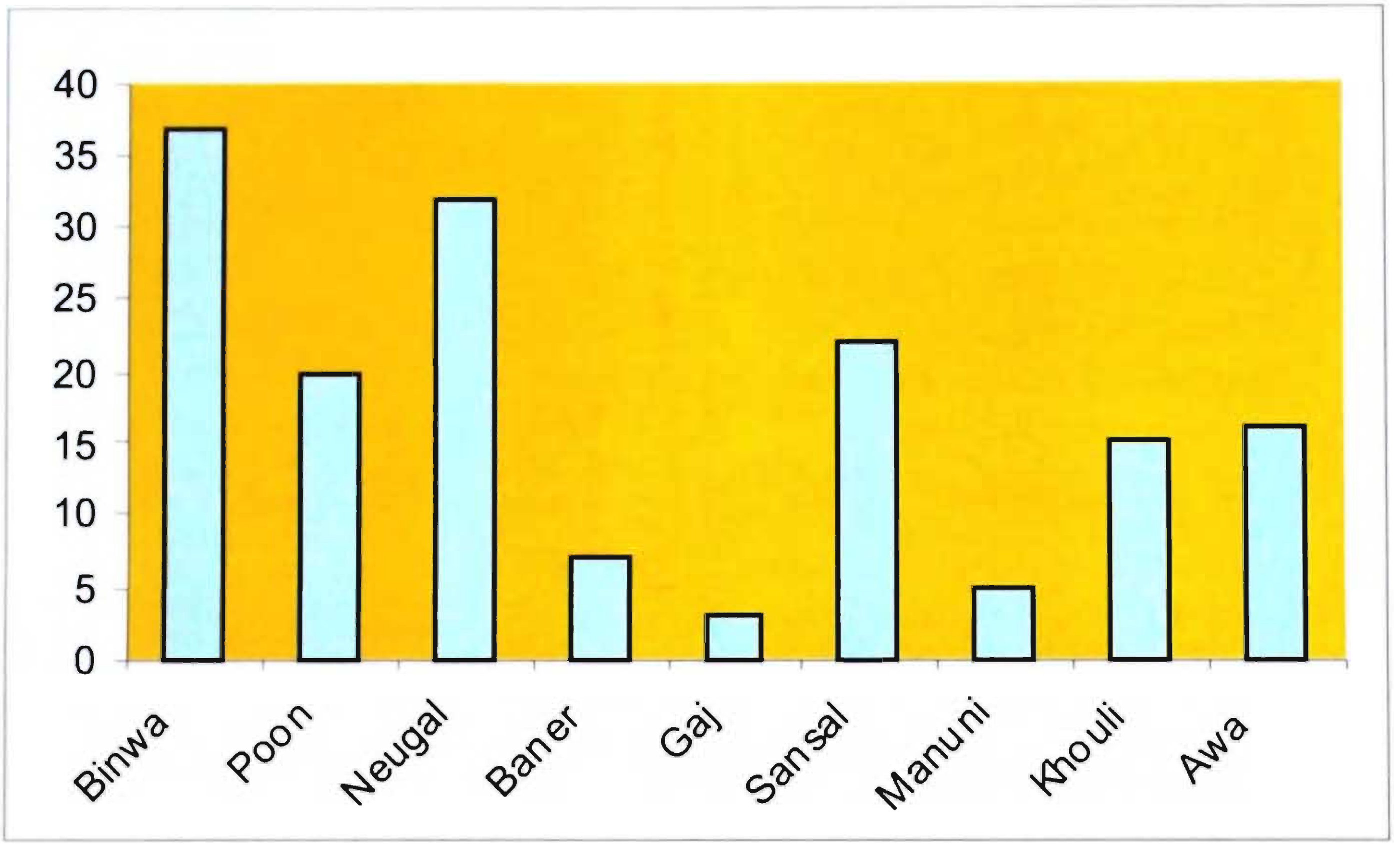

Fig. 28. Catch composition of Snow trout Fish at tributaries of Beas River, dist. Kangra

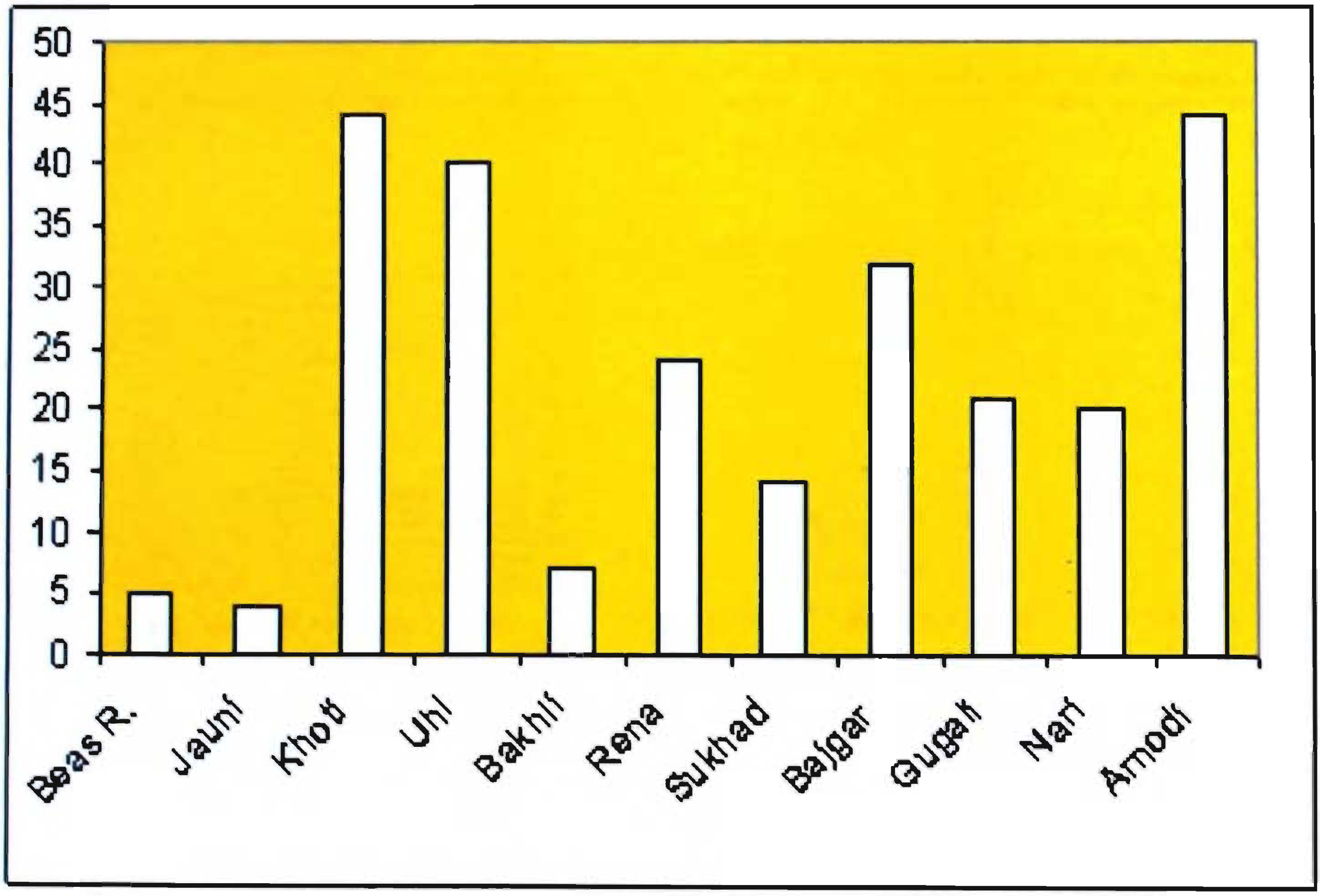

Fig. 29. Catch composition of Snow trout Fish at tributaries of Beas River, dist. Mandi

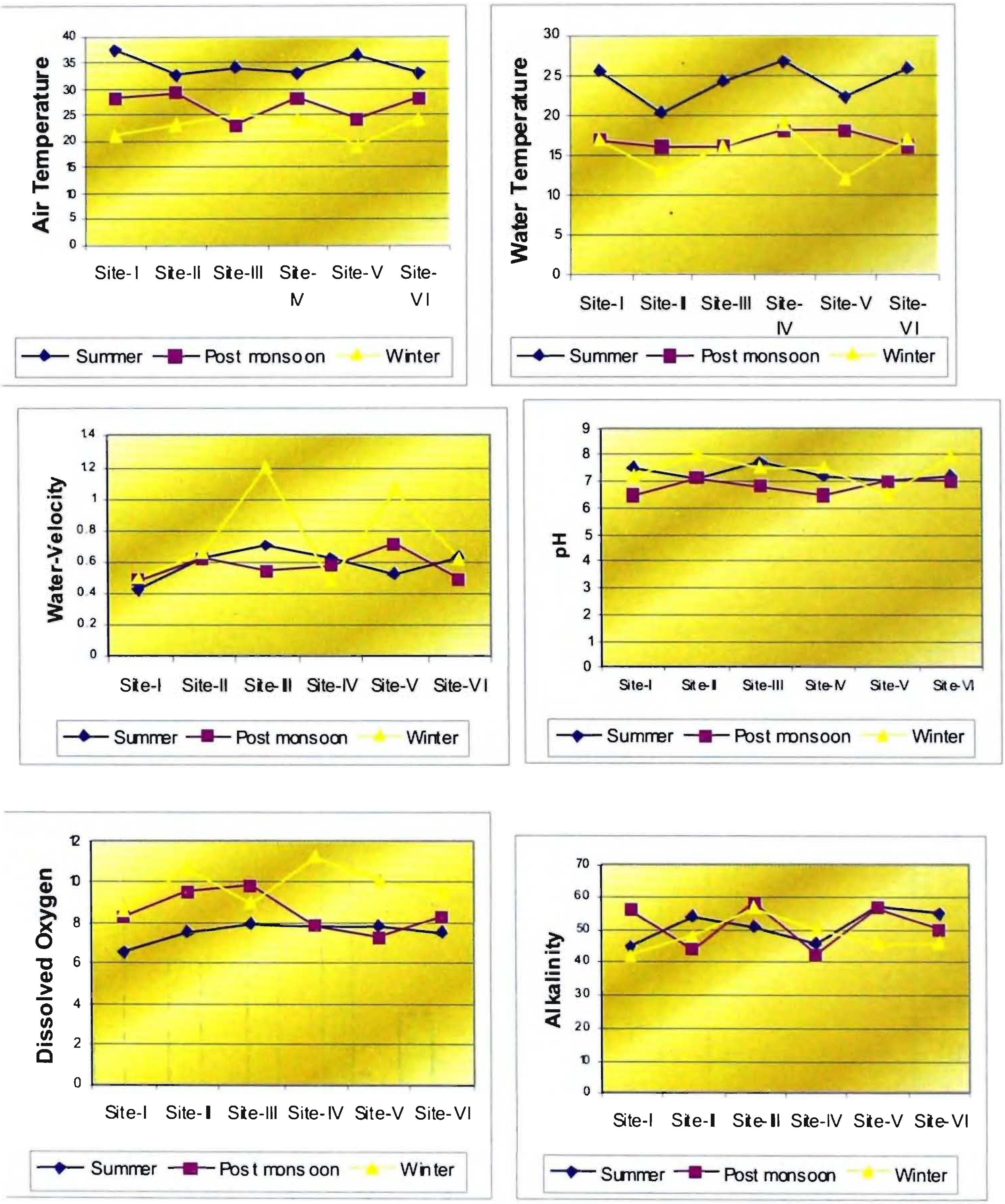

Fig. 30. Physico-Chemical parameters of Tributaries of Beas River in dist. Kangra (H.P.)

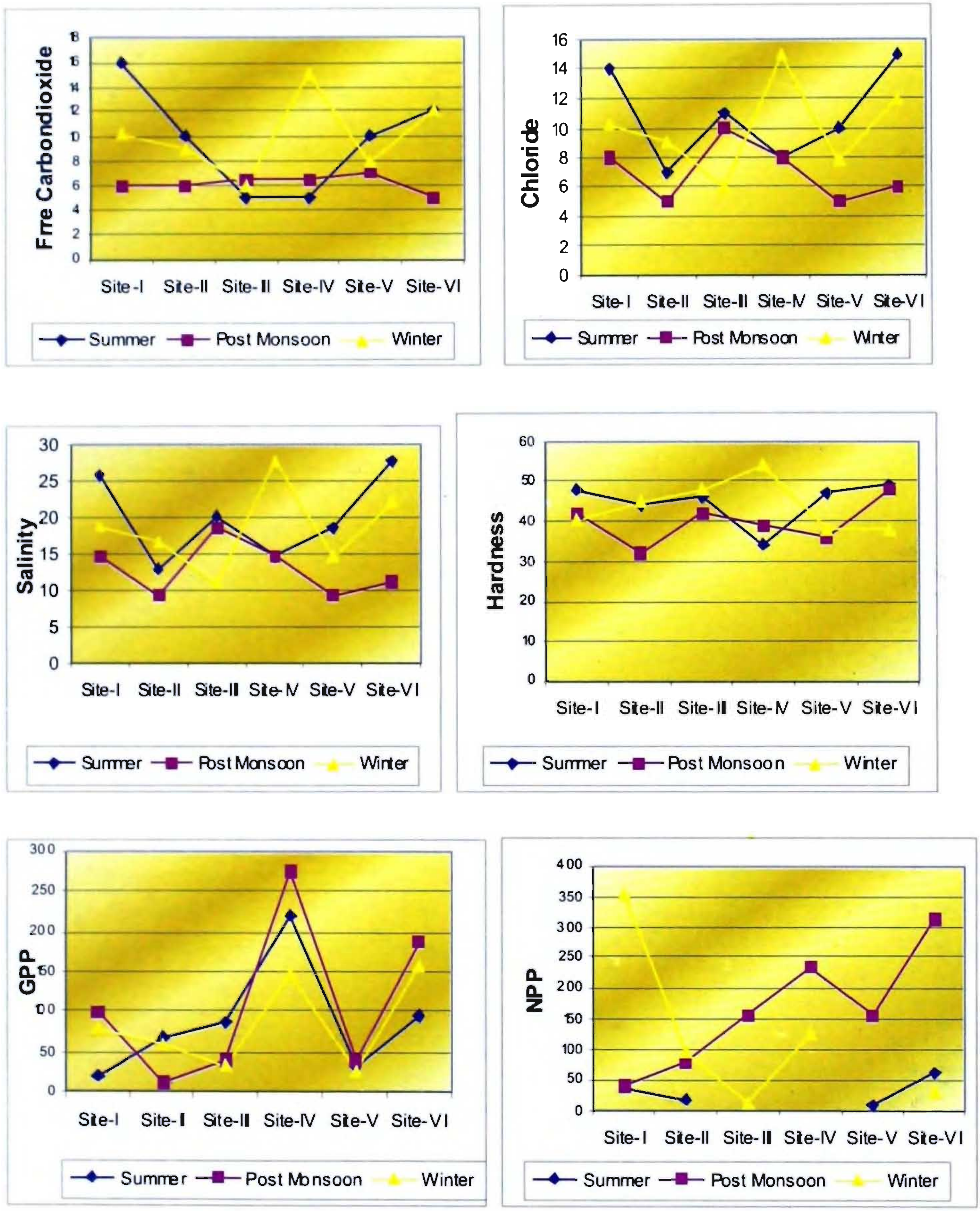

Fig. 31. Physico-Chemical parameters of Tributaries of Beas River in dist. Kangra (H.P.)

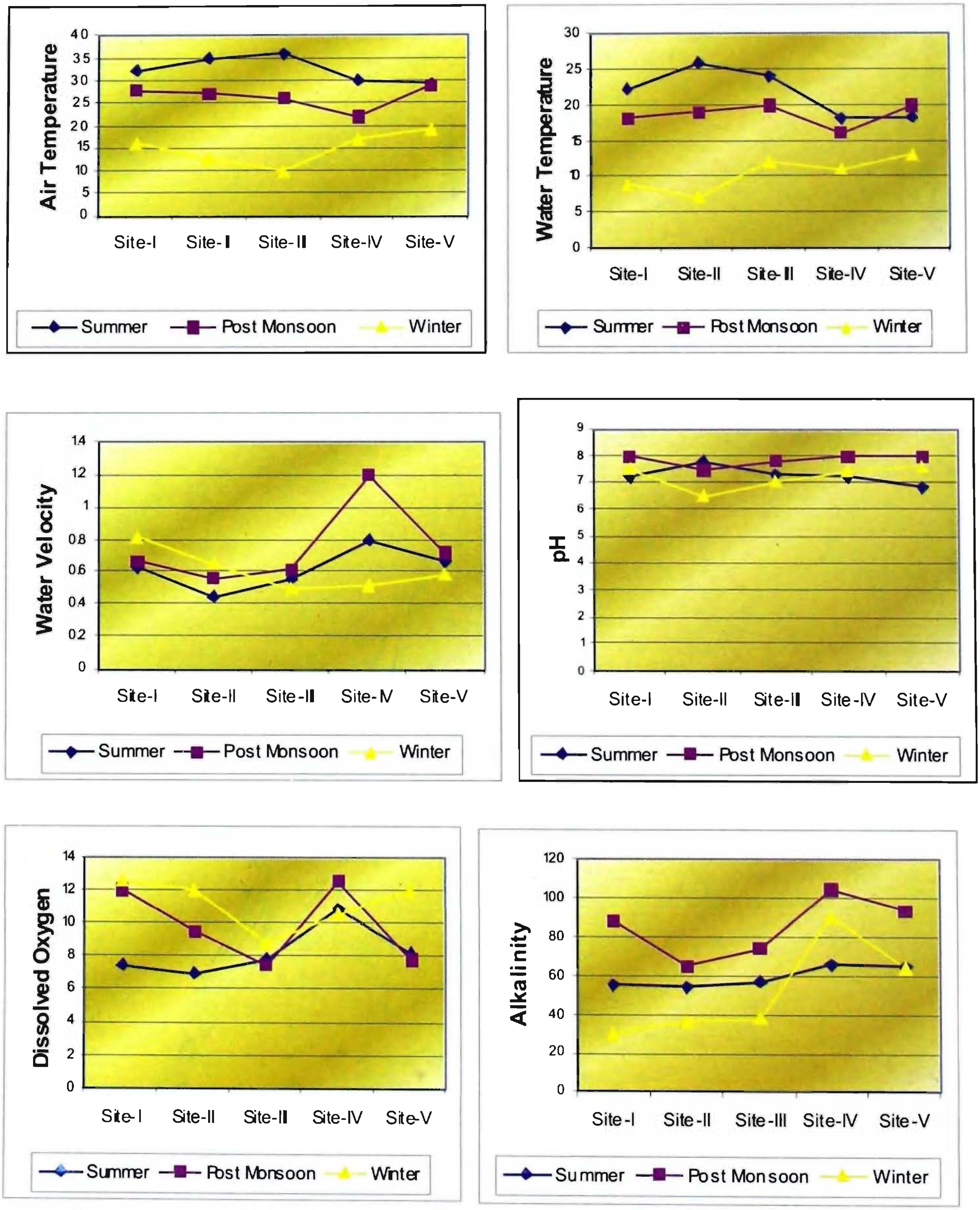

Fig. 32. Physico-Chemical parameters of Tributaries of Beas River in dist. Mandi (H.P.)

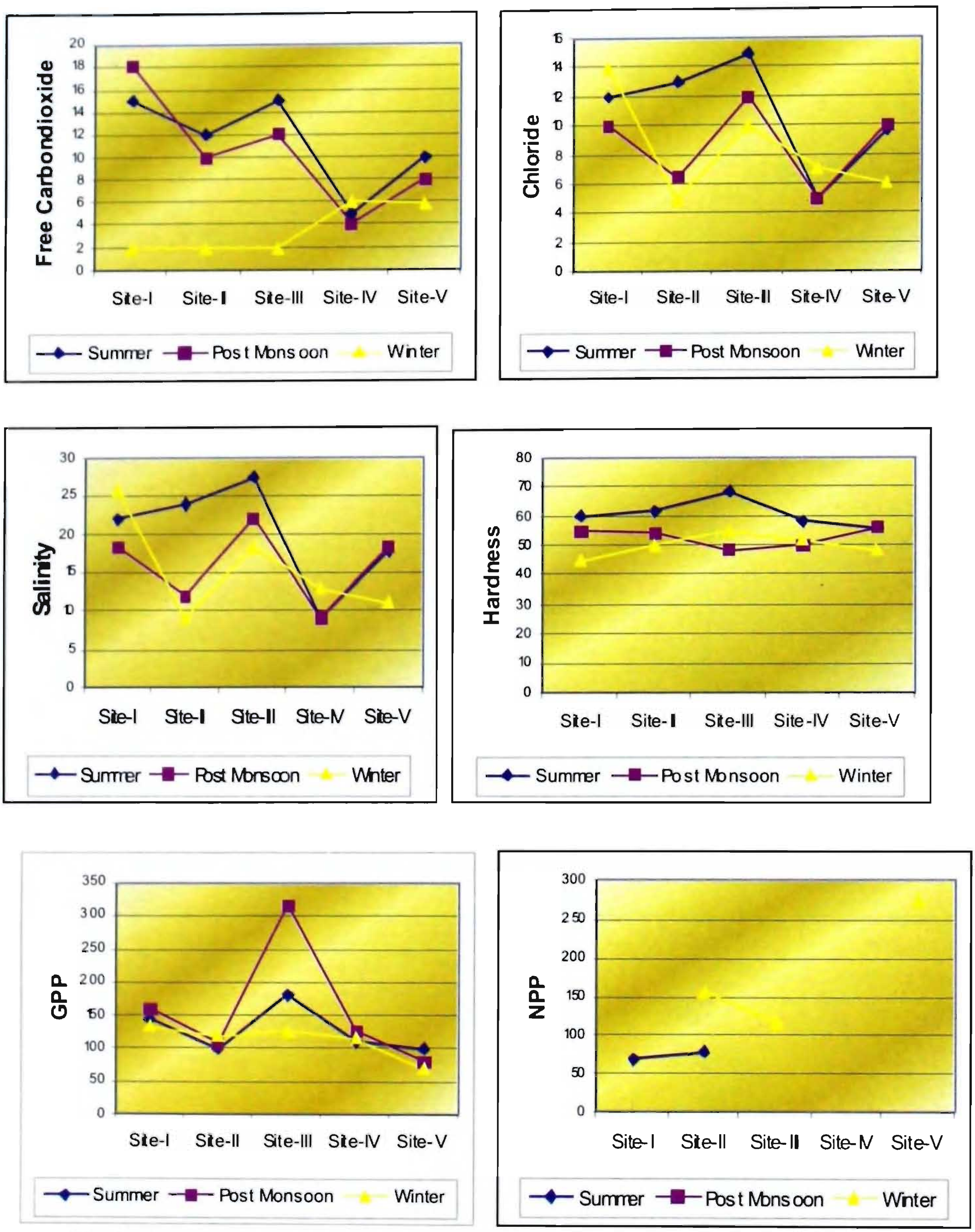

Fig. 33. Physico-Chemical parameters of Tributaries of Beas River in dist. Mandi (H.P.)