6. SUMMARY

The present study was carried out during the period January 2004 to December 2005. Two important tributaries of the river Beas viz. Tirthan (77°00' E, 31°58' N) i.e. Gushaini (T1), Deori (T2), Fagu Pul (T3), Larji (T4) and Sainj (77°06', 31°58' N) i.e. Ropa (S1), Shalwar (S2), Tiara (S3), Bhihali (S4), have been selected. The study area lies in the Kullu district of Himachal Pradesh. The state of Himachal Pradesh covers an area of 55,673 sq. km. and lies between the latitude 30°22' to 33°10' N and longitude 70°46' and 79°00' E respectively.

The present study aims to assess the interactions between various biotic and abiotic factors such as physicochemical parameters, habitat, substrate, water current, geomorphology and anthropogenic activities. Efforts have been made to evaluate the direct as well as indirect impact of anthropogenic activities on stream morphology as well on its floral and faunal communities of the streams on upper region. The literature concerning stream hydrology (classification, hydrology) stream ecology (flora and fauna) and the interaction between stream hydrology and stream morphology with special reference to various biotic and abiotic factors has been reviewed with a view to ascertained the past history and work already on the ecology of hillstreams of India and other countries.

The perusal of literature shows that almost no historic work related to habitat ecology and fishes has been available in the upper Himalayan hillstreams due to the difficult terrain, lack of accessibility and unfriendly conditions. The lack of information indicates that these hillstreams never subjected to any detail hydrobiological, ecological and ichthyological investigations so far, though they support a variety of organisms because of having diverse ecological conditions and the organism inhabit these streams have developed special adaptive morphological features in order to cope with the harsh environmental conditions prevailing in these particular habitats of upper Himalayan hillstreams.
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After extensive survey of streams under report, a total of eight study sites were shortlisted for the collection of samples on the basis of following criteria

1. The site must be easily accessible so that in one or two days, for sampling can be done.
2. The site must represent different habitats.
3. The site must have different substrate compositions.
4. Care was taken to include sites having some anthropogenic impacts.
5. The site must have different altitude.

For the present study, eight sites have been selected. All these sites differ in altitude, habitat, riparian removal and substrate composition. Monthly water sampling for analyzing the hydrological parameters and biotic components was done during the period January 2004 to December 2005. A total of eight study sites from Tirthan stream viz. Gushaini (T1), Deori (T2), Fagu Pul (T3), and Larji (T4); and Sainj stream i.e. Ropa (S1), Shalwar (S2), Tiara (S3), and Bhihali (S4) has been selected for present investigations and has been visited once in a month. Karl-Pearson’s coefficient of correlation has been calculated between different genera viz. phytoplankton, macroinvertebrates, zooplankton and different genera of fishes as well as between various physicochemical factors. Shannon diversity and Morisita similarity indices have been employed for calculation of species diversity.

Out of sixteen physicochemical parameters, e.g. air temperature (°C), water temperature (°C), pH, conductivity (μS/cm), dissolved oxygen (mg/l), TDS (mg/l), water current (cm/sec), chlorides (mg/l), total alkalinity (mg/l), total hardness (mg/l), calcium hardness (mg/l), magnesium hardness (mg/l), nitrates (mg/l), phosphates (mg/l), humidity (%), light (Lux), the maximum variations value was observed in water current, hardness, conductivity followed by TDS and alkalinity. Parameters like air temperature, water temperature (°C), dissolved
oxygen (mg/l), pH, conductivity (µS/cm) were measured in the field with the help of “Multi 340i/SET water analysis kit”. Total dissolved solids were determined by using E-Merck’s TDS Scan Meter. Rest of the parameters like total alkalinity (mg/l), total hardness (mg/l), nitrates (mg/l), phosphates (mg/l) and chlorides (mg/l) were determined according to the method described in APHA (1998) in the laboratory.

The data were analyzed based on stream morphology, substrate and habitat. The streams and study sites were classified according to classification given by Rosgen (1996). As far as morphology of steams is concerned, four habitat variables viz. pool, riffle, runs and rapids have been identified. The parameters like altitude, substrate, habitat and gradients have been used for the categorization of study sites. Two types viz., A and B types of study sites have been encountered with more than 4% gradients and between 2-4% gradient is encountered in the A and B types of study sites respectively.

Air temperature, water temperature, pH, conductivity, TDS, water current, chlorides, total alkalinity, total hardness, calcium hardness, magnesium hardness, nitrates, phosphates show increasing trend towards lower altitude while dissolved oxygen shows reverse trend which is higher in higher altitudes. In general, the streams under report are cold water, oxygen rich and alkaline. It has been observed that values of most of physicochemical parameters show marked seasonal variations except the phosphates and nitrates. The value of phosphates and nitrates show minor variations and occurred in small amount. pH and dissolved oxygen showed almost moderate type of variations.

In all study sites, 24 genera of phytoplankton have been identified, belong to families' Chlorophyceae (12), Bacillariophyceae (9), and Cynophyceae (3). It has been observed that though there is greater diversity of Chlorophyceae yet the Bacillariophyceae were found to be more abundant. The density as well as diversity showed increasing trend from higher altitude towards lower altitude in the stream under report as implicates by Shannon diversity index. On the basis of Karl-
Pearson’s coefficient of correlation between density of phytoplankton and various physicochemical parameters, phytoplankton showed a significant positive correlation between parameters like hardness, total alkalinity, TDS, phosphates, nitrates and conductivity and rest of parameters like chloride and pH showed negative non-significant correlation while significant negative relationship has been shown by the parameters like temperature and water current.

Three animal groups constitute benthic macroinvertebrates community in study sites namely Arthropoda, Annelida and Mollusca, which include major 25 genera. Of the 25 genera, 22 belong to Arthropoda, 1 belongs to Annelida and 2 belong to Mollusca. The 22 genera of Arthropoda are distributed among four orders viz. (8 to Ephemeroptera, 5 to Plecoptera 4 to Diptera and 5 to Trichoptera). There are variations in the quantity of density of benthic macroinvertebrates. The higher density was recorded in lower altitudes and minimum density in the higher altitude stream. There is general trend of increasing density as well diversity from higher altitudes towards lower altitudes. The minimum density occurs during monsoon months whereas maximum density occurred during spring and winter months. The various individuals of communities of benthic macroinvertebrates showed maximum adaptation to the fast torrential water in these hillstreams. The total density of benthic macroinvertebrates showed a significant positive correlation between the parameters like TDS, hardness, total alkalinity, whereas nonsignificant correlation has been shown by the parameters like conductivity, dissolved oxygen and nitrates. The major group of benthic macroinvertebrates, Ephemeroptera showed a significant positive correlation with parameters like conductivity, TDS, total alkalinity and hardness.

Zooplankton diversity in all the study sites includes four genera of protozoans, three genera of rotifers and one genus each of copepod and cladoceran respectively.
Of the four genera of protozoans, *Arcella* spp., *Paramecium* spp. occurred more frequently whereas *Branchionus* spp. and *Rugipies* spp. occurred less frequently. *Branchionus* spp. and *Notholoca* spp. (Rotifer), *Cyclops* (Copepods), and *Daphnia* spp. occurred more frequently in the study sites. Review of literature showed that the scattered and little information is available on the zooplankton as far as the ecology of zooplankton in the hillstreams is concerned. Moreover, their abundance is low in the streams having high water current.

Three fish species viz. *Schizothorax richardsonii*, *Salmo trutta fario* and *Crossocheilus latius* have been found to inhibit the stream under report during the present investigations. The *Schizothorax richardsonii* has accounted maximum in all the study sites, followed by *Salmo trutta fario* whereas *Crossocheilus latius* encountered least in number and recorded in study sites situated in the lower altitudes. In the higher altitudes study sites, individuals of *Crossocheilus latius* were absent. The total density of fish population was higher in the lower altitude and catch decreases as we proceeds towards higher altitude. Based on Morisita-Horn index it can be inferred that the study sites in these hillstreams are similar to each other as far as the distribution of fishes is concerned. Based on coefficient of correlation between density of total density of fishes and various physicochemical parameters, total fish density showed a significant positive correlation between parameters like conductivity, dissolved oxygen, TDS, total alkalinity and hardness, whereas significant negative correlation has been shown by the parameters like water temperature and water current. The total density of fishes shows nonsignificant correlation with parameters like pH, chlorides, nitrates and phosphates. Coefficient of correlation between density of total fishes density and various biotic factors (phytoplankton and benthic macroinvertebrates) have been studied. It has been found that both phytoplankton and benthic macroinvertebrates play a significant role in the density and distribution of fishes. Moreover good degree of correlation *Schizothorax richardsonii*, phytoplankton, *Salmo trutta fario*, and benthic macroinvertebrates suggest that these
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are herbivorous and carnivorous fishes respectively.

Scanning electron microscopic investigation carried on the benthic macroinvertebrates e.g. *Bibiocephala* spp. and *Isoperla* spp. showed the presence of various attachment structures which help to cope with the fast flowing water current of these hillstreams. In *Bibiocephala* spp. there are present half dozen suckers on the ventral part of the body besides the presence of lateral spines in the body, while in the *Isoperla* spp. there are present very small cup like structures known as attachment pads. These structures represent the most advance case of morphological adaptations as these help in the process of attachment of the animals to the even the smooth surface of substratum of these fast flowing hillstreams and enables the organism to attach them firmly.

The common vertebrates around the vicinity of study streams includes *Rana tigrina*, *Calotes versicolor* (Duden), *Hemidactylus flavivirdis* *Alcido attvis* (Common Kingfisher), *Rhesus macaque*, *Himalayan Thar* spp., *Passer domesticus* (House sparrow), *Corvus domesticus* (Jungle Crow), *Columba livia* (Common Pigeon), and *Acridotheres attthis* (common Mynah).

Various anthropogenic activities that influencing the delicate ecology of the study streams under report include, hydroelectric dams, dredging and extraction of bed material, siltation, channelization, diversion of water, channel, sedimentation/ soil erosion, tourism, agricultural activities, pollution, destructive fishing methods.

The riparian vegetations in the study streams under report comprises the Bryophytes, Pteridophytes Gymnosperms and Angiosperms. The main riparian cover in the higher altitude comprises *Riccia* spp., *Sphagnum* spp., *Adiantum* spp., *Pinus wallichiana*, *Cedrus deodara*, *Taxus wallichiana* and *Rhododendron campanulatum* whereas the riparian cover in the lower altitude study sites comprises wide varieties of vegetations, the common ones are *Funaria* spp., *Selaginella* spp., *Pinus longifolia*, *Polygonatum erticillatum*, *Dalbargia sissoo*, *Cedrela toona* and *Berberis lyceum* respectively.
RECOMMENDATIONS AND SUGGESTIONS

1. The present study deals with interrelationship of various biotic and abiotic factors in the selected study sites of Tirthan and Sainj streams. The knowledge gathered could be helpful in “habitat restoration programmes”. The restoration should include abiotic and biotic environment of the fishes and other fauna.

2. Continuous monitoring of hillstreams will be helpful to know the areas that need restoration.

3. The riffles and pools are habitats for macroinvertebrates and fishes so these habitats should be protected.

4. The local peoples are first to use and first to harm the natural environment, so awareness on regular basis and their involvement plays a key role in restoration and maintenance of these hillstreams.

5. Strict laws will help to check on illegal practices.

6. Disposal of non-biodegradable waste in water bodies should be checked.

7. Construction in and around the streams, disturbs the habitat structure considerably, moreover there is addition of silt to the pockets between stones, thereby reduce shelter for the benthic macroinvertebrates and these activities should be discouraged.

8. Tourism activities should be restricted and if not, then these should least disturbs the natural habitat structure and, pollution by tourist should be checked.

9. Time to time, launching of restoration programme by governmental and nongovernmental organizations can help to reduce the impact made by anthropogenic activities and natural disaster.

10. Organizing workshops, seminars and symposia at regular intervals is the need of the hour.

With the advent of various technology and increasing human populations there is always a pressure on these valuable water resources. Various anthropogenic activities harms these aesthetic places to a greater extent, therefore these valuable natural resources should be properly managed and save it from further degradations.