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SPATIAL DISTRIBUTION AND DIVERSITY OF FISHES IN DIFFERENT ECOLOGICAL SECTIONS OF SPRING- FED RIVER MANDAL FROM UTTARAKHAND, INDIA

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ABSTRACT

The fish play an important role in the life of rural folk in Garhwal Himalaya as it is a cheaply available protein rich source. In the present communication an attempt has been made to study the spatial distribution, density and diversity of fishes in three different sections of river Mandal in Pauri Garhwal. The study was based on two spots in upper rhithon section, two spots on lower rhithron section and one spot in the lower potamon section. It was observed that the middle stretch (Lower rhithron zone) was more diverse and productive where fish productivity was 46 CPP at Spot no 3 (19 species) and 34 CPP at spot no 4 (13 species). Upper stretch of the river was less productive. The lowermost section has low diversity in term of taxon but the biomass production was maximum. Overall 20 taxa were observed wit the dominance of family cyprinidae with 10 taxon and cobitidae with 7 taxon. Channidae was represented by 2 taxon and family balitoridae, ambliceptidae and mastacembelidae by 1 taxon each. Diversity was assessed with the help of Simpson, Shannon and Wiener, Menhinick, Margalef and equitability J indices. Multivariate analysis was done with the help of cluster and principal component analysis. Some detrimental ecological parameters were also analysed which had either positive (pH and temperature) or negative (velocity of water current and dissoved oxygen) impact on fish population.

INTRODUCTION

Fishes have been associated with man since ages. Many references of fishes are available in Matsyapuran, Upnisad and Vedas (The religious books of Hindus). In present time the fish has an important role in the life of human being medically as well as economically. Fish are valuable source of high-grade protein and other organic products and nutritionally important human diet, which are the necessary part of human food. Fish occupy a significant position in socio-economic fabric of the many countries by providing the nutritious food and employment opportunities. The fish has also attracted the attention of taxonomist, naturalists and zoo-geographers as it is the most diverse group of vertebrates which possess diverse behaviors in its feeding and breeding physiology. There is a vast number of fish species inhabiting both the marine and the fresh water habitats. Majority of the freshwater fishes are available in India and its adjacent countries like Pakistan, Bangladesh and Srilanka etc. India is a rich country in fresh water resources. So many large and small rivers (snow fed and spring fed), their tributaries, ponds and lakes provide a suitable habitat for fish and other aquatic animals.

Garhwal Himalaya forms a considerable part of Central Himalaya. The whole region cover an area of 30,000 square kilometers with several cold water lentic and lotic bodies that owe their origin either in the snow peaks or in the springs of mountains. The lotic water bodies are some snow fed and spring fed river while the lentic water bodies are natural cold water lakes and few man made reservoirs. Ganga, Yamuna, Alaknanda, Bhagirathi, Mandakini, Kedarganga, Jarganga, Bhilangana, Nayar, Song and Khoh are some important snow and spring fed river of this river. About 68 fish species sre reported from this region (Singh, et.al,1987). Snow trout, Mahseer and *Labeo* are the main food fish and *Puntius, Barilius, Garra, Noemaheilus* and *Glyptothorax* are some other common fishes inhabiting in this region.

River Mandal has been considered as important spring fed stream in Garhwal Himalaya (Latitude 29 º 45' N – 29 º 55' 40"N and longitudes 78º 17' 15" E - 78 º 55' 20" E). Studies on its diversity in terms of fish population, Plankton and

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benthic flora and fauna has been made for the first time by the present authors. In the present communication an attempt has been made to describe the taxonomic richness and diversity of fishes in river Mandal at five different spots located in three different zones of the stream. The first stretch was a rhithron zone with faster velocity less depth and mostly the stony-pebbly bottom (Spots 1 and 2). The second stretch was also a rhithron but it was in a less gradient zone which had low water velocity in comparison to the first one (Spots 3 and 4). The third section of the stream was a potamon zone which had lowest velocity of water current and comparatively lowest gradient. The span of river was also wide. The stream overall being a spring fed one, with moderately warm water, is highly productive for biotic life.

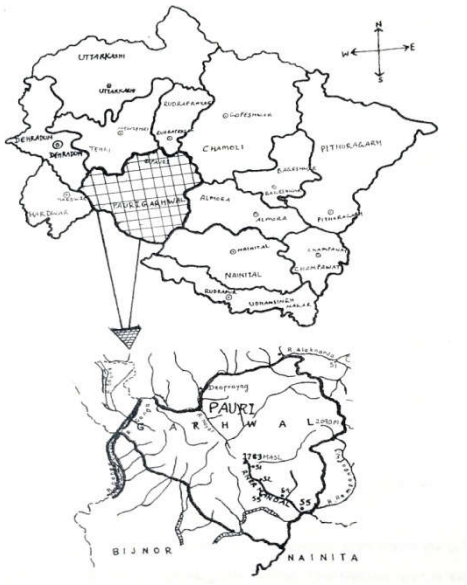

Fig 1 Location map of river Mandal

During early surveys of the Garhwal Himalayan streams till late eighty's, several workers reported a colourful and more diverse fish fauna from river Nayar, which was recognised as a natural abode for the migratory mahseer (Badola,1975; Nautiyal, 1982; Dobriyal, 1983; Tilak and Baluni (1984), Singh et.al., 1987; Dobriyal *et. al*., 1992).

MATERIAL AND METHODS

The fish fauna of the Mandal river was surveyed at 5 spots in three different stretches since 2003 to 2006 Fig 1). Fish identification was made on the basis of characters as described by Day (1878), Talwar and Jhingran (1991) and Badola (2009). Some detrimental ecological parameters (current velocity, dissolved oxygen, pH) were studied as per standard methodology, APHA, and Welch,1948). Various species dominance and diversity indices (Dominance-D, Shanbon Wiener Index H', Margalef D, Menhinick index, Fisher α) and multivariate analysis (Principal Component analysis and Clusture analysis) are calculated by the statistical software Paleontological Statistics (PAST) version 3.14. Impact of ecological parameters on fish populations is traced by the method of regression and correlation analysis.

RESULTS AND DISCUSSION

The faunal inventory during this period is shown in Table 1. It was observed that the middle stretch (Lower rhithron zone) was more diverse and productive where fish productivity was 46 CPP at Spot no 3 (19 species) and 34 CPP at spot no 4 (13 species). The second spot had productivity of 20 CPP (10 species), which was also lower rhithron. The last spot had 19 CPP (7 species) productivity where the catch was more but the diversity of fish was less. (To estimate the fish potential at different spot the calculated productivity points system-CPP was used as suggested by Dobriyal and Singh (1988).

Table 1 List of different fish species and their relative abundance in the upper, middle and lower stretches of the river Mandal during 2003-05

SN	Name of species	Upper Stretch (CPP)		Middle Stretch (CPP)		Lower Stretch (CPP)
		Sp. 1	Sp. 2	Sp. 3	Sp. 4	Sp. 5
1	*Puntius conchonius* (Ham.-Buch.)	0	1	3	3	3
2	*Barilius bendelisis* (Ham.-Buch.)	2	2	3	0	0
3	*Barilius barna* (Ham. Buch)	1	2	2	0	0
4	*Barilius vagra* (Ham. Buch)	1	1	2	2	0
5	*Tor Putitora* (Ham. Buch)	0	0	0	2	2
6	*Tor Chelynoides* (McClelland)	2	2	3	0	0
7	*Schizothorax richardsonii* (Gary)	0	0	0	3	3
8	*Schizothorax plagiostomus* (Gary)	0	0	3	0	3
9	*Crossocheilus latius latius* (Ham. Buch)	0	0	3	3	0
10	*Garra gotyla gotyla* (Gary)	0	0	0	3	0
11	*Botia dayi* Hora	0	0	3	0	0
12	*Lepidocephalus Guntea* (Ham.-Buch)	0	0	2	3	0
13	*Xenetodon cancila* (Ham.)	0	0	3	2	3
14	*Nemacheilus botia* (Ham.)	1	1	2	3	0
15	*Nemacheilus denisoni* Day	1	2	2	2	0
16	*Nemacheilus montanus* (McClelland)	3	3	2	0	0
17	*Nemacheilus rupecola* (McClelland)	3	3	2	0	0
18	*Nemacheilus Savona* (Ham.-Buch)	3	3	2	0	0
19	*Amblyceps mangois* (Ham.)	0	0	2	0	0
20	*Mastacembelus armatus* (Lacepede)	0	0	3	3	3
21	*Channa punctatus* (Bloch)	0	0	2	3	0
22	*Channa Orientalis* Bloch Schneider	0	0	2	2	2
	Total	17	20	46	34	19

3=Abumdant, 2=Common, 1=Rare, 0=Nil

(i) 9 Species found in Ist Zone

(ii) 10 Species found in IInd Zone

(iii) 19 Species found in IIIrd Zone

(iv) 13 Species found in IVth Zone

(v) 7 Species found in Vth Zone

Table 2 Taxonomic Position of Fish Fauna of The River Mandal

Systematic Position	Scientific Name	Local Name	English Name	Fin Formula	Distribution	
a.	**Order : Cypriniformes Family: Cyprinidae**					
1.	*Puntius conchonius* (Ham.-Buch)	Dhamra	Rosy barb	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Ganga, Brahmaputra, Mahanadi, Cauvery, Nepal, Bangladesh.	A
2.	*Barilius bendelisis* (Ham.)	Jabula	Hamilton's barila	$D_{2/7-8,A2-3/5},P_{1/18},V_{1/8}$	Pakistan, Nepal, Sri Lanka, Bangladesh, India.	A
3.	*B. barna* (Ham.-Buch)	Jabula	Barna barila	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Ganga, Brahmaputra, Mhanadi, Orissa, Bangladesh,	C
4.	*B. Vagra* (Ham-Buch)	Jabula	Vagra baril	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Iddus Plain, Pakistan, Afghanistan, Nopal, Bangladesh, Sri Lanka.	C
5.	*Tor Putitora* (Ham-Buch)	Kanita	Himalayan golden mahseer	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	India, Afghanistan, Nepal, Bangladesh.	C
6.	*Tor Chelynoides* McClelland	Kanita	Dark mahseer	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	North Eastern Baluchistan, Pakistan,Assam, Garhwal Eastan & Westen Nayer, Ganga.	C
7.	*Schizathorax richardsonii* (Gray)	Kanchula	Snow trout	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Jammu & Kashmir, H.P., Uttaranchal, Assam, Sikkim, Bhutan, Pakistan, Nepal, Afghanistan.	C
8.	*Schizothorax plagiostomus* (Gray)	Kanchula	Snow trout	D ,A ,P ,V		C
9.	*Crossocheilus latius latius* (Ham.-Buch)	Sendora	Gangetic latia	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Drainages of the Ganga, Mahanadi River drainagex in Orissa, Western Ghats, South to the headwaters of Krishna river.	C
10.	*Garra gotyla gotyla* (Gray)	Gothela	Gotyla	$D_{3/7-8,A2-3/5},P_{1/18},V_{1/8}$	Pakistan, Bangaladesh, Upper Burma along the Himalaya, Chota Nagpur Plateau.	C
b.	**Family : Cobitidae**					
1.	*Botia dayi* Hora	Baag machi	Hora loach	$D_{2-3/9},A_{2/5,11-12},V_{1/7}$	Pakistan, Darjeeling Himalaya, Brahimaputra drainage of Assam, Garhwal spring feed rivers.	R
2.	*Lepidocephalus guntea* (Ham.-Buch)	Sueen gadiyal	Guntea Loach	$D_{2-3/6-7},A_{2-3/5},P_{1/6-7},V_{1/6-7}$	Pakistan, Bangladesh, Nepal, Burma, Thailand, North India.	C
3.	*Nemacheilus botia* (Ham.)	Gadiyal	Loaches	$D_{3/9-11},A_{3/5},P_{1/11},V_{1/7}$	India, Pakistan,Indus-basin, Northern India, Brahmaputra, Ganga basins.	A
4.	*N. denisoni*i Day	Gadiyal	Loaches	$D_{3/8},A_{2-3/5},P_{1/9-10},V_{1/6}$	Peninsular India, Bihar and M.P (Bastar), Hill-stream of Garhwal.	C
5.	N. montanus (McClelland)	Gadiyal	Loaches	$D_{3/7},A_{2/5},P_{1/9},V_{1/6}$	H.P, Uttaranchal.	C
6.	*N. rupecola* (McClelland)	Gadiyal	Loaches	$D_{2/8},A_{2/5},P_{1/11},V_{1/7}$	Westen Himalaya, Kumaon, Garhwal Hills, Sutlej & Beas drainages of H.P.	C
7.	*N. Savona* (Ham.-Buch)	Gadiyal	Loaches	$D_{3/9},A_{2/5},P_{1/9},V_{1/6}$	Tista drainage at Darjeeling through Nepal, Uttaranchal hills of Garhwal.	C
c.	**Family : Balitoridae**					
1.	*Xenetodon cancila* (Ham.-Buch)	Suee machi	Fresh Water gar Fish	$D_{15-18},A_{16-18},P_{11},V_{6}$	India, Uttaranchal, Pakistan, Bangladesh, Sri Lanka, Burma & Thailand.	C
d	**Family : Ambliceptidae**					
1.	*Amblyceps mangois* (Hamilton)	Seeple	Indian torrent Catfish	$D_{1/5-6},A_{2-3/6-8},P_{1/7},V_{1/5-6}$	Pakistan, India : along the foot hills of the Himalaya from Kangra Valley (Himanchal Pradesh) to Assam, Bangladesh, Northern Burma, Thailand.	C
e.	**Family : Mastacembelidae**					
	Mastacembelus armatus (Lacepede)	Gair	Tiretrack	$D_{32-40/64-92},A_{3/64-90},P_{21-27},C_{14/17}$	Srilanka, Nepal, Bruma, Pakistan, Thailand & Malaya to Southern China, Garhwal Spring fed river (India)	A
f.	**Family : Channidae**					
1.	*Channa punctatus* (Bloch)	Sangla	Spotted Snakehead	$D_{28-33},A_{20-23},P_{15-18},V_{6}$	India, Pakistan, Afghanistan, Nepal, Bangladesh, Burma, Yunnan (China), Sri Lanka.	C
2.	*Channa orientalis* Bloch & Schneider	Sangla	Asiatic Snake	$D_{32-37},A_{20-23},P_{14-15},V_{6}$	Iran, Pakistan, Afghanistan, India, Nepal, Sri Lanka, Bangladeshy, Burma, East Indies.	C

The species which were abundant in the uppermost section (Spot 1 and 2) included *Nemacheilus montanus* (McClelland), *Nemacheilus rupecola* (McClelland), *Nemacheilus Savona* (Ham.-Buch), *Barilius bendelisis* (Ham.-Buch.), *Barilius barna* (Ham. Buch), *Barilius vagra* (Ham. Buch), *Tor Chelynoides* (McClelland) *Nemacheilus botia* (Ham.) and *Nemacheilus denisoni* Day.

The species which preferred middle stretch (Spot 3 and 4) were *Puntius conchonius* (Ham.-Buch.), *Tor Putitora* (Ham. Buch), *Garra gotyla gotyla* (Gray), *Crossocheilus latius latius* (Ham-Buch), *Schizothorax richardsonii* (Gary), *Schizothorax*

plagiostomus (Gary), *Xenetodon cancila* (Ham.), *Mastacembelus armatus* (Lacepede), *Lepidicephalichthys guntia* (Ham.-Buch.), *Amblyceps mangois* (Ham.), *Barilus vagra* (Ham.-Buch.), *Channa punctatus* (Bloch), *Botia dayi* Hora and *Channa Orientalis* Bloch Schneider.

Last spot in lower stretch interesting had very high catch in comparison to other spots, but with lowest diversity of species *Puntius conchonius* (Ham.-Buch.), *Tor Putitora* (Ham. Buch), *Schizothorax richardsonii* (Gary), *Schizothorax plagiostomus* (Gary), *Xenetodon cancila* (Ham.), *Mastacembelus armatus* (Lacepede) and *Channa Orientalis* Bloch Schneider.

The taxonomic details of all fish species is listed in Table 2. Maximum diversity was from family cyprinidae (order Cypriniforms) which was represented by ten species (*Puntius conchonius*, *Tor Putitora*, *Schizothorax richardsonii*, *Schizothorax plagiostomus*, *Barilius bendelisis*, *Barilius barna*, *Barilius vagra*, *Tor Chelynoides, Garra gotyla gotyla and Crossocheilus latius latius)*. Family cobitidae was represented by seven species (*Nemacheilus montanus*, *Nemacheilus rupecola*, *Nemacheilus Savona*, *Nemacheilus botia Nemacheilus denisoni*, *Botia dayi, and Lepidocephalus huntea)*. Family Channidae was represented by two species (*Channa punctatus* and *Channa Orientalis)*. The families Balotoridae (*Xenentodon cancila*), Ambliceptidae (*Ambliceps mangois*), and Mastacembelidae (*Mastacembelus armatus*) was represented by one species each.

Different species richness and diversity indices are presented in Table 3. Spot No 3 in the middle stretch was observed with the highest number of taxa (19) and richest CPP (46) which was followed by the spot number 4 also in the middle stretch with 13 taxa and 34 CPP, and spot number 2 with 10 taxa and 20 CPP. Spot 1 and 5 had low diversity. Simpson Diversity index (1-D) measures the evenness of community from 0 to 1.

It was observed maximum 0.9452 at spot no 3 followed in decreasing order by 0.9204 at spot no 4, 0.885 at spot no 2, 0.8651 at spot no 1 and 0.8532 at spot no 5.

Shannon wiener ($H^{/}$) is the best diversity index which takes into account number of individuals as well as no of taxa. It varies from 0 for single taxon to high for increasing no of taxon. Its vale was highest for spot no 3 (2.924) with 19 taxon, followed by spot no 4 (0.9204) with 13 taxon, spot no 2 (2.224) with 10 taxon , spot no 1 (2.089) with 9 taxon and lowest (1.931) with 7 taxon. Menhinick richness index was highest 2.801 (Spot 3) followed in decreasing order by 2.236 (Spot 4), 2.229 (Spot 2), 2.089 (spot 1) and lowest 1.606 at spot No 4.

Margalef richness (D_{MG}) has a better differentiation in index being as high as 4.701 (S-3), followed by 3.403 (S-4), 3.004 (S-2), 2.824 (S-1) and 2.038 (S-5). The Equitability J index measures evenness with which individuals are devided among taxa. It was high 0.993 at spot 3rd and 4th followed by 0,9924 at spot no 5 and 0.9659 at spot 2 and 0.9505 at spot 1.

Multivaraite analysis was done with clusture technique for different fish species (Fig 2) which showed that primary clusture were firmed between *N. botia –N denisonii, L guntea – C punctatus, S. plagiostomus - A mangois , P conchonius- M armatus, T. putitora- S richardsonii and T chelynoides – G gotyla gotyla.*

Table 3 Species diversity analysis of fish fauna in 5 different spots in river Mandal

Spots	1	2	3	4	5
Number of Taxa	9	10	19	13	7
Individuals	17	20	46	34	19
Simpson_1-D	0.8651	0.885	0.9452	0.9204	0.8532
Shannon Wiener $H^{/}$	2.089	2.224	2.924	2.547	1.931
Menhinick	2.183	2.229	2.801	2.236	1.606
Margalef	2.824	3.004	4.701	3.403	2.038
Equitability_J	0.9505	0.9659	0.993	0.993	0.9924

Secondary clusture was made between *N rupicola- N savona* with *T chelynoides – G gotyla gotyla*; *C latius latius* with *N. botia –N denisonii; C orientalis* with *P conchonius- M armatus*; Top clusture was made between group of *T chelynoides – G gotyla gotyla and N rupicola- N savona* with all other clustures.Clusture for fish population of different spots from river Mandal is presemted in Fig 3 which indicated that Population of Spot no 3 and 4 and on the other hand Spot no 2 and 5 made a clusture at bottom. Secondary clusture was made by population of Spot 1 with that of Spt 2 and 5. Final clusture was made between Spots 3-4 with rest others. Which clearly shows the similarity as also evidenced by other diversity indices discueed earlier.

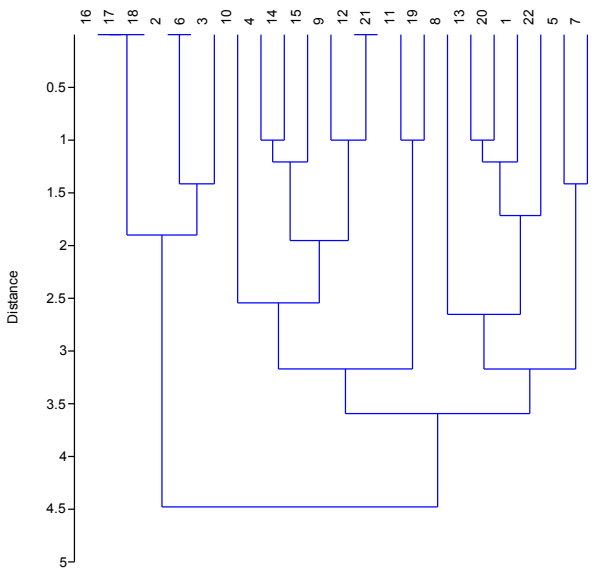

Fig 2 Clusture analysis of different fish species from River Mandal, Uttarakhand, India

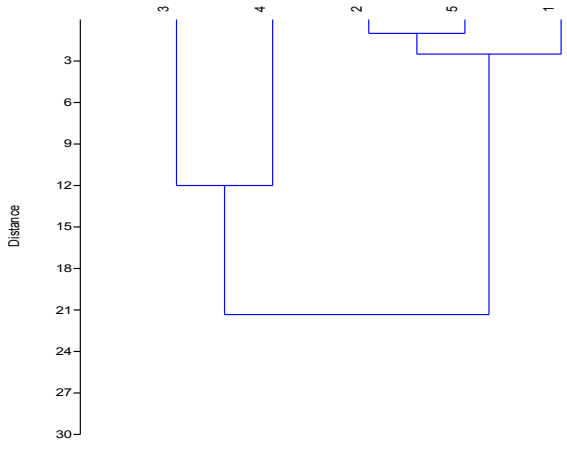

Fig 3 Clusture analysis of fish population of different spots from river Mandal Uttarakhand, India

Simiar results were obtained when PCA was done between populations of these spots (Fig 5). C and D points in the figure denote population diversity of spot 3 and 4 followd in decreasing order by A and B point for spot no 1 and 2 and the least by E for spot no 5.

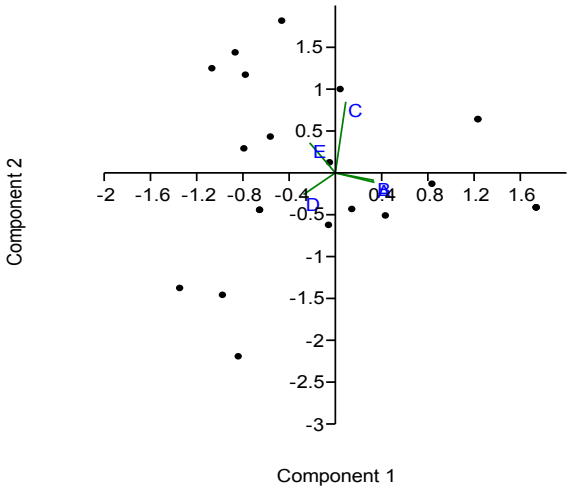

Fig 5 Principle Component Analysis (correlation basis) of fish diversity on 5 different spots in river Mandal, Uttarakhand, India

The detrimental ecological parameters in the river Mandal are represented in Table 4.The velocity of water current was high in the upper stretch (0.48 ± 0.5 m.sec^{-1}) and lowest in the lower stretch (0.34 ± 0.26 m.sec^{-1}). The dissolved oxygen was also high in the upper most stretch (9.4± 1.2 mg.l^{-1}) and minimum in the lower stretch (8.1 mg.l^{-1}). It was due to gradient and clarity of water. However the water temperature and pH were (22 ±6 ^{o}C and 7.5 ± 0.6 respectively) low in the upper stretch and high in the lower stretch (24.2 ± 4.3^{o}C and 8.1 ±0.7 respectively).

Table 4 Average values of some detrimental ecological factors in upper, middle and lower stretch of river Mandal

SN	Ecological parameter	Upper stretch Spot 1	Upper stretch Spot 2	Middle stretch Spot 3	Middle stretch Spot 4	Lower stretch Spot 5
1	Velocity of water current m.sec^{-1}	0.48± 0.5	0.45± 0.4	0.36± 0.15	0.37± 0.2	0.34± 0.26
2	Dissolved oxygen mg.l^{-1}	9.4 ± 1.2	8.8 ± 1.7	8.7 ± 1.4	8.6 ± 1.7	8.1 ± 0.7
3	Water Temperature ^{o}C	22.0 ± 6.0	21,8 ± 7.2	24.0 ±5. 6	23.5± 5.2	24.2± 4.3
4	Ph	7.5 ± 0.6	7.7 ± 0.8	7.9 ± 1.4	7.8 ± 1.1	8.1 ± 0.7
5	Substratum heterogeneity	Stones/ cobbles	Cobbles	Cobbles/ Pebbles	Pebbles	Pebbles/Sand

The impact of ecological parameters on fish population was studied through Regression analysis (a= intercept, b= regression coefficient), coefficient of correlation (r) and coefficient of determination (r^2). Velocity of water current has a sharp negative relationship (Fig 6) with fish population (a= 70.93, b= - 109.3, r= - 0.5357, r^2= 0.287). Dissolved oxygen (Fig 7) also had a negative relationship (a= 63.56, b= - 4.17, r= - 0.1549, r^2= 0.024). However the water temperature (Fig 8: a= -114.6, b= 6.141, r= 0.554, r^2= 0.307) and pH(Fig 9) had a positive relationship (a= - 97.6, b= 16, r= 0.286, r^2= 0.082).

CONCLUSION

Hill streams play an important role in the socio-economic life of the rural folk in Garhwal region of India as it not only provides cheap protein rich diet to them but also insure their economic standing. The hypothesis set for this experiment was based on the analysis of population dynamics and diversity of fish population through different ecological sections of the stream. It was also kept in mind that the study might be helpful in conservation of fish that environmental condition. On the basis of diversity and multivariate analysis, it was noticed that on the one hand the diversity of fish species was more in middle-lower stretch where the temperature, pH, DO and current velocity was moderate and conducive for benthic biota. On upper stretches diversity as well as density of population was low due to faster current and unfavorable substratum heterogeneity. The lowermost stretch had voluminous water, low current velocity, high pH but DO on lower side. This spot had low diversity of species but food fishes were available in good number. Each stretch of stream can be developed according to the species available there. An interaction was made with rural folk to encourage them for fish development and create awareness towards use of eco-friendly fishing techniques

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