Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 14 Issue 1 Version 1.0 Year 2014
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Diversity of Aquatic Insects and Function of Fluvial Ecosystem of Song River of Rajaji National Park, India

By Nusrat Samweel & Tahir Nazir
DIBNS Dehradun, India

Abstract- Aquatic insect diversity of Rajaji National Park, India has been monitored for a period of twelve months. Some of the important hydrological attributes were also measured in continuity of one-month interval. Aquatic insects were sampled from two sites (S1 and S2) of the Song River of the Rajaji National Park. A significant difference in the density ($t=2.86455$, $p<0.05$) and diversity ($t=5.23425$, $p<0.001$) of aquatic insects was found due to differences in physicochemical setup of aquatic environment of these sites. It was also revealed that the nature, size and composition of bottom substrates have their significant impact on the diversity of benthic aquatic insects. The diversity of benthic aquatic insects ranged from 3.0270-4.4561 indicating the good quality of water. A high diversity (4.1085-4.4561) among aquatic insects was recorded in winter months when the water was almost clear with moderate temperature and water current, and high dissolved oxygen in the Song river of Rajaji National Park.

Keywords: *aquatic insects, monitoring, rajaji national park, physico-chemical parameters, song river, uttrakhand.*

GJSFR-H Classification : *FOR Code: 070402*

Strictly as per the compliance and regulations of :

© 2014. Nusrat Samweel & Tahir Nazir. This is a research/review paper, distributed under the terms of the Creative Commons Attribution-Noncommercial 3.0 Unported License http://creativecommons.org/licenses/by-nc/3.0/), permitting all non commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Diversity of Aquatic Insects and Function of Fluvial Ecosystem of Song River of Rajaji National Park, India

Nusrat Samweel [α] & Tahir Nazir [σ]

Abstract- Aquatic insect diversity of Rajaji National Park, India has been monitored for a period of twelve months. Some of the important hydrological attributes were also measured in continuity of one-month interval. Aquatic insects were sampled from two sites (S1 and S2) of the Song River of the Rajaji National Park. A significant difference in the density ($t=2.86455$, $p<0.05$) and diversity ($t=5.23425$, $p<0.001$) of aquatic insects was found due to differences in physico-chemical setup of aquatic environment of these sites. It was also revealed that the nature, size and composition of bottom substrates have their significant impact on the diversity of benthic aquatic insects. The diversity of benthic aquatic insects ranged from 3.0270-4.4561 indicating the good quality of water. A high diversity (4.1085-4.4561) among aquatic insects was recorded in winter months when the water was almost clear with moderate temperature and water current, and high dissolved oxygen in the Song river of Rajaji National Park.

Keywords: aquatic insects, monitoring, rajaji national park, physico-chemical parameters, song river, uttrakhand.

I. Introduction

Importance of aquatic insects in an aquatic ecosystem cannot be ignored as they constitute important part of the food chain in the fluvial ecosystem. They have also been considered as an indicator of stream condition and assessment of river water quality (Noris, Noris 1995). They exhibit a great breadth of species 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 have been used to assess the biological integrity of stream ecosystem in various studies (Rosenberg, Resh 1993; Resh, McElravy 1993; Resh, *et.al* 1995; Baroor, *et.al*; 1996). 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, Joshi *et al*.2002, LeFevre 2003, Jacobsoen *et al*. 2003, Anbalagan *et al*. 2004, McIntosh *et al*.2004, Anbalagan and Dinakaran, 2006; Sarmistha *et al*., 2009) and at national level (Sivaramakrishnan *et.al,* 1996, and 1998; Bhattacharya, 1998; Mukerjee *et.al* 1998; and Sharma, 1986; Bhattacharaya, 2000; and Balaram, 2005,Subramanian and Sivaramakrishnan 2005). A very little information is available on the diversity of aquatic insects of Garhwal Himalaya except some scattered reports (Badola 1979; Sharma 1986). However, no information is available so far on the aquatic biodiversity and the function of fluvial ecosystem of the Song river of Rajaji National Park. Therefore, the present work on the diversity of aquatic insects and function of fluvial system of river Song of the Rajaji National Park was undertaken.

Author α σ : Department of Forestry Dolphin P.G. Institute of Bio-medical and Natural Sciences Manduwala Dehradun Uttrakhand, India. e-mails: nusrat_samweel@rediffmail.com, tahir_nazir@rediffmail.com

II. Study Area

Rajaji National Park is situated in the foothills of Shiwalik Range of the newly carved out state Uttarakhand of India. It is the part of the Dehradun, Hardwar and Pauri district of Uttarakhand State ($77^0 55'$-78^0 $30'$; Latitude 29^0 $50'$-30^0- $15'$N). Three sanctuaries, Motichur (59.5 km^2), Rajaji (247.0 km^2), Chila (249.02 km^2) and other reserve forests (234.5 km^2) are amalgamated into large protected area which is named as Rajaji National Park. The total area of the Rajaji National Park is 820.42 km^2. To the north of the Rajaji National Park lie the Dehradun and Tehri Forest Division. River Suswa forms the northern natural boundary up to Ganges (Fig. 1).

Song is the perennial river draining Rajaji National Park in northeastern slopes of Shiwalik. The northeastern 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 more or less on flat or gently sloping area often cut by small drainage (nalas). Suswa and Song rivers drain the forests of eastern Doon. River Song forms its confluence in the Banbaha forest block. From there, it flows in a southeastern direction till it discharges into the Ganges near Satyanarian. Some seasonal tributaries also meet Song river at Bindal, Rispana, Ren and Jakhan. The river Suswa flows very closely and opposite to Asan River to the east of Saharanpur-Mussoorie highway and flows in a southeasterly direction to discharge into the Song.

© 2014 Global Journals Inc. (US)

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, lie the revenue lands and villages of Haridwar district. A part of southeastern 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.

III. Materials and Methods

a) Sampling

A preliminary survey of the Park was done for undertaking the present study. Two sampling sites (S_1 and S_2) were identified at the Song River in the Rajaji National Park. The first sampling site S_1 was identified at Shampur (320m above m.s.l.), while the second sampling site S_2 at Chhidarwala (300m above m.s.l.) (Fig. 1).

Monthly sampling was conducted during the period 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). The control dynamics conductivity meter (model-5DIM) was used for measuring conductivity. Nitrates and phosphates were estimated by the microprocessor based 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 the titrimetric methods outlined in Wetzel, Likens (1991) and APHA (1998).

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

b) 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 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.

c) 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.

IV. Results

a) Composition of bottom substrates

Composition of bottom substrates at both the sampling sites of Song River has been presented in Table 1. Bottom substrates were contributed by boulders (50%), cobbles (20%), pebbles (15%), sand (12%), silt (2%) and clay (1%) at S_1. However, these substrates were contributed by boulders (40%), cobbles (25%), pebbles (20%), sand (10%) and silt (3%) and clay (2%) at S_2. Sparse riparian vegetation was found to occur at S_1 while a dense riparian vegetation cover was noticed at S_2.

b) Analysis of the physic-chemical parameters

Analysis of physic-chemical setup of the aquatic environment of both the sampling sites of the Song river revealed that air temperature ranged from 23^{0}C to 30^{0}C at both the sites. Water temperature ranged from 21^{0}C (January) to 28.5^{0}C (August) (Table II). However, the water temperature ranged from a minimum of 20^{0}C in January to a maximum of 25^{0}C in the month of August at S_2 (Table III). The water current ranged from 0.280 m sec^{-1}(January) to 1.525 m sec^{-1} (July) at S_1 and at S_2 it ranged from 0.49 (January) to 1.54 m sec^{-1} (July). The turbidity was higher only in the monsoon (July-September) months and fluctuated between 58-97 NTU at both the sampling sites at the Song river. The hydro median depth (HMD) ranged from 40 - 49.20 cm at both the sites. The conductivity did not show any significant variation in different months at both the sites. Total dissolved solids (TDS) ranged from 120 mg l^{-1} to 780 mg l^{-1} at S_1 and 180 mg l^{-1} to 780 mg l^{-1} at S_2. Dissolved

© 2014 Global Journals Inc. (US)

oxygen concentration fluctuated between 8.00-15.50 mg l^{-1} at S_1 however it fluctuated between 9.30-14.90 mg l^{-1} at S_2. Free CO_2 concentration in the Song River ranged from 0.15-1.92 mg l^{-1} at S_1 and 0.6-1.61 mg l^{-1} at S_2. pH fluctuated between 8.00-8.50 at S_1 and 7.86-8.20 at S_2. The concentration of dissolved phosphates ranged from0.070-0.083 mg l^{-1} at S_1 and 0.070-0.92 mg l^{-1} at S_2. Nitrates in the Song water ranged from 0.001 mg l^{-1} to 0.060 mg l^{-1} at S_1 and 0.041 mg l^{-1} to 0.080 mg l^{-1} at S_2. Chlorides concentration fluctuated between 5.02-6.96 mg l^{-1} at S_1 and 4.00- 5.96 mg l^{-1} at S_2. The concentration of dissolved sodium ranged from 10.00-20.00 mg l^{-1} at S_1 and at S_2 it fluctuated between 12.00-20.00 mg l^{-1}. Potassium concentration in the Song water fluctuated between 0.40-0.90 mg l^{-1} at S_1 (Table II) and 0.30-0.90 mg l^{-1} at S_2 (Table III).

A significant difference in mean air temperature ($t = 2.239$, $p<0.05$), water temperature ($t = 9.608$, $p<0.01$), water-current ($t = 3.466$, $p<0.01$), conductivity ($t = 2.994$, $p< 0.05$), dissolved oxygen ($t = 4.938$, $p<0.001$), nitrates ($t = 4.456$, $p< 0.001$), alkalinity ($t = 6.733$, $p<0.001$), phosphates ($t = 3.033$, $p<0.01$), chlorides ($t = 6.181$, $p<0.001$), and pH ($t = 3.989$, $p<0.01$) was found between the two sampling sites sustaining aquatic insect diversity under the present study.

c) Qualitative and quantitative analysis of aquatic insects

Aquatic insects dwelling the Song River are represented by immature stages of the insect orders Ephemeroptera, Plecoptera, Tricoptera, Coleoptera, Odonata and Diptera class of insect. Eight species *(Ephemerella, Ecdyonurus, Baetis, Centroptilum, Cloeon, Siphlonurus, Potamanthus, Habrophlebia)* of Ephemeropterans were found to occur during the study period. Ephemerella was found to be the abundant species among Ephemeropterans. Plecopterans *(Taeniopteryx, Claassenia, Phasganophora, Neoperla),* Tricopterans *(Hydropsyche, Diplectrona, Philopotamus, Hydroptila)* and Dipterans (*Tendipes, Eulalia, Megistocera, Ephydra)* were represented by four genera each. Coleopterans were represented by three genera *(Psephenus, Ectopria, peltodytes).* However, the Odonatans were represented by five genera (*Gomphus, Agrion, Macromia, Sympetrum, Ischnura, Libellua*). Ephemeropterans, Plecopterans, Tricopterans and Dipterans were present throughout the study period whereas Odonatans, could not show their regular presence in the Song river.

Percentage composition profile of the aquatic insects of Song River revealed that this composition was contributed by Ephemeropterans (30.5%), Plecopterans (19.76%), Tricopterans (18.30%), Dipterans (14.03%), Coleopterans (14.40%) and Odonatans (2.92%) at S_1. However, at S_2 Ephemeropterans, Plecopterans, Tricopterans, Dipterans, Coleopterans and Odonatans contributed 31.27%, 21.86%, 17.66%, 11.73%, 13.31% and 4.14% respectively (Fig.2).

The quantitative abundance of aquatic insects dwelling the Song river of Rajaji National Park revealed that the maximum benthic density (1406 ind.$m^{-2}$and 1372 ind.m^{-2})was found in the month of February (winter) at both the sampling sites. However, the minimum density of aquatic insects (97 ind.$m^{-2}$and 90 ind.m^{-2}) was recorded during July (monsoon) at both the sampling sites of the Rajaji National Park (Table IV).

d) Diversity indices and concentration of dominance (C)

The diversity indices (Shannon-Wiener) of aquatic insects ranged from 3.1282 - 4.4561 at S_1 and 3.0270 - 4.3960 at S_2 under the present study. Maximum values of the diversity indices, 4.4561 and 4.3960 was recorded in February (winter) respectively at S1 and S2 and minimum values, 3.1282 and 3.0270 at S1 and S2 during July (monsoon), respectively (Table V).

A significant difference in the density ($t = 2.86455$, $p< 0.05$) and diversity ($t = 5.23425$, $p<0.001$) was computed between the two sampling sites (S_1, S_2) located at the river Song of the Rajaji National Park.

The Concentration of dominance (C) varied between 0.0565-0.1315 at S_1 and 0.0586-0.1328 at S_2 during the study period. The concentration of dominance was found to be maximum, (0.1315 and 0.13280) in July while minimum (0.0565 and 0.0586) in January at both the sampling sites, respectively (Table VI).

e) Statistical correlation among hydrological attributes

Correlations among hydrological attributes are presented in (Table VII). A highly positive correlation ($r=0.826$) was found between the air temperature and water temperature. Total dissolved solids were positively correlated to Turbidity ($r=0.696$). Dissolved oxygen was negatively correlation with water temperature ($r = -0.7360$) and turbidity ($r=-0.880$). Free CO_2 was negatively correlated with dissolved oxygen ($r=-0.690$). However, no significant correlation was found between the concentration of nitrates and phosphates during the study period.

f) Relationship between hydrological attributes and aquatic insects' density

Aquatic insects density had a significant inverse relationship with water temperature ($r=-0.744$, $p>0.01$), turbidity ($r=-0.723$; $p>0.01$), hydromedian depth ($r=-0.777$; $p>0.01$), free CO_2 ($r=-0.566$; $p>0.05$), TDS ($r=-0.848$; $p>0.001$) and potassium ($r= -0.898$, $p>0.001$). However, a positive relationship ($r= 0.858$; $p>0.001$) was found between the aquatic insects density and dissolved oxygen (Table VII).

A multiple regression analysis showed that a myriad of different abiotic factors played a significant role (multiple $R=0.9898$, $R^2=0.9798$ and $F=21.234$,

© 2014 Global Journals Inc. (US)

P<0.0002) in determining the density of the aquatic insects dwelling Song river.

V. Discussion

The nature of bottom substrates is one of the most significant environmental parameters in influencing the biodiversity of stream (Wisely 1962, Hynes 1970, Hawkins 1984, Minshall 1984, Angrerdi 1996). The riverine ecosystem of Song River comprises of boulders, pebbles, sand, silt and clay. The sampling site S_1 is dominated by big boulders which do not provide a suitable shelter to aquatic benthos while site S_2 was dominated by small boulders and cobbles which provide a suitable shelter for aquatic benthic organisms. Ward (1994) also pointed out that the boulders and cobbles are the dominant features of headwater streams. Physico-chemical parameters play an important role in determining the structure and function of an ecosystem. Density of aquatic insects showed negative correlation with water temperature (r =-0.744) 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 life cycle phenomenon of insects such as emergence which leads to increase in density. (Ward and Dufford 1979). A negative correlation (r =-0.723) was found to occur between turbidity and density of aquatic insects. Dutta, Malhotra (1986) also noticed that increased load of suspended solids reduce the abundance of benthos by creating unfavorable conditions on bottom due to blanketing action. There exists a negative correlation (r =-0.566) between free CO_2 and density of aquatic insects.

Dissolved oxygen concentration decreased with increasing temperature in the Song River of the Rajaji National Park. Solubility of oxygen is affected non-linearly by temperature and increase in the cold water (Welch 1952, Wetzel 1983). The high concentration of dissolved solids in the monsoon season may be due to the addition of inorganic salts and organic matter carried along with the increased rain water and surface run-off. Water current and nature of substrata are also important factors responsible for seasonal variations in aquatic insects. A negative correlation (r =-0.689) between water current and density of aquatic insects was found indicating that an increase in water current decreases the density of aquatic insects. 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 aquatic insects community. He also stated that larger the stones, more complex are the substratum and more diverse is the benthic fauna, which is true in case of the river Song where maximum aquatic insects existed during the period of low water current. The complex substrata structure of the river consists of mainly boulders, cobbles and pebbles supported a rich diversity of aquatic insects.

The Shannon-Weiner diversity index for aquatic insects remained above 3.0 throughout the study period indicating the good quality of Song water. Maximum insect diversity was recorded during winter season while monsoon period showed minimum diversity of aquatic insects which may be attributed to intense competition among aquatic insects for the limited food supply within the community during monsoon season. The similar seasonal pattern of occurrence of macro- invertebrates has been recorded Badola and Singh (1981) from Alaknanda River and Gusian (1994) from river Bhilangana. However, Singh et al. (1982), Sharma (1985), Mohan et al. (1989) and Sunder (1997), also observed the similar trend in other Himalayan rivers. The concentration of dominance was found to be inversely proportional to the diversity indices.

Singh and Nautiyal (1990) recorded 30 taxa of macro-invertebrates dominated by Ephemeroptera and followed by Diptera, Tricoptera and Plecoptera in the river Ganges. 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 Bhatt and Pathak (1992) recorded 68 genera of insects from various rivers of Kumaon region. Under the present study, 29 genera of aquatic insects dominated by Ephmeroptera and followed by Diptera, Trichoptera, Plecoptera and Odonata indicates that Song River which has all major components of typical hill stream shows a good distributional pattern of benthic invertebrates.

Free carbon dioxide was recorded higher in monsoon months while a low concentration was observed in winters. The rise in CO_2 concentration during monsoons and low oxygen consumption by the organic matter in turbid state of water retards the photosynthetic activity. Bhatt *et al.* (1985) reported the similar type of observations.

A significant difference in density and diversity of the aquatic insects between the two sampling sites in the Song River may be attributed to the significant difference in physic-chemical parameters (air temperature, water temperature, water current, conductivity, dissolved oxygen, pH, nitrates, alkalinity, phosphates and chlorides). This difference in the density and diversity of aquatic insects may also be attributed to some of the anthropogenic influences (heavy tourist influx, grazing near stream bank) in the stream water. Presence of Van Gujjars (nomads) in the Rajaji National Park is also responsible for deteriorating the quality of water. Extraction of building materials such as boulders, pebbles, stones, gravel and sand form the river beds destroying the niche of the aquatic insects consequently decline in the density and diversity of the aquatic insects.

© 2014 Global Journals Inc. (US)

Thus, it was revealed that the variations in the density and diversity of aquatic insects may be due to the function of dominant physico-chemical attributes (water temperature, turbidity, free CO2, pH, dissolved oxygen, total alkalinity and conductivity) in addition to the natural and anthropogenic disturbances.

VI. Acknowledgement

Thanks are due to the Ministry of Environment and forests, Govt. of India for financial assistance.

References Références Referencias

1. Angradi, T.R. 1996. Inter-habitat variations in benthic community structure function and organic matter storage in 3 Appalachian headwater streams. *J. Am. Benthos L. Soc*. **15**, 42-63.
2. Anbalagan,S, B. Kalceswaran and. Balasubramanian,C.2004. Diversity and Trophic categorization aquatic insects of Courtallam hills of Western Ghats. *Entomon.,* **29**, 1-6.
3. 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.
4. APHA 1998. *Standard Methods for the Examination of water and waste water*, 20th Ed. American Public Health Association, New York, USA.
5. Badola, S.P; and Singh, H.R. 1981. Hydrobiology of the River Alaknanda of Garhwal Himalaya. *Indian J. Ecology*, **8:** 269-276.
6. Balaram, P. 2005. Insect of tropical streams. *Curr. Sci.,* **89**, 914.
7. 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.
8. 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.
9. Clausen, B. and Biggs, B.J.F. 1997. Relationship between benthic biota and hydrological indices in New Zealand Streams. *Freshwater Biology*, **38:** 327-342.
10. Clausen, B. and Biggs, B.J.F. 1998. *Stream Flow Variability Indices for Riverine Environmental Studies*. In: Wheather, H; Kirby. J. [Eds.] *A changing Environment*. Wiley. PP. 357-364.
11. 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.
12. Collier, K.J., Smith, J.B; and Quinn, J.M. 2000. Biodiversity of stream invertebrate fauna in a walkathon hill-country catchment in relation to landuse, New Zealand. *Entomologist,* **23:** 9-22.
13. Dutta, S.P.S., Malhotra, Y.R. 1986. Seasonal variations in the macrobenthic fauna of Gadigarh stream
14. Gusain, M. 1994. River Alaknanda. In: Nautiyal, P. [Ed.] *Mahseer the Game Fish*: *Natural History Status and Conservation Practices in India and Nepal*. Jagdamba Prakashan, Dehradun.
15. Hawkins, C.P. 1984. Substrate association and longitudinal distribution in species of Ephemerellidae (Ephemerotera: Insect) from western Oregon. *Freshwater Invertebrate Biology* **3(94),** 18-88.
16. Hynes, H.B.N. 1970. *The Ecology of Running Waters.* Liverpool University Press, Liver. pp. 1-555.
17. Jacobson, D., Rostgaard, S., Vasconez, J.J.2003. Are macroinvertebrates in high altitude streams affected by oxygen deficiency? *Freshwater Biology* **48**, 2025-2032.
18. Joshi, C.B.1991. Benthos composition of hill stream in western Himalayas. J*. Indian Indt.Sci.***71**, 372-382.
19. Joshi, P.C., Kumar, K., Badoni, V., Singh, A. 2002. An ecological study on the above-ground entomofauna of Nanda Devi Biosphere Reserve. In: Sharma, J.K., Easa, P.S., Mohanan, C., Sasidharan, N., Rai, R.K. [Eds.] *Biosphere Reserves in India and their Management Ministry of Environment and Forests,* Govt.of India*,* New Delhi. pp. 143-149.
20. LeFevre. S.R., Sitlinger, D.L. 2003. Assessment of interstate streams in the Susquehanna River basin. Monitoring report No. 16, July 2001, through June 30, 2002. Publication Susquehanna River basin commission, Harrisburg, Pennsylvania.
21. McIntosh, M.D., Merritt, R.W., Lougheed, V.L., Parker, C.A., Stevenson, R. J. 2004. *Macro-invertebrate diversity of isolated wetlands: Are wetland quality and size important factors?* NABS Annual Meeting, Vancouver, British Columbia.
22. Minshall, G.W. 1984. Aquatic insect substratum relationship. In: Resh, V.H., Rosenberg, D.M.[Eds.]. *The Ecology of Aquatic Insects*. Praeger pulb. New York. 3.
23. Mohan, M., Bisht, R.S., Das, S.M.1989. Physico-chemical parameters in relation to aquatic entomofauna of river Bhagirathi and Bhillangana, Tehri- Garhwal, Himalaya. In: Khulbe, R. D. [Ed.] *Perspectives in Aquatic Biology*, Papyrus publishing house, New Delhi, pp. 197-203.
24. 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.
25. Resh. V.A., McElravy, E.P. 1993. Contemporary quantitative approaches to biomonitoring using benthic macroinvertebrates. In: Rosenbert, D.M., Resh, V.H. [Eds] *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, N.Y. pp.488.

© 2014 Global Journals Inc. (US)

26. Resh, V. H. &. Carter, J. L. 2000. A survey of methods used for collecting lotic benthic invertebrates for bioassessments. Bull. n.am. *Benthol*. Soc. 17: 233.
27. Rosenberg, D.M., and Resh, V.H. 1993. *Freshwater Biomonitoring and benthic Invertebrates*. Chapman and hall, New York.488 pp.
28. 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.
29. Sehgal, K.L. 1990. Report on the impact of construction and completion of Beas-Sutlej Link (BSL). Project on limnology and fisheries of river Beas. CIFR\NRC\CWF\; Publication.
30. Shannon, C.E. and Wiener, W. 1964. '*The Mathematical Theory of Communication*' University of Illinois Press, Urbana, U.S.A.
31. Sharma, R.C.1985. Seasonal Abundance of Phytoplankton in the Bhagirathi River Garhwal Himalaya. *Indian Journal of Ecology* **12 (1),** 157-160
32. Sharma, R.C. 1986. Effect of Physico-Chemical Factors on Benthic Fauna of Bhagirathi River, Garhwal Himalaya. *Indian Journal Ecology*, **13,** 133-137.
33. Simpson, E.H. 1949. Measurement of Diversity. *Nature*. 163-688.
34. Singh, H.R., Badola, S.P., Dobriyal, A.K. 1982. Ecology of the river Nayar of Garhwal Himalaya. *Uttar Pradesh J. Zoology* **6(2),** 127-133.
35. 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.
36. Sivaramakrishnana, R.G., Venkataram, K. 1990. Abundance, altitudinal distribution and swarming of Ephemeroptera in Palni Hills, South India. In: Campbell, I.C. [Ed.], *Mayflies and Stoneflies*: *Life Histories and Biology*. Klumer Academic Publishers. Dordrecht. pp. 209-213.
37. Subramanian, K.A and K.G Sivaramakrishnan. 2005. Habitat and microhabitat distribution of stream insect communities of the Western Ghats. *Curr.Sci.**89**, 976-987*.
38. Sunder, S. 1997. Biotic Communities of Kumaon Himalyan River Gaula I. macrobenthic invertebrates. *Proc. Nat. Acad. Science. India*. **67 (B)**, **11,** 157-168.
39. 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 Macroinvertebrate Communities. *Freshwater Biology*, **46,** 535-551.
40. Ward J.V., and Dufford, R.G. 1979. Longitudinal and seasonal distributions of macro invertebrates and epilithic algae in a Colorado spring brook pond System. *Arch. Hydrobiol*. **86(3),** 284-329.
41. Ward, H.B., Whipple, G. C. 1992. *Freshwater Biology*. John Wiley and Sons (2nd ed.) New York. 1-1248.
42. Ward, J.V. 1994. Ecology of Alpine streams, *Freshwater Biology* **32**, 277-294.
43. Welch, P.S. 1952. *Limnology.* McGraw- Hill Book Company Inc., London.
44. Wetzel, R.G.1983. *Limnology.* Sauders Publishers, Philadephia. 1-650.
45. Wetzel, R.G., Likens, G.E. 1991. *Limnological Analyses*. Springer-Verlag, New York. 1-175.
46. Wisely, B. 1962. Studies on Ephemeroptera II. *Coloburiscus humeralis* (Walker); ecology and distribution of the nymphs. *Trans. R. Soc. N.N. Zool*. **2**, 209-220.

© 2014 Global Journals Inc. (US)

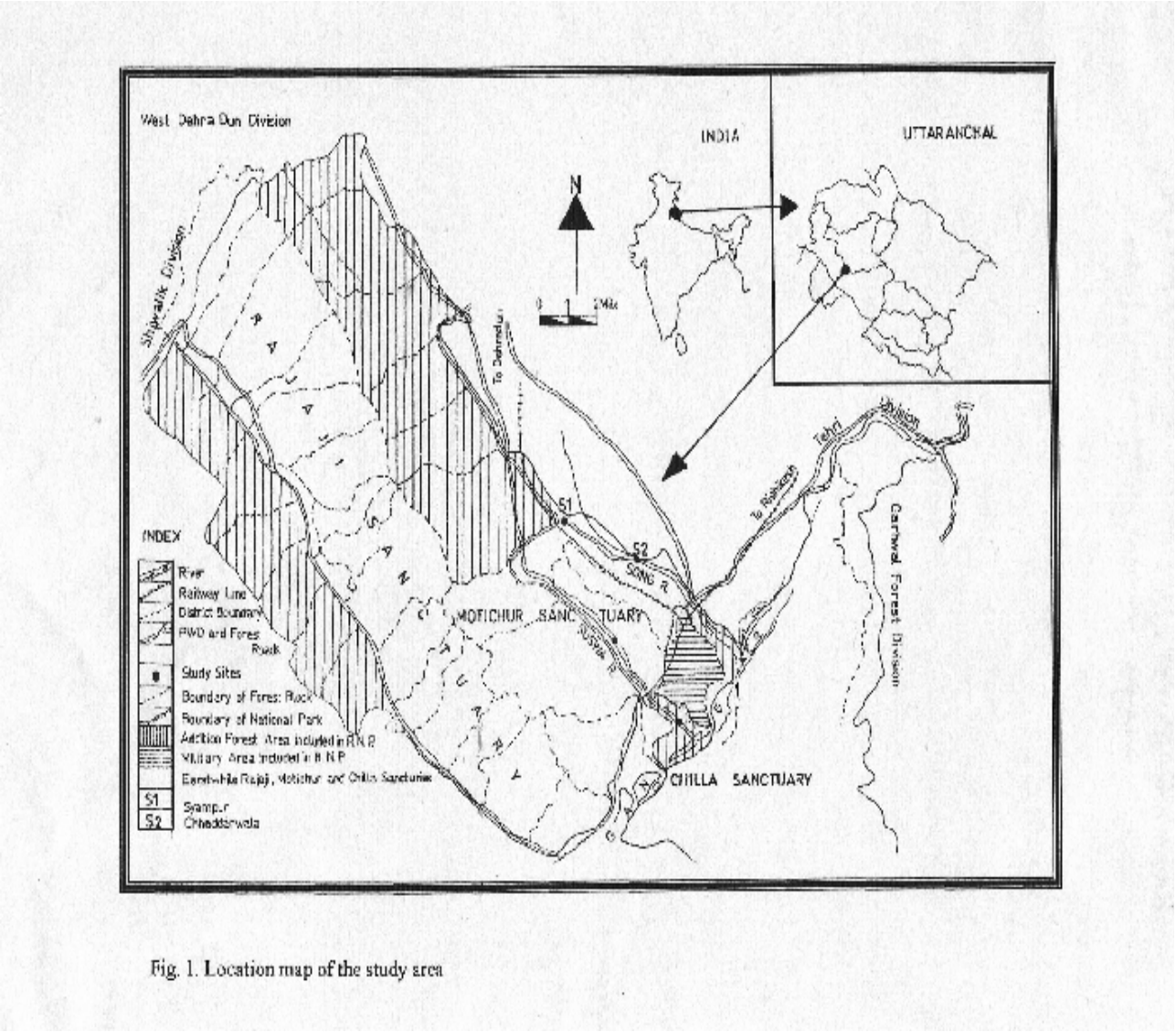

Fig. 1. Location map of the study area

Figure 1 : Location map of the study area

Table 1 : Physiographic characteristics of aquatic habitat of the Song river of Rajaji National Park

Parameters	S1	S2
Latitude	30°02'	30°11'30"
Longitude	78°12'	78°07'
Altitude (m above m.s.l)	320	300
Embankment	Sparse riparian vegetation	Dense riparian vegetation
Boulders (%)	50	40
Cobbles (%)	20	25
Pebbles (%)	15	20
Sand (%)	12	10
Silt (%)	2	3
Clay (%)	1	2

© 2014 Global Journals Inc. (US)

Table 2 : Monthly variations in physico - chemical parameters recorded at sampling site S_1 of the Song river of Rajaji National Park, Uttarakhand 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
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
Chlorides (mg l^{-1})	5.24	5.30	5.10	5.10	5.02	5.15	6.96	6.400	6.96	5.84	5.26	5.21	5.61±0.74
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
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 3 : Monthly variations in physico - chemical parameters recorded at sampling site S_2 of the Song river of Rajaji National Park, Uttarakhand 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
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 4 : Monthly variations in the density (ind.m^{-2}) of aquatic insects dwelling the river Song during September 2001-August 2002

Aquatic insects	Site	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual Mean	%
Ephemeroptera	S_1	126	127	226	322	378	646	296	211	106	66	37	26	198.7	30.50
	S_2	120	130	204	306	404	503	289	123	67	57	20	50	189.4	31.27
Plecoptera	S_1	107	123	180	223	239	273	193	89	43	27	17	30	128.6	19.76
	S_2	117	143	173	210	240	273	193	113	50	27	20	30	132.4	21.86
Trichoptera	S_1	107	120	163	164	230	252	157	123	57	23	10	23	119.0	18.30
	S_2	100	123	173	187	200	227	113	73	43	33	0	17	107.4	17.66
Diptera	S_1	40	46	83	116	173	200	176	100	77	44	17	23	91.25	14.03
	S_2	40	53	80	90	111	166	197	50	30	16	10	10	71.08	11.73
Coleoptera	S_1	43	73	107	153	177	193	146	96	63	30	13	30	93.66	14.40
	S_2	40	80	99	130	153	170	110	80	33	23	20	30	80.66	13.31
Odonata	S_1	9	10	37	33	44	24	20	16	13	13	3	6	19.00	2.92
	S_2	15	14	42	30	40	33	20	26	24	14	20	23	25.08	4.14
Total Density (ind.m^2)	S1	432	499	769	1011	1241	1406	988	635	359	203	97	138	650.2	
	S2	432	543	771	953	1148	1372	922	465	247	170	90	160	605.6	

© 2014 Global Journals Inc. (US)

Table 5 : Diversity indices calculated for aquatic insects of the river Song river of Rajaji National Park during September 2001- August 2002

Months	S_1	S_2
Sep	3.5610	3.4723
Oct	3.5287	3.6038
Nov	4.1085	4.1825
Dec	4.2810	4.3333
Jan	4.4385	4.3841
Feb	4.4561	4.3960
Mar	4.4232	4.2298
Apr	4.2461	4.0018
May	4.1662	3.7355
Jun	3.8867	3.3777
Jul	3.1282	3.0270
Aug	3.7820	3.4876

Table 6 : Concentration of dominance calculated for aquatic insects of the Song river of Rajaji National Park during September 2001- August 2002

Months	S_1	S_2
Sep	0.1015	0.1058
Oct	0.1011	0.0957
Nov	0.0732	0.0695
Dec	0.0645	0.0614
Jan	0.0565	0.0586
Feb	0.0566	0.0596
Mar	0.0561	0.0631
Apr	0.0659	0.0772
May	0.0629	0.0892
Jun	0.0746	0.1111
Jul	0.1315	0.1328
Aug	0.0801	0.0948

Table 7 : Correlation between hydrological attributes and density of aquatic insects of Song river of Rajaji National Park for the period September 2001-August 2002

	Dn	AT	WT	WC	Tu	HMD	Co	TDS	DO	F Co2	pH	PO3	NO3	Chl	Alk	Na	K
Dn	1																
AT	-0.89	1															
WT	-0.744	0.826	1														
WC	-0.689	0.637	0.560	1													
Tu	-0.723	0.669	0.685	0.814	1												
HMD	-0.777	0.516	0.535	0.617	0.665	1											
Co	-0.21	-0.024	-0.216	0.225	0.304	0.428	1										
TDS	-0.848	0.879	0.818	0.751	0.696	0.592	0.020	1									
DO	0.858	-0.839	-0.736	-0.787	-0.88	-0.644	-0.125	-0.806	1								
F Co2	-0.566	0.546	0.557	0.838	0.722	0.499	-0.031	0.658	-0.685	1							
pH	-0.016	0.055	0.219	-0.03	0.15	0.017	-0.240	-0.199	-0.068	-0.029	1						
PO3	-0.493	0.476	0.221	0.416	0.415	0.378	0.491	0.528	-0.468	0.211	-0.443	1					
NO3	-0.061	-0.147	-0.439	0.183	0.004	0.239	0.659	-0.029	-0.006	-0.126	-0.472	0.428	1				
Chl	0.166	0.299	-0.552	-0.187	-0.109	-0.039	-0.665	0.277	0.003	-0.099	-0.181	-0.221	-0.557	1			
Alk	-0.367	0.249	0.237	0.384	0.367	0.356	0.140	0.189	-0.224	0.456	0.456	0.068	-0.11	-0.067	1		
Na	-0.455	0.437	0.278	0.685	0.584	0.420	0.190	0.443	-0.624	0.479	0.304	0.191	0.241	-0.269	0.109	1	
K	-0.898	0.876	0.832	0.79	0.843	0.709	0.203	0.828	-0.886	0.597	0.191	0.415	-0.046	0.155	0.301	0.531	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

© 2014 Global Journals Inc. (US)

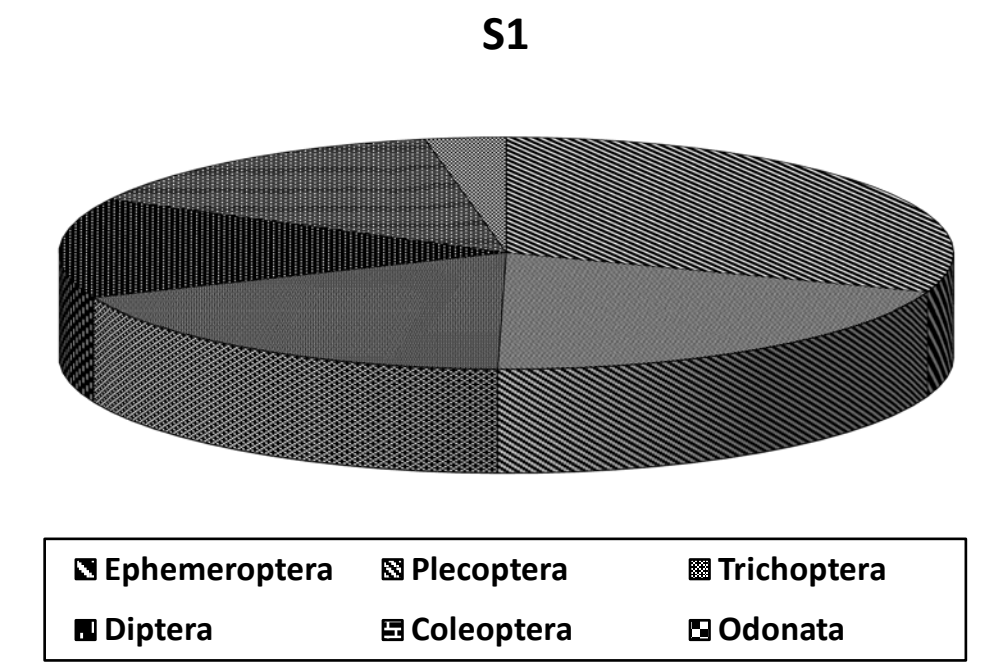

Figure 2

© 2014 Global Journals Inc. (US)