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RESEARCH ARTICLE

DIVERSITY OF AQUATIC INSECTS AND FUNCTION OF FLUVIAL SYSTEM OF SONG AND SUSWA RIVER OF RAJAJI NATIONAL PARK, UTTRAKHAND, INDIA

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ABSTRACT

Aquatic insect diversity of Rajaji National Park has been monitored for a period of twelve months. Some of the hydrological attributes were measured in continuity of one month interval. Aquatic insects were sampled from four sampling sites (S_1, S_2, S_3 and S_4) of Song and Suswa river of Rajaji National Park. The study revealed that some of the physico-chemical parameters in addition to nature and size of substrate have their significant impact on aquatic insect diversity. The diversity of benthic macro invertebrates have found to be high in winter months comparatively due to low turbidity, high water transparency, moderate water temperature, high dissolved oxygen and low water velocity. The abundance of aquatic insects were also associated with the high primary production during winter season. Some suggestions were also made for the conservation and management of the diversity of aquatic insects dwelling the Song and Suswa rivers of Rajaji National Park.

INTRODUCTION

Importance of aquatic insects in an aquatic ecosystem cannot be ignored as they constitute important part of the food chain in the ecosystem. They have also been considered as an indicator of stream condition and assessment of river water quality (Noris and Noris, 1995). They exhibit a great breath of genetic diversity hence their maintenance is essential for the survival of any lentic and lotic ecosystem. Distribution, density and biomass of aquatic insects depend upon the physico-chemical attributes of water, nature of substratum, biological complexes such as food, predation and other factors. Aquatic insects has been used to assess the biological integrity of stream ecosystem in various studies (Rosenberg and Resh, 1993; Resh *et al.*, 1995). The majority of these efforts have been conducted on variety of streams at global level (Clausen and Biggs, 1997, 1998 and 2000; Collier *et al*., 1997, 2000 and 2001*;* Royer *et al*., 2001; Walsh *et al.,* 2001; Anbalagan and Dinakaran, 2006; Anbalagan *et al*., 2004; Sarmistha *et al*., 2009; Tang *et al.,* 2010) and at national level (Sivaramakrishnan *et al.*, 1996, 1996 and 1998; Bhattacharya, 1998; Mukerjee *et al.,* 1998; and Sharma, 1986; Bhattacharaya, 2000; and Balaram, 2005). Meager information is available on aquatic insects of Garhwal Himalayas except some preliminary studies by Badola, 1979 and Sharma, 1986:

Considerable work has been done on the terrestrial biodiversity of Rajaji National Park (Diwakar, 1995, Panwar and Mishra, 1994) but no information is available so far on the aquatic biodiversity and the function of fluvial ecosystem of Rajaji National Park. Therefore the present work on the monitoring and conservation of aquatic insects of the river Song and Suswa of Rajaji National Park was carried out.

Aquatic habitat in rajaji national park

Song and Suswa are two perennial rivers draining Rajaji National Park in north eastern slopes of Shiwalik. The north eastern slopes of Shiwaliks are very steep and rugged in the upper portion but in the lower portion it has a quiet easy gradient. There are large number of short, shallow dry and bouldery streams locally known as "raus" coming down from upper slopes and carring their discharge into Song and Suswa rivers. The forest on both the sides of the Suswa river is more or less on flat or gently sloping area often cut by nalas. The forests of eastern Doon are drained by Suswa and Song rivers. River Song and Suswa form its confluence in the Banbaha forest block. From there, it flows in a south eastern direction till it discharges into the Ganges near Satyanarian. Some seasonal tributaries also meet Song and Suswa river at Bindal, Rispana, Ren and Jakhan The river Suswa flows very nearly opposite to Asan river to the east of Saharanpur-Mussoorie highway and flows in a south easterly direction to discharge into the Song.

Study Sites

Rajaji National Park is situated in the foothills of Shiwalik Range of the newly carved out state Uttaranchal. It is the part of the Dehradun, Hardwar and Pauri district of Uttaranchal. Three sanctuaries, Motichur Sanctuary (59.5sq.km), Rajaji Sanctuary (247.0sq.km), Chila Sanctuary (249.02sq.km) and other reserve forests (234.5sq.km) are amalgamated into large protected area which is named as Rajaji National Park. The total area of the Rajaji National Park is 820.42km^2. To the north of the Rajaji National Park lies the Dehradun and Tehri Forest Division. River Suswa forms the northern natural boundary upto Ganges. River Ganges divides the Park into two units, the Chila Sanctuary complex in the east and Rajaji Motichur Sanctuary Complex in the west. To the south of Rajaji lies the revenue lands and villages of Haridwar District. Part of south eastern portion is covered by Bijnore forest division. The Garhwal forest division lies to the east of the park. Rawsan river forms a small portion of natural south eastern boundary of the park. To the west of the Rajaji lies the Shiwalik Forest Division. A preliminary survey was undertaken before sampling of aquatic insects and analyses of water quality. The two major rivers of Rajaji National Park, Song and Suswa rivers has been identified for studying the aquatic biodiversity in relation to function of these riverine ecosystems. Four sampling sites (S_1,S_2, S_3 and S_4) two each

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on the Song and Suswa rivers have been identified.. Site S_1 was selected at Shampur, S_2 at Chidderwala on Song river. S_3 and S_4 at Satyanarian and Kansroa on Suswa river of Rajaji National Park.

METHODS

Sampling

Sampling was conducted during the months of September 2001-August 2002. Water temperature was recorded with the help of a Centigrade 0-110 ^{0}C thermometer. The mean velocity was measured using electromagnetic current meter (model-PVM-2A). pH was estimated by control dynamics pH meter (model-APX15\C) while turbidity was measured by turbidity meter (model-5D1M). Nitrates and phosphates were estimated by the spectrophotometer (Spectronic 20D Series) and sodium and potassium were estimated by the digital flame photometer (model-1381). Dissolved oxygen and Free CO_2 were measured following methods outlined in APHA (1998). The control dynamics conductivity meter (model-API 185) was used for measuring conductivity.

The percentage cover of different sized substrata within each surber quadrate was estimated visually using the substrate size classes (after Bovee and Milhous 1978) of sand (0.06-2mm), fine gravel (2-32mm), coarse gravel (32-64mm), cobbles (64-256mm) and boulders (>256mm) with Surber Sampler (0.5mm mesh net) to a depth about 10cm in a quadrat. Samples were preserved in 4% formalin .The invertebrate fauna were identified to the possible lowest taxonomic level and counted. The quantitative analysis were made by using Ward and Whipple (1992) and several taxonomic keys of Freshwater Biological Association, UK.

Diversity Index

Diversity indices are mathematical expressions that combine three components of community structure-richness (number of species present), evenness (the distribution of individuals among species) and abundance (total number of organisms present). It is used to describe the response of a community to the quality of its environment. The most widely used diversity index, Shannon and Wiener (1964) has been used:

Shannon Weiner diversity indices

Species diversity index ($\overline{H}$) was calculated using the Shannon Wiener information function (Shannon and Weiner 1964).

$$(\overline{H}) = \sum_{l-1}^{s}\left(\frac{ni}{N}\right)\log_2\left(\frac{ni}{N}\right)$$

Where,

$\overline{H}$ = Shannon Wiener index of diversity;
Ni = Total no of individual of a species;
N = Total no of individuals of all species.

Concentration of Dominance (C)

The Concentration of Dominance (C) was computed by Simpson (1949) index as

$$C = -\sum_{i=1}^{s}\left(\frac{n_i}{N}\right)^2$$

where,

C = concentration of dominance;
Ni = total no of individuals of a species;
N = total no of individuals of all species.

RESULTS

Inventorying of Diversity of Aquatic Insects

Aquatic insects dwelling the Song and Suswa river are represented by immature stages of the insect order Ephemeroptera, Plecoptera, Tricoptera, Coleoptera, Odonata, and Diptera. Crustaceans, Molluscs, Annelids and Nematods were also found to occur during the study period. Eight species of Ephemeropterans were found to occur. Ephemerella was found to be the abundant species among Ephemeropterans. Plecopterans were represented by four genera. Tricopterans were represented by four genera,. Dipterans were represented by four genera among which Tendipes were the abundant species.The Coleopterans were represented by three genera. The Odonatans were represented by five genera. Molluscans were represented by Bivalves and Gastropodes. Ephemeropterans, Plecopterans, Tricopterans, Dipterans and Molluscans were presents throughout the study period whereas Odonates, Crustaceans, Annelids and Nematods didnot show regular presence. During the present investigation, a total of 38 genera of macro-invertebrates were recorded from the Song and Suswa river of Rajaji National Park. Ephemeroptera was found to be the dominant group. Singh and Nautiyal (1990) recorded 30 taxa of macro-invertebrates dominated by Ephemeroptera and followed by Diptera, Tricoptera and Plecoptera. Sehgal (1990) recorded 57 genera of insects from 11 rivers of the North-Western Himalaya, Joshi (1991) observed 50 genera of insects from Sherkhad stream in Himachal Pradesh and Bhat and Pathak (1992) recorded 68 genera of insects from various rivers of Kumaon region. According to Minshall (1984), *Heptagenia* and *Ephemeralla* were found on smooth surfaces of stones, *Tendipes* burrow into the substrates. The river Song and Suswa which has all major components of typical hill stream has shown a good distributional pattern of benthic invertebrates.

Diversity Indices and Concentration of Dominance (C)

The diversity index ranged from 3.1829-4.4561 at S_1, 3.0270-4.3960 at S_2, 3.1829-4.5040 at S_3 and 3.3343-4.5253 at S_4 during the study period. Maximum diversity was recorded during winters and minimum during monsoon. The Concentration of dominance (C) varied between 0.0566-0.1015 at $S_{1,}$ 0.0586-0.1328 at S_2, 0.0552 - 0.1185 at S_3 and 0.0529-0.0941 at S_4 during the study period. Dominance was found to be maximum in monsoons while minimum in winter Dominance was found reverse of the diversity.

Quantitative abundance

The quantitative abundance of aquatic insects dwelling the Song and Suswa river of Rajaji National Park revealed that the maximum benthic density was found in the month of February (1661ind.m^{-2}) while the minimum density was recorded in July (94 ind.m^{-2}) at site S_4 during the study period. The mean density ranged from a minimum of (103+-6.95ind.m^{-2}) in July to a maximum of (1602+-48.86ind.m^{-2}) in February during the study period. Ephemeropterans contribute about 24.48%, Plecoptera 17.14%, Tricoptera 15.86%, Diptera 12.16%, Coleoptera 12.48%, Odonata 2.53%, Molluscans 12.52%, Crustaceans 0.33%, Annelids 0.29% and Nematods 0.21% during the study period. Macroinvertebrates of river Song and Suswa were recorded to be minimum during monsoons and maximum during winter season. The same seasonal pattern of occurrence of macro-invertebrates has been recorded by Badola and Singh (1981) from Allaknanda river and Gusian (1994) from river Bhilanga, where as, Singh *et al.* (1982), Sharma (1985), Man Mohan *et al.* (1989) and Sunder (1997) also observed the same trend in other Himalayan rivers.

Relationship between hydrological attributes

Correlations among hydrological attributes are presented in (Table 5 and 6). Both air and water temperature are correlated positively (r=0.804)

Table 1. Monthly variations in physico - chemical parameters recorded at sampling site S_1 of the Song river of Rajaji National Park, Uttaranchal during the period from September 2001-August 2002

Parameters	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	x ± S.D.
Air temperature (^{0}C)	28.00	27.00	27.60	23.50	23.00	24.00	27.00	27.00	28.00	28.50	29.50	30.00	26.9±2.27
Water temperature (^{0}C)	25.00	23.00	23.30	22.00	21.00	22.50	24.50	25.00	26.00	27.00	26.70	28.50	24.54±2.25
Water current (m sec^{-1})	0.802	0.450	0.354	0.300	0.280	0.270	0.500	0.350	0.360	0.615	1.525	1.320	0.59±0.41
Turbidity (NTU)	58.0	0	0	0	0	0	0	0	0	89.0	93.00	97.00	28.08±42.51
HMD (cm)	46.70	46.50	44.00	45.00	45.3	40.20	40.00	43.00	47.00	48.00	48.00	48.20	45.15±2.86
Transparency (cm)	46.70	46.50	44.00	45.00	45.3	40.20	40.00	43.00	47.00	48.00	48.00	48.20	45.15±2.86
Conductivity (µm cm^{-1})	0.361	0.364	0.377	0.373	0.370	0.371	0.173	0.214	0.246	0.403	0.305	0.309	0.32±0.07
TDS (mg l^{-1})	410	400	320	160	120	250	460	500	520	560	630	780	393.63±164.63
Dissolved oxygen (mg l^{-1})	10.30	13.60	14.00	14.5	15.0	15.50	13.4	13.0	12.50	10.80	9.80	8.00	12.53± 2.31
Free CO_2 (mg l^{-1})	0.40	0.20	0.15	0.20	0.30	0.20	0.60	0.54	0.60	1.10	1.92	1.80	0.56± 0.52
pH	8.50	8.30	8.50	8.40	8.30	8.00	8.20	8.40	8.00	8.50	8.50	8.00	8.83 ± 0.20
Phosphates (mg l^{-1})	0.079	0.080	0.082	0.080	0.070	0.083	0.079	0.074	0.079	0.082	0.080	0.081	0.07 ± 0.00
Nitrates (mg l^{-1})	0.060	0.040	0.020	0.030	0.060	0.020	0.020	0.010	0.001	0.001	0.013	0.012	0.02 ± 0.02
Alkalinity (mg l^{-1}	35.00	33.00	40.00	36.00	32.00	30.00	34.00	40.00	35.00	45.00	46.00	30.00	41.22±6.48
Chlorides (mg l^{-1})	5.24	5.30	5.10	5.10	5.02	5.15	6.96	6.40	6.96	5.84	5.26	5.21	5.61±0.74
Sodium (mg l^{-1})	20.00	15.00	13.00	14.0	13.0	12.00	12.00	15.00	13.00	12.00	20.00	20.00	14.91 ± 3.23
Potassium (mg l^{-1})	00.80	00.60	00.60	00.50	00.40	00.40	00.50	00.50	00.60	00.80	00.90	00.90	0.62± 0.18

Table 2. Monthly variations in physico- chemical parameters recorded at sampling site S_2 of the Song river of Rajaji National Park, Uttaranchal during the period from September 2001- August 2002

Parameters	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	x ± S.D.
Air temperature (^{0}C)	27.50	27.30	27.50	23.90	23.30	23.80	26.00	26.90	27.40	28.00	28.30	28.70	26.55±1.86
Water temperature (^{0}C)	22.90	22.00	21.00	19.80	20.00	20.60	23.00	23.30	23.70	24.00	24.90	25.00	22.51±1.81
Water current (m sec^{-1})	0.63	0.54	0.52	0.50	0.49	0.53	0.55	0.66	0.67	0.67	1.54	1.50	0.73±0.37
Turbidity (NTU)	60.00	0	0	0	0	0	0	0	0	77.00	80.00	94.00	25.91±38.96
HMD (cm)	46.00	45.00	40.00	43.00	44.00	44.50	44.80	47.30	48.00	48.50	48.70	49.20	45.75±2.73
Transparency (cm)	46.00	45.00	40.00	43.00	44.00	44.50	44.80	47.30	48.00	48.50	48.70	49.20	45.75±2.73
Conductivity (µm cm^{-1})	0.362	0.365	0.380	0.373	0.352	0.365	0.370	0.381	0.400	0.512	0.486	0.400	0.39±0.05
TDS (mg l^{-1})	500	480	340	180	200	300	500	480	500	520	780	600	448.33±169.37
Dissolved oxygen (mg l^{-1})	10.30	11.70	13.00	14.20	14.90	14.70	15.00	14.40	12.00	10.9	10.00	9.30	12.53±2.09
Free CO_2 (mg l^{-1})	0.60	0.63	0.60	0.78	0.80	0.76	0.70	0.67	0.76	0.61	0.96	1.61	0.79±0.27
pH	8.00	7.96	8.00	8.20	8.10	8.00	7.86	7.93	8.00	7.94	7.96	8.20	8.01±0.10
Phosphates (mg l^{-1})	0.091	0.086	0.084	0.070	0.079	0.080	0.086	0.080	0.090	0.092	0.089	0.092	0.08 ± 0.00
Nitrates (mg l^{-1})	0.058	0.057	0.050	0.041	0.050	0.052	0.060	0.063	0.070	0.073	0.080	0.060	0.05±0.01
Chlorides (mg l^{-1})	4.83	4.96	4.26	4.16	4.00	4.23	5.46	5.96	4.90	4.70	4.69	4.65	4.73±0.56
Alkalinity (mg l^{-1}	32.00	30.00	35.00	40.00	39.00	36.00	35.00	37.00	40.00	38.00	38.00	45.00	41.66±13.20
Sodium (mg l^{-1})	19.00	14.00	17.00	16.00	10.00	20.00	10.00	18.00	13.00	16.00	20.00	20.00	16.08±3.65
Potassium (mg l^{-1})	00.60	00.60	00.50	00.40	00.30	00.30	00.50	00.60	00.60	00.70	00.90	00.80	0.56±0.18

Table 3. Monthly variations in physico- chemsical parameters recorded at sampling site S_3 of the Suswa river of Rajaji National Park ,Uttaranchal during the period from September 2001 - August 2002

Parameters	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	x ± S.D.
Air temperature (^{0}C)	28.00	27.20	27.60	24.80	23.00	23.20	26.70	27.00	27.50	29.50	29.00	28.60	26.84±2.12
Water temperature (^{0}C)	23.00	22.60	22.00	20.00	19.00	20.00	22.80	23.00	23.60	24.00	24.60	24.00	22.38±1.79
Water current (m sec^{-1})	0.700	0.69	0.65	0.59	0.54	0.56	0.620	0.625	0.632	0.655	1.620	1.580	0.78±0.38
Turbidity (NTU)	60.00	0	0	0	0	0	0	0	0	90.00	95.00	98.00	28.58±43.19
HMD (cm)	43.00	44.00	42.00	41.80	41.50	41.20	42.20	42.30	43.00	44.80	49.00	48.70	43.62±2.64
Transparency (cm)	43.00	44.00	42.00	41.80	41.50	41.20	42.20	42.30	43.00	44.80	49.00	48.70	43.62±2.64
Conductivity (µm cm^{-1})	0.355	0.357	0.354	0.356	0.354	0.352	0.334	0.332	0.470	0.518	0.493	0.399	0.38±0.06
TDS (mg l^{-1})	500	480	380	260	200	220	320	500	560	650	760	860	474.16±210.73
Dissolved oxygen (mg l^{-1})	10.10	12.60	13.5	14.00	14.70	15.30	15.20	13.0	12.50	10.50	9.50	8.00	12.40±2.38
Free CO_2 (mg l^{-1})	0.50	0.24	0.30	0.20	0.17	0.22	0.63	0.50	0.57	1.00	1.82	1.75	0.65±0.57
pH	8.00	8.30	8.50	8.40	7.99	7.90	8.00	8.30	8.40	8.50	8.00	8.20	8.20±0.22
Phosphates (mg l^{-1})	0.065	0.068	0.063	0.062	0.060	0.063	0.075	0.079	0.081	0.084	0.085	0.081	0.07 ± 0.00
Nitrates (mg l^{-1})	0.005	0.001	0.001	0.001	0.001	0.020	0.010	0.010	0.030	0.031	0.033	0.030	0.01±0.01
Chlorides (mg l^{-1})	5.78	5.68	5.63	5.30	5.42	5.510	5.62	4.26	4.30	4.10	4.28	4.30	5.01±0.68
Alkalinity (mg l^{-1}	45.00	50.00	54.00	53.00	50.00	48.00	49.00	50.00	53.00	55.00	50.00	55.00	36.66±15.71
Sodium (mg l^{-1})	20.00	14.00	17.00	16.00	10.00	12.00	14.00	20.00	18.00	15.00	20.00	20.00	16.33±3.42
Potassium (mg l^{-1})	00.80	00.70	00.70	00.60	00.50	00.60	00.50	00.50	00.70	00.60	00.70	00.90	0.65±0.12

Table 4. Monthly variations in physico - chemical parameters recorded at sampling site S_4 of the Suswa river of Rajaji National park, Uttaranchal during the period from September 2001 -Aug 2002

Parameters	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	x ± S.D.
Air temperature (^{0}C)	27.80	27.50	27.00	23.00	23.50	23.80	26.00	26.20	27.00	28.30	28.00	29.00	26.42 ±1.99
Water temperature (^{0}C)	22.30	221.0	20.30	18.00	18.50	21.10	21.50	22.00	22.50	23.20	23.60	23.00	21.50 ±1.77
Water current (m sec^{-1})	0.626	0.600	0.566	0.500	0.466	0.540	0.620	0.662	0.672	0.740	1.600	1.540	0.76 ±0.38
Turbidity (NTU)	64.00	0	0	0	0	0	0	0	0	80.00	86.00	93.00	26.91 ±40.27
HMD (cm)	42.00	42.00	41.20	40.80	39.90	39.40	40.00	41.50	41.90	43.60	44.50	44.00	41.73±1.63
Transparency (cm)	42.00	42.00	41.20	40.80	39.90	39.40	40.00	41.50	41.90	43.60	44.50	44.00	41.73±1.63
Conductivity (µm cm^{-1})	0.356	0.362	0.368	0.372	0.376	0.370	0.360	0.366	0.460	0.517	0.374	0.360	0.38 ±0.04
TDS (mg l^{-1})	500	500	360	160	180	280	320	500	460	520	760	780	443.33 ±197.22
Dissolved oxygen (mg l^{-1})	10.50	12.90	13.70	14.60	15.20	15.0	13.30	12.90	12.50	10.60	9.60	8.30	12.42 ±2.21
Free CO_2 (mg l^{-1})	0.39	0.22	0.29	0.19	0.12	0.10	0.26	0.23	0.28	0.32	1.16	1.86	0.45 ±0.52
pH	8.30	8.10	8.60	8.40	7.94	7.99	8.50	8.30	8.40	8.20	8.00	8.20	8.24 ±0.21
Phosphates (mg l^{-1})	0.073	0.071	0.070	0.068	0.065	0.064	0.073	0.079	0.082	0.087	0.089	0.081	0.07 ± 0.00
Nitrates (mg l^{-1})	0.005	0.003	0.003	0.002	0.001	0.002	0.001	0.003	0.020	0.022	0.031	0.033	0.01 ±0.01
Chlorides (mg l^{-1})	4.28	4.26	4.21	4.14	4.10	4.12	5.82	5.26	5.45	5.40	4.30	4.28	4.63±0.64
Alkalinity (mg l^{-1}	40.00	38.00	55.00	50.00	45.00	48.00	50.00	49.00	50.00	48.00	45.00	49.00	32.91±13.56
Sodium (mg l^{-1})	18.00	14.00	17.00	16.00	10.00	14.00	16.00	19.00	12.00	16.00	20.00	20.00	16.00 ±3.10
Potassium (mg l^{-1})	00.70	00.60	00.50	00.30	00.30	00.40	00.60	00.50	00.60	00.50	00.70	00.80	0.54 ±0.15

Table 5. Correlation between hydrological attributes and density of macro-invertebrates of river Song and Suswa of Rajaji National Park for the period September 2001-August 2002

	Dn	AT	WT	WC	Tu	HMD	Ta	Co	TDS	DO	F Co2	pH	PO3	NO3	Chl	Alk	Na	K
Dn	1																	
AT	-0.894	1																
WT	-0.747	0.804	1															
WC	-0.585	0.520	0.476	1														
Tu	-0.721	0.676	0.605	0.681	1													
HMD	-0.683	0.535	0.675	0.556	0.618	1												
Ta	-0.683	0.535	0.675	0.556	0.618	1.000	1											
Co	-0.340	0.167	-0.044	0.268	0.368	0.273	0.273	1										
TDS	-0.880	0.869	0.749	0.672	0.751	0.589	0.589	0.208	1									
DO	0.868	-0.830	-0.674	-0.659	-0.893	-0.609	-0.609	-0.246	-0.870	1								
F Co2	-0.624	0.592	0.602	0.668	0.756	0.656	0.656	0.084	0.740	-0.731	1							
pH	-0.098	0.161	0.082	-0.101	0.002	-0.101	-0.101	-0.021	-0.061	-0.062	-0.104	1						
PO3	-0.119	0.199	0.542	-0.029	0.165	0.235	0.235	-0.333	0.101	-0.137	0.135	0.374	1					
NO3	-0.243	0.094	0.146	0.171	0.185	0.561	0.561	0.352	0.162	-0.167	0.270	-0.350	-0.170	1				
Chl	-0.016	0.115	0.368	-0.179	-0.194	0.025	0.025	-0.504	-0.020	0.113	-0.175	0.044	0.396	-0.218	1			
Alk	-0.086	0.072	-0.215	0.200	0.109	-0.243	-0.243	0.291	0.117	-0.084	0.043	0.400	-0.333	-0.503	-0.192	1		
Na	-0.545	0.530	0.350	0.573	0.565	0.359	0.359	0.146	0.576	-0.661	0.511	0.128	-0.074	0.158	-0.269	0.146	1	
K	-0.767	0.791	0.721	0.632	0.712	0.606	0.606	0.152	0.774	-0.819	0.593	0.128	0.196	0.093	0.148	0.118	0.539	1

Abbreviations : Den = density, A.T= Air temperature, W.T = Water temperature, W.C = Water Current, HMD = Hydro medium depth, Ta = Transparency, Tu = Turbidity, Co = Conductivity, TDS = Total Dissolved Solids, pH = Hydrogen Ion Concentration, D.O = Dissolved Oxygen, F.CO_2 = Free Carbon dioxide, NO_2 = Nitrates, PO_3 = Phosphates, Na = Sodium, K = Potassium

Table 6. Correlation between hydrological attributes of river Song and Suswa of Rajaji National Park for the period September 2001-August 2002

	AT	WT	WC	Tu	HMD	Ta	Co	TDS	DO	F Co_2	pH	PO_3	NO3	Chl	Alk	Na	K
AT	1																
WT	0.804	1															
WC	0.520	0.476	1														
Tu	0.676	0.605	0.681	1													
HMD	0.535	0.675	0.556	0.618	1												
Ta	0.535	0.675	0.556	0.618	1.000	1											
Co	0.167	-0.044	0.268	0.368	0.273	0.273	1										
TDS	0.869	0.749	0.672	0.751	0.589	0.589	0.208	1									
DO	-0.830	-0.674	-0.659	-0.893	-0.609	-0.609	-0.246	-0.870	1								
F Co_2	0.592	0.602	0.668	0.756	0.656	0.656	0.084	0.740	-0.731	1							
pH	0.161	0.082	-0.101	0.002	-0.101	-0.101	-0.021	-0.061	-0.062	-0.104	1						
PO_3	0.199	0.542	-0.029	0.165	0.235	0.235	-0.333	0.101	-0.137	0.135	0.374	1					
NO3	0.094	0.146	0.171	0.185	0.561	0.561	0.352	0.162	-0.167	0.270	-0.350	-0.170	1				
Chl	0.115	0.368	-0.179	-0.194	0.025	0.025	-0.504	-0.020	0.113	-0.175	0.044	0.396	-0.218	1			
Alk	0.072	-0.215	0.200	0.109	-0.243	-0.243	0.291	0.117	-0.084	0.043	0.400	-0.333	-0.503	-0.192	1		
Na	0.530	0.350	0.573	0.565	0.359	0.359	0.146	0.576	-0.661	0.511	0.128	-0.074	0.158	-0.269	0.146	1	
K	0.791	0.721	0.632	0.712	0.606	0.606	0.152	0.774	-0.819	0.593	0.128	0.196	0.093	0.148	0.118	0.539	1

Abbreviations : A.T= Air temperature, W.T = Water temperature, W.C = Water Current, HMD = Hydro medium depth, Ta = Transparency, Tu = Turbidity, Co = Conductivity, TDS = Total Dissolved Solids, pH = Hydrogen Ion Concentration, D.O = Dissolved Oxygen, F.CO_2 = Free Carbon dioxide, NO_2 = Nitrates, PO_3 = Phosphates, Na = Sodium, K = Potassium

Table 7. Monthly variations in the density (ind.m^{-2}) of macroinvertebrates dwelling the river Song and Suswa during September 2001-August 2002

Macrobenthos		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual Mean	%
Ephemeroptera	S_1	126	127	226	322	378	464	296	211	106	66	37	26	199	26.5
	S_2	120	130	204	306	404	503	289	123	67	57	20	50	189	27.5
	S_3	100	120	191	292	345	413	370	156	80	66	13	24	181	24.7
	S_4	134	173	276	338	423	510	291	130	73	47	20	33	204	26.7
Plecoptera	S_1	107	123	180	223	239	273	193	89	43	27	17	30	128.6	17.1
	S_2	117	143	173	210	240	273	193	113	50	27	20	30	132.4	19.2
	S_3	100	137	166	200	223	243	113	66	40	20	10	26	112	15.3
	S_4	90	110	193	223	260	276	190	103	63	34	10	16	130.6	17.1
Trichoptera	S_1	107	120	163	164	230	252	157	123	57	23	10	23	119	15.8
	S_2	100	123	173	187	200	227	113	73	43	33	0	17	107.4	15.6
	S_3	90	133	164	203	233	283	160	80	40	23	20	13	120.1	16.4
	S_4	146	173	227	240	289	310	193	107	53	33	17	20	150.6	19.7
Diptera	S_1	40	46	83	116	173	200	176	100	77	44	17	23	91.2	12.1
	S_2	40	53	80	90	111	166	197	50	30	16	10	10	64.4	9.3
	S_3	50	60	80	162	184	204	143	90	53	30	17	30	91.9	12.5
	S_4	54	63	83	140	194	210	146	76	33	17	10	13	86.5	11.3
Coleoptera	S_1	43	73	107	153	177	193	146	96	63	30	13	30	93.6	12.4
	S_2	40	80	99	130	153	170	110	80	33	23	20	30	80.6	11.7
	S_3	50	67	117	163	203	227	133	80	33	13	7	33	93.8	12.8
	S_4	60	63	126	154	173	197	153	70	50	26	10	30	92.6	12.1
Odonata	S_1	9	10	37	33	44	24	20	16	13	13	3	6	19	2.5
	S_2	15	14	42	30	40	33	20	26	24	14	20	23	24.9	3.6
	S_3	6	10	37	33	44	58	30	13	13	13	20	16	24.4	3.3
	S_4	9	10	37	26	30	43	51	29	30	10	13	10	24.8	3.2
Molluscans	S_1	60	70	126	143	173	186	126	90	70	47	10	27	94	12.5
	S_2	63	66	117	143	169	166	116	63	33	20	10	43	84	12.2
	S_3	96	124	149	176	170	157	96	76	67	40	23	46	101.6	13.9
	S_4	100	96	150	136	134	106	79	47	30	30	7	30	78.7	10.3
Crustaceans	S_1	3	0	7	3	0	14	0	0	0	3	0	0	2.5	0.3
	S_2	0	3	10	0	0	3	0	3	0	3	0	0	1.8	0.2
	S_3	0	3	7	3	6	3	0	0	3	0	0	0	2.0	0.2
	S_4	3	3	0	0	0	3	3	7	3	0	3	3	2.3	0.3
Annelida	S_1	3	7	3	0	0	3	7	3	0	0	0	0	2.1	0.2
	S_2	3	0	3	0	0	0	0	0	3	0	3	0	1.0	0.1
	S_3	3	3	7	3	10	0	0	0	3	0	0	3	2.6	0.3
	S_4	17	7	3	0	0	3	3	14	6	0	0	0	4.4	0.5
Nematoda	S_1	3	3	3	1	3	3	3	0	0	0	0	0	4.5	0.1
	S_2	0	0	0	4	3	2	1	0	0	0	0	0	0.8	0.1
	S_3	0	3	0	4	1	4	0	0	0	0	0	1	1.0	0.1
	S_4	0	0	3	1	1	3	0	2	0	2	4	0	1.3	0.1
Total Density	S_1	501	579	935	1158	1417	1612	1124	728	429	253	107	165	750.6	
	S_2	498	612	899	1100	1320	1543	959	531	283	193	103	207	687	
	S_3	495	660	918	1239	1419	1592	1046	561	332	205	110	189	730.5	
	S_4	613	698	1098	1258	1504	1661	1109	585	341	199	94	305	763.3	

during the present study. Total dissolved solids all positively correlated to Turbidity (r=0.751). Dissolved oxygen show negative correlation (r=-0.674) with water temperature and turbidity (r=-0.893). Free CO_2 was negatively correlated with dissolved oxygen (r=-0.731) and pH (r=-0.104). No significant correlation between the concentration of nitrates and phosphates was observed during the study period.

Relationship between hydrological attributes and Macroinvertebrates

Macroinvertebrates had a significant inverse relationship with water temperature (r=-0.747, p>0.001), turbidity (r=-0.721; p>0.001), hydromedian depth (r=-0.680; p>0.01), Free CO2 (r=-0.624 ; p>0.01), TDS (r=-0.880; p>0.001) and potassium (r=0.767, p>0.001). Total invertebrate density found to have positive relationship with dissolved oxygen (r= 0.868; p>0.001) (Table 5 and 6).

DISCUSSION

The Shannon-Weiner diversity index (H) for macroinvertebrates always remained above 3.0 throughout the study period, showing the good quality of water. Maximum diversity was recorded during winter while monsoon period showed minimum diversity index. It may be due to more intense competition among macroinvertebrates for the limited food supply within the community. Density of macroinvertebrates showed negative correlation with water temperature (r=-0.747) indicating that an increase in density with decrease in water temperature i.e they increased with the decreasing temperature and vice-versa. Temperature pattern influences the life cycle phenomenon of insects such as emergence which leads to increase in density. (Ward and Dufford, 1979). A negative correlation was found to occur between turbidity and microinvertebrate density (r=-0.721). Turbidity was maximum during monsoon season when macroinvertebrate density was minimum. This shows that increased turbidity was found to be unfavourable for macroinvertebrates as the density of these insects decreased during monsoons, which can be supported by Dutta and Malhotra (1986) that increased load of suspended solids reduce benthos by creating unfavourable conditions on bottom due to blanketing action. There exists a negative correlation between Free CO_2 and density of macroinvertebrates (r = -0.624). Free carbon dioxide was recorded higher in monsoon while a low concentration was observed in winters (Table 1 to 4). The rise in monsoons may be attributed due to retarted photosynthetic activity or due to low oxygen consumption by the organic matter in turbid state of water or due to failure of carbon dioxide being poorly utilized during the state of low density (Bhat *et al*., 1985). Thus all these relationships prove that the fluctuation of macroinvertebrate density that is maximum in winter and minimum during monsoon was due to lowest ebb of water temperature, turbidity, free CO_2 and high values of pH, dissolved oxygen, total alkalinity and conductivity during winter. This explanation is in agreement with Badola and Singh (1981), Singh *et al*. (1982), Man Mohan *et al*. (1994), Gusain (1994) and Sunder (1997). Last but not the least, water current and nature of substrata are also important factors responsible for several variations of macroinvertebrates. Water current is also negatively correlated to density of macroinvertebrates (r=-0.585). Water current was minimum during winters and maximum during monsoon. This means that increase in water current decreases the macroinvertebrate density. According to Hynes, (1970), current speed is an important factor of major importance in running waters. It controls the occurrence and abundance of species and hence the whole structure of animal community. He also states that larger the stones, more complex is the substratum and more diverse is the invertebrate fauna, which is true in case of the river Song and Suswa where maximum macroinvertebrates existed during the low water current.. The complex substrata structure of these rivers consists of mainly boulders, cobbles and pebbles supported a variety of macrobenthic genera.

Conservation Status of Aquatic insects

Most aquatic habitats, particularly free flowing streams and waters with acceptable water quality and substrate conditions support diverse macroinvertebrate communities in which there is a reasonable balanced distribution of species of species among the total number of individuals present. Such communities respond to changing habitats and water quality by alternations in community structure (invertebrate abundance and composition). However, many habitats especially disturbed ones are dominated by few species. Benthic macroinvertebrates have been used to assess the biological integrity of stream ecosystem with the relatively good success throughout the world (Rosenberg and Resh, 1993). Macroinvertebrate community responses to environmental changes are useful in assessing the impact of municipal, industrial, oil and agricultural wastes and impact from other land uses pattern of macroinvertebrate community structure change have been documented are increased inorganic micronutrients, increased organic loading, substrate alteration and toxic chemical pollution. Inorganic micronutrients and several organic pollution usually results in a restriction in the variety of macroinvertebrates. In some cases of severe organic pollution, siltation or toxic chemical pollution, there may be reduction or even elimination in the entire macro invertebrate community from an affected area. A host of suggestions are made for the conservation of macro invertebrates.

- There should be record of all the macro invertebrates. Information about their size, condition, location, density and diversity. This information being vital signs of life carefully entered in daily logs and statistical sheets.
- Record on baseline information gathered during the initial assessment. Continuing monitoring of vital signs will indicate if populations are shifting.
- Selection of' indicator species' for long term monitoring. If the population of the indicator species shifts, it is likely that changes in the natural system have occurred.
- Efforts to determine why and how those changes came about and the extent to which they may negatively impact the natural system.

Deluming the order of points for conservation

The river Song and Suswa of Rajaji National Park has a wide range of diversity and immense variability in genotypes inhabiting lotic environment. The following measures should be considered for the conservation of aquatic biodiversity.

Ex-situ conservation

In Ex-situ conservation, the seeds and forms of individuals of the organisms dwelling river Song and Suswa should be kept outside their natural habitat. The scope of Ex-situ conservation covers both wild as well as cultivated species. It could be in the form of living collections, as seeds or other forms. Large scale ex-situ conservation and careful management should be carried out in the entire area Rajaji National Park.

In-situ conservation

Under the in-situ conservation, the aquatic communities can be conserved by protecting the ecosystem in which it occurs naturally. As far as Rajaji National Park is concerned there should be the concept of creation of “aquatic Sanctuaries”. These aquatic sanctuaries should have continuous connection with a perennial source of water and should be free from disturbances and human intervention. Wide publicity through printed pamphlets and lectures should be used to promote protection of aquatic flora and fauna in the Rajaji National Park. Legal measures against defaulters should be widely notified and efforts should be made to ensure local co-operation in the venture with active public support.

In addition to the above, following measures should also be taken for protecting the aquatic biodiversity of the Song and Suswa river

1. Grazing and cattle wading in and around the Rajaji National Park should be stopped, as it is a significant source of pollution in the fluvial system of Rajaji National Park and needs immediate attention
2. Public participation should be encouraged for the conservation of aquatic biodiversity.
3. Ban should be imposed in the catchment area of Rajaji National Park on indiscriminate drainage, land cleaning, burning, spurious fishing, cattle grazing, harvesting of potential food plants and dumping of domestic refuse garbage that detrimentally affect the food-chain.
4. For the successful conservation and management of aquatic biodiversity, collaboration of scientists and managers is of immense importance. Scientists and managers should be involved in designing, implementation and assessment of the project. Management agencies should have the responsibility to offer management expertise and authority for the sites to be managed
5. The local people inhabiting in the catchment area and the van gujjars present in the park use the water of river Song and Suswa for bathing and washing which adds chemicals to the river water and thus deteriorate the quality of the water

REFERENCES

Anbalagan, S, B. Kaleeswaran and. Balasubramanian, C. 2004. Diversity and Trophic categorization of aquatic insects of Courtallam hills of Western Ghats. *Entomon*., 29, 1-6.

Anbalagan, S. and. Dinakaran, S. 2006 Seasonal variation of diversity and habitat preferences of aquatic insects along the longitudinal gradient of the Gadana river basin, South-West Ghats, (India). *Acta Zoologica Bulgarica* 58, 253-264).

APHA 1998. Standard Methods for the Examination of water and waste water. American Public Health Association. New York, USA.

Badola, S.P. 1979. Ecological Studies on the Icthyofauna of some water Sources of Garhwal Region. Ph. D. Thesis submitted to the Garhwal University, *Srinagar Garhwal*. 1-280.

Badola, S.P. and Singh, H.R. 1981. Hydrobiology of the River Alaknanda of Garhwal Himalaya. Indian J. Ecology, 8: 269-276

Badola, S.P. and Singh, H.R. 1981. Hydrobiology of the River Alaknanda of Garhwal Himalaya. *Indian J. Ecology*, 8: 269-276.

Balaram, P. 2005. Insect of tropical streams. *Curr. Sci*., 89, 914.

Bhattacharya, D.K.: 2000.Insect fauna associated with large water hyacinth in freshwater Wetlands of West Bengal. Diversity and Environment. Proc. Nat. Seminar on Environ. Biol. (Eds.: A.K. Aditya and P. Haldar), Daya Publishing House, Delhi. pp. 165-169. Chironomids and other macroinvertebrates across different levels of pollution in streams.

Clausen, B and Biggs, B.J.F.2000.Flow Variables for Ecological Studies Temperate Streams: Groupings based on Covariance. *Journal of Hydrology*, 237: 184-197.

Clausen, B. and Biggs, B.J.F. 1997. Relationship between Benthic Biota and Hydrological Indices in New Zealand Streams. *Freshwater Biology*, 38: 327-342.

Clausen, B. and Biggs, B.J.F. 1998. Stream Flow Variability Indices for Riverine Environmental Studies a changing Environment. (ed.) *Wheather H. Kirby. J. Wiley*. 357-364.

Collier, K.J., Fowls, C. and Hogs, I. 2000. Management, Education and Conservation. In: New Zealand Stream Invertebrate: Ecology and Implications for Management (eds.) K.J. Collier and M.J. Winterbourne. The Limnlogical Society, Christchurch. 374-400.

Collier, K.J., Smith, J.B. and Quinn, J.M. 2001. Biodiversity of Stream Invertebrate Faunas in a walkathon Hill-Country Catchment in Relation to Landuse, New Zealand. *Entomologist* 23: 9-22.

Collier, K.J., Smith, J.B. and Quinn, J.M.2 001. Biodiversity of Stream Invertebrate Faunas in a walkathon Hill-Country Catchment in Relation to Landuse, New Zealand. *Entomologist* 23: 9-22.

Diwakar K. 1995. *Management plan of Rajaji National Park, Dehradun for the period of 1995-96 to 2005-2006 Vol. I and II.*

Diwakar K. 1995. *Management plan of Rajaji National Park, Dehradun for the period of 1995-96 to 2005-2006 Vol. I and II.*

Gusain, M. 1994. River Alaknanda. In: Mahseer the Game Fish: Natural History Status and Conservation Practices in India and Nepal. (ed.) P. nautiyal, Jagdamba Prakashan, Dehradun. 123-135.

Gusain, M. 1994. River Alaknanda. In: Mahseer the Game Fish: Natural History Status and Conservation Practices in India and Nepal. (ed.) P. nautiyal, Jagdamba Prakashan, Dehradun. 123-135. J. Environ. Biol. 30(2), 283-287.

Minshall, G.W. 1985. Stream Ecosystem Theory: A Global Perspective. J. North Am. Benthol. Soc., 7 : 263-288.

Norris, R.H. and Norris, K.R. 1995. "The Need for Biological Assessment of Water Quality: Australian Perspective." *Australian Journal of Ecology*. 2 : 1-6.

Panwar H.S., Mishra, B.K. 1994. *Rajaji National Park, Real Issues, Problems and Prospects. Wildlife Institute of India, Newletter April - June 1994*.

Resh, V. H. and. Carter, J. L. 2000. A survey of methods used for collecting lotic benthic invertebrates for bioassessments. Bull. n.am. *Benthol. Soc*. 17: 233.

Rosenberg, D.M. and Resh, V.H. 1993. Freshwater Biomonitoring and benthic Invertebrates. Chapman and hall, New York.488 pp.

Rosenberg, D.M. and Resh, V.H. 1993. Freshwater Biomonitoring and benthic Invertebrates. Chapman and hall, New York.488 pp.

Sarmistha Jana, Priti R. Pahari, Tapan Kr. Dutta and Tanmay Bhattacharya. .2009. Diversity and community structure of aquatic insects in a pond in Midnapore town, West Bengal, India

Shannon, C.E. and Wiener, W. 1964. 'The Mathematical Theory of Communication' University of Illinois Press. Urbana, U.S.A

Sharma, R.C. 1986. Effect of Physico-Chemical Factors on Benthic Fauna of Bhagirathi River, Garhwal Himalaya. Indian Journal Ecology, 13: 133-137.

Sharma, R.C.1985. Seasonal Abundance of Phytoplankton in the Bhagirathi River Garhwal Himalaya. *Indian Journal of Ecology* 12 (1): 157-160

Sharma, R.C.1985. Seasonal Abundance of Phytoplankton in the Bhagirathi River Garhwal Himalaya. *Indian Journal of Ecology* 12 (1): 157-160

Singh, H.R. and Nautiyal, P. 1990. Altitudinal Changes and the Impact of municipal sewage on the Community structure of Macrobenthic Insects in the Torrential Reaches of the river Ganges in the Garhwal Himalaya (India). *Acta Hydrobiology*, 32(3/4): 407-421.

Sunder, S. 1997. Biotic Communities of Kumaon Himalyan River Gaula I. Macrobenthic Invertebrates. *Proc. Nat. Acad. Science*. India 167 (B) 11 : 157-168

Sunder, S.1997. Biotic Communities of Kumaon Himalyan River Gaula I. Macrobenthic Invertebrates. *Proc. Nat. Acad. Science*. India 167 (B) 11 : 157-168

Tang H, Song MY, Cho WS, Park YS & Chon TS. 2010. Species abundance distribution of benthic chironomids and other macroinvertebrates across different levels of pollution in streams. *International Journal of Limnology* 46: 53–66.

Walsh, C.J., A.K. Breen, P.F. and Sonneman, J.A. 2001. Effects of Urbanization on Streams of the Melbourne region, Victoria, Australia. I. Benthic Macro invertebrate Communities. *Freshwater Biology*, 46: 535-551.

Ward J.V. and Dufford, R.G. 1979. Longitudinal and Seasonal Distribution of Macro invertebrates and Epilithic Algae in a Colorado Spring brook-pond System; *Arch. Hydrobiology*, 74: 247-275.

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