

## BIODIVERSITY OF FRESHWATER INSECTS: A REVIEW

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### -----ABSTRACT-----

*Aquatic insects may considered model organisms in analyzing the structure and function of the freshwater ecosystem because of their high abundance, high birth rate with short generation time, large biomass and rapid colonization of freshwater habitats. Aquatic insects are found associated with water for most part of their life cycle, any change in their number and composition in the population at a given time and space may indicate a change in the water quality. They also act as an indicator of trophic structure, water quality and eutrophication of the aquatic ecosystems.*

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### I. INTRODUCTION

There are about 7, 51,000 known species of insects, which is about three-fourth known species of plants and animals on the planet. These are also the only invertebrates that can fly (Voshell, 2002). Even though a majority of the insect species live in freshwater environments, such as swamps, ponds, lakes, springs, streams and rivers, these are called aquatic insects (Voshell, 2002). There are about 45000 species of insects, known to inhabit diverse freshwater ecosystems (Balaram, 2005). Less than 3% of all species of insects have aquatic stages in some freshwater biotopes, insects may comprise over 95% of the total individual or species of macro-invertebrates. They play important ecological roles in keeping freshwater ecosystems functioning properly. There are many different kinds of aquatic insects as almost every type of freshwater environment habitats from puddles to river to lakes, including both lentic and lotic habitats, can belong to various species of aquatic insects. They constitute a dominating group of benthic, limnetic and littoral fauna of aquatic ecosystems. Diversity of insects in lentic water tends to increase with increased nutrients (Daly, 1998). According to (Lewis and Gripenberg, 2008) aquatic insects often make good indicators because they are present in some quantity in almost every type of habitat and many are habitat specialists. Aquatic insects are used for monitoring the health of aquatic environments because of their differential responses to stimuli in their aquatic habitat and determining the quality of that environment (Merritt; Cummins and Berg, 2008). The presence or absence of certain families of aquatic insects can indicate whether a particular water body is healthy or polluted.

#### Types of aquatic insects:

Aquatic insects include following taxonomic orders:

- (i) Collembola - the springtails (springs and spring ponds).
- (ii) Ephemeroptera - the mayflies (lakes and streams).
- (iii) Odonata - the dragonflies and damselflies (lakes and streams).
- (iv) Plecoptera - the stone flies (streams).
- (v) Hemiptera - the true bugs (lake and stream margin).
- (vi) Neuroptera/Megaloptera - the dobsonflies, alderflies, and spongillaflyies, parasitic on sponges (mainly streams).
- (vii) Trichoptera - the caddisflies (lakes and streams).
- (viii) Lepidoptera - the butterflies and moths (aquatic catterpillar).
- (ix) Coleoptera - the beetles (lakes and streams).
- (x) Hymenoptera –diving wasps (terrestrial, parasitic on aquatic insects).
- (xi) Diptera - the true flies (all aquatic habitats).

### II. ROLE OF AQUATIC INSECTS IN FRESHWATER ECOSYSTEM:

Aquatic insects may considered model organisms in analyzing the structure and function of the freshwater ecosystem because of their high abundance, high birth rate with short generation time, large biomass and rapid colonization of freshwater habitats. Aquatic insects are found associated with water for most part of their life cycle, any change in their number and composition in the population at a given time and space may indicate a

change in the water quality. They also act as an indicator of trophic structure, water quality and eutrophication of the aquatic ecosystems (Varma and Pratap, 2006). Aquatic insects are integral part of the aquatic ecosystem, they have both ecological and economical value. They have been the primary tool for studying ecology, growth of population, evolution, genetics and many other areas of biology. Some of the aquatic insects break down the dead leaves and other plant parts that fall into the waterbody from land. This material provides the base of food chain in aquatic environments. Some scrape the algae that grow on all firm surfaces in water, such as rocks, logs, leaves and stem of live rooted plants. This layer of algae, which produces much oxygen and food for other organisms, is more productive if this is kept thin by the grazing of aquatic insects and other invertebrates. Some specific aquatic insects filter fine particles that are suspended in water. This is useful as it helps to keep the water clean enough for light to penetrate where algae and other plants are growing on the bottom. Other aquatic insects mix the soft bottom sediments as they burrow in search of food. This makes the bottom healthier for organisms because it puts oxygen from the water into the bottom.

Predators such as *Dytiscus* reduce the number of other invertebrates and help to keep the balance among the different kinds of organisms and the food that is available in the freshwater ecosystem.

A feature of the odonate species is that they prefer to live in freshwater, non-contaminated and well oxygenated habitats. Hence, they can serve as valuable bio-indicators for environmental contamination studies (Needham et al., 2000; Morin, 1984). The odonate larva use as energetic source in their diet the *Anopheles larva*, by maintaining the control over their population numbers, which itself are responsible for spreading of the epidemic illness like malaria (Mitra, 2002).

Chironomid larvae are an important food source for fish and waterfowls (Cibrowski and Corkum, 2003). Chironomids species diversity and their sensitivity to eutrophic conditions have been used to create trophic classification of lakes into oligotrophic, mesotrophic and eutrophic (Saether, 1975; Winnel and White, 1985; Langdon et al., 2006). Dipteran flies are the most important arthropod vectors of disease in humans and other animals. For example, malaria is a major cause of illness in many tropical countries. About 70 species of *Anopheles* mosquito transmit an estimated 500,000 cases of malaria every year. Yellow fever is transmitted by single mosquito, *Aedes aegypti*. Dengue or break bone fever is transmitted by *Aedes aegypti* and *A. albopictus*.

Hemipterans are the primary food for many wild and cultivable fishes, which make them valuable predators, are also occasional pests in the man-made nursery ponds for fish culture where they feed on young fish (McCafferty, 1981). Certain families of bugs may be utilized in the biological control of mosquito larvae (Ohba and Nakasuji, 2006; Saha et al., 2007). In many cultures these insects are eaten and enjoyed. For example, *Mangdana*, as species of giant water bug, that is enjoyed by Thailand people in stirfries and salads (Glausiusz, 2004).

The mayfly naiads are an important source of food for fish and other aquatic wildlife. Anglers often use mayflies as bait, or tie “flies” that are made to resemble imagos and subimagos. The larvae are important as food for other aquatic organisms.

Plecoptera have been used as biogeographical indicators and in evolutionary research. Plecoptera (stoneflies) are a source of food for many game fishes. They have been used for centuries in the sport of fly fishing, and fishermen have good knowledge of them.

Trichopteran feed on debris, cleaning the freshwater ecosystem in which they live besides being an important source of food for fish. Trichoptera larvae, pupae and adults also form an important link in the food chain and they have also been used extensively by trout fishing enthusiasts as models for “flies” (McCafferty, 1981). Caddisflies are considered to be of great economic importance as pests, they are beneficially important in the trophic dynamics and energy flow in aquatic ecosystems.

### III. BIODIVERSITY OF AQUATIC INSECTS:

Aquatic biodiversity is one of the most essential characteristics of aquatic ecosystem for maintaining its stability (Vinson and Hawkins, 1998; Sharma et al., 2004). Aquatic ecosystems are under increasing pressure from various kinds of disturbances (Tachet et al., 2003). This situation threatens both aquatic living resources and human population (Ramade, 2002). Biodiversity loss in freshwater ecosystems is an increasing phenomenon, mainly due to human activities (Abell, 2002). The main causes are the habitat destruction and defragmentation, exotic species introduction and global climate change impacts (Saunders et al., 2002). Removal or loss of aquatic insects can cause negative effects in the eco-systems stability and diversity (Krishnan et al., 1988).

**Odonates:** Odonata population can be indicative of the richness of other invertebrates and macrophytes (Bried and Ervin, 2005). Odonates are characterized as an excellent habitat indicator of present and past (long term) environmental conditions in aquatic habitats (Watson et al., 1982; Steward and Samway, 1988).

**Diptera:** Dipterans are the most ubiquitous of the entire macrobenthic invertebrate group in tropics (Victor and Onomivbpri, 1996). The dipterans prefer lentic habitats as breeding ground and early life stages (Majumder, Goswami and Agarwala, 2011). Insects restricted to heavily enriched habits e.g. 'bloodworm' midge larva indicate that water bodies are organically enriched.

**Hemiptera:** Aquatic Hemiptera have an intermediate place in the food chain, apart from being eaten, are often important predators too (Runck and Blinn, 1994). The species of predatory aquatic bugs of superfamily Nepoidea, including families Belostomatidae and Nepidae, have been designated as threatened-vulnerable species in Red Book of Japan (IUCN, 1990) and are regarded as effective predators of fresh water snails and mosquito larvae (Ohba and Nakasuji, 2006). Certain families of the bugs may be utilized in the biological control of mosquito larvae (Ohba and Nakasuji, 2006; Saha et al., 2007). These insects are mosquito regulator than widely used mosquito-fish which cannot move out from one waterbody to other. Researchers are looking into use of predator Hemiptera for mosquito control (Neri- Barbosa et al., 1997). Insecticide run-off could be damaging to the population of predatory aquatic bugs of superfamily Nepoidea, including families Belostomatidae and Nepidae (Vasuki, 1996).

**Coleoptera:** Order Coleoptera, or beetles, is represented by some 3, 50,000 known species (Lawrence et al., 1982), but recent estimates suggest that there are hundreds of thousands or even millions of species which are not described. There are about 18,000 species of aquatic coleopteran are present on the earth at present. Aquatic coleopterans are highly diverse and distributed to nearly 30 families. The water beetles show wide diversity of colour, form and life pattern (Vazirani, 1977). Dytiscidae family generally inhabits leaf of bottom macrophytes of the clean freshwater and are predacious in nature. Hydrophilidae family are water scavenger beetles and generally occur in shallower regions of the wetland with abundant macrophytes particularly emergent ones and feed mainly on detritus, algae and decaying vegetative matter (Khan and Ghosh, 2001).

**Ephemeroptera:** Ephemeroptera have advantages for monitoring as they are highly visible, relatively easy to sample and are represented by a few species in such habitats, which makes identification easier. Mayfly nymphs consume epiphytic algae and fine particulate organic matter (Francis et al., 2010). The main reasons for the low population density and low diversity of Ephemeropterans could be related to habitat degradation by pollution.

**Plecoptera:** Stone flies represent a very important component of ponds both as biomass and diversity. They are prey for the other macro-vertebrates and fishes, including those of economic importance. Plecoptera is a sensitive order of aquatic insects and restricted to habitats where there is a little human interference, clear water, and high dissolved oxygen content.

**Trichoptera:** Trichoptera are important processors of organic matter, collectively known as functional feeding groups (FFG) of animals, they display the full array of feeding modes (Cummins, 1973). Probably the most important aspect of ecological diversity among Trichopterans is the ability to produce silk. Silk production has enabled caddisflies to exploit a wide range of aquatic habitats. Silk utilization is different in most families and has more or less defined the ecological role of caddisflies. According to (Mackay and Wiggins, 1978), three modes of existence have resulted from silk utilization. Five groups within the three superfamilies of Trichoptera have been identified based on case - building behavior alone (Malick, 2010). This behavior has enhanced defensive capabilities which have allowed subsequent improvements in habitat selection and ecological diversity. Case-building behavior is usually species specific although construction may vary depending upon available habitat. Cases function as ballast camouflage, and mechanical defence (Malick, 2010). The ability of larval Trichoptera, therefore, to construct cases from silk and surrounding material has led to their ecological diversification and utilization of habitats unavailable to other aquatic macro -invertebrates. It has been demonstrated (Otto 1987b; Rowlands and Hansell, 1987) that caseless larvae are preferentially preyed upon more than cased individuals and avoid cased and uncased Trichopteran larva. Thus, case building caddisfly species have developed a defence suitable for aquatic environments that allow them to utilize optimal microclimate which other non-case building species cannot because of predation pressure.

#### IV. AQUATIC INSECTS DIVERSITY AND WATER QUALITY:

Aquatic insects allow us to know about the health of a stream, pond, river or a lake. Aquatic insects are good indicators of water quality because they are affected by the physical, chemical, and biological conditions of the water body. They cannot escape pollution and show the collective effects of short and long term pollution events. They are particularly sensitive to the water quality like the amount of dissolved oxygen. Aquatic ecosystems are under increasing pressure from various kinds of disturbances (Tachet et al., 2003).

**Odonates:** Studies have included Odonata relationship with water quality, such as Temperature, pH, TDS, DO, Total alkalinity and Total Hardness etc (Azrina et al., 2006), biotope quality (Clark and Samways, 1996; Clausnitzer, 2003) and general species richness (Sahlen and Ekestubbe, 2001; Briers and Biggs, 2003), and use of Odonata as indicators for wetland conservation (Bried et al., 2007), riparian management needs (Samways and Steytler, 1996), wetland buffer width requirements (Bried and Ervin, 2006) and shallow lake restoration (D'Amico et al., 2004). This is largely because many of criteria of good indicator species, such as being taxonomically well known, relatively easy to identify and having distinct habitat requirements (Krebs, 2001) are fulfilled by Odonates (Corbet, 1999). Odonata constituted the third most abundant group of insect fauna. This group was represented by *Anax* nymph, *Ictinogomphus* nymph, *Crocothemis* nymph and *Pseudagrion* nymph. The investigations indicates that Odonata can live in polluted as well as clean water, but the algal abundance and luxuriant growth of macrophytes are prior requirements. Odonata prefer fresh water habitat with rich oxygen so their abundance are seen in winter because there is high dissolved oxygen in freshwater ecosystem in this season. In the present studies, their abundance was seen from December to January.

In the present studies the value of dissolved oxygen reached up to 8-11mg/l and temperature decreased from 22-17°C. Odonata shows least diversity and were very sparse in distribution, indicating their preference for freshwater, non-contaminated and well oxygenated habitats.....

**Diptera:** Presence of saprophilic species of diptera indicates that water bodies are grossly polluted with poor water quality characterized by low oxygen and high nutrient concentration (eutrophic). Large numbers of pollution tolerant chironomids are often indicative of poor water quality (characterized by low dissolved oxygen and high nutrient concentrations). Excellent water quality conditions are often characterized by relatively low densities and high species diversity. The high abundance of *Chironomus* sp. in aquatic body indicates eutrophic nature of water body.

In the present studies, during summer season less dissolved oxygen 2 mg/l was noticed in the freshwater ecosystem, as the presence of chironomids is inversely proportional to the dissolved oxygen their abundance are seen during this season. Their abundance is seen from April to June, when the temperature reaches from 28-32°C.

**Hemiptera:** Environmental reclamation of aquatic habitats is aided by aquatic Hemipterans which often can function as bio-indicators. These bugs, since they can survive in heavily polluted areas, are often used to gauge the toxins in an environment (Papacek, 2001 and Wollmann, 2001). Aquatic hemipterans stand out as an important group of aquatic insects, which are considered important in environmental reclamation of aquatic habitats and are often used to gauge toxins in an environment (Jansson, 1987; Papacek, 2001; Wollman, 2001). The hemipterans are associated with macrophytes, their diversity is high during winter as the increasing growth of macrophytes.

In the present studies, Hemiptera formed the first most abundant group of insect fauna in the selected lake when the dissolved oxygen reached up to 8-11mg/l and temperature decreased from 20-17°C. This group was represented by the genera *Belostoma* sp., *Coroxid* sp., *Gerris* sp., *Nepa* sp., *Notonecta* sp., and *Ranatra* sp.

**Coleoptera:** Among coleopteran, the Hydrophilids (water scavenger beetles) are predominant in rivers and streams. The members of family Dytiscidae (Predacious diving beetles) have adapted perfectly well to aquatic life. All adults and larvae are aquatic. The members of family Gyrinidae (whirling beetles) are found in fresh water ponds, lakes, open flowing streams etc. The members of Haliplidae (crawling water beetles) live among aquatic vegetation along the edges of ponds, lakes, streams and creeks. Their abundance occurs in summer because of high rate of decomposition of organic matter due to high temperature which reaches up to 28-30°C. Coleoptera formed the second most abundant group of insect fauna. This group was represented by *Cybister* sp., *Dystiscus* sp., and *Hydrophilus* sp.

In the present studies dominance of Coleopteran species were seen during summer in all sites of the lake which can be related to the availability of food and vegetation, which enhances the growth of insects during this period. Their abundance were seen during April to June. The present findings are in conformity with the findings of Kaur et al., (1995) and Bath and Kour, (1998).

**Ephemeroptera:** Ephemeroptera larvae are recognized worldwide for their sensitivity to oxygen depletion, and are therefore commonly used as bio indicators in many monitoring programmes. A high sensitivity of mayfly taxa to oxygen depletion, acidification, and various contaminants including metals, ammonia and other chemicals was demonstrated in both observational and experimental studies (Hubbard and Peters, 1978; Moog et al., 1997; Hickey and Clements, 1998). Various biological indices including mayflies to assess water quality have been developed over the years (Lenat, 1988; Kerans and Karr, 1994). Mayflies are considered as “keystone” species and their presence is believed to be an important indicator of oligotrophic to mesotrophic (low to moderately productive) condition in running waters (Barbour et al., 1999; Bauernfeind and Moog, 2000). On contrary mayflies inhabiting lentic waters (e.g. lakes and ponds), have been poorly used in biomonitoring programmes (Madenjian et al., 1998). Nevertheless, in such environments, it is expected that mayflies also integrate some aspect of water quality.

In the present studies Ephemeroptera shows a significant association with moderately polluted water; their abundance could be seen during winter from February to March as temperature of water was not so high (19-22 °C), there was slight decomposition of organic matter present in water body making it moderately polluted. Ephemeroptera constituted the fifth abundant group of insect fauna. This group was represented by *Baetis* sp. and *Caenis* sp. Their presence indicates that these larvae are able to survive in polluted water with sufficient dissolved oxygen (> 2.6 mg/l).

**Plecoptera:** Plecoptera are used as biological indicators of water quality, especially dissolved oxygen levels, thus deteriorating populations of stoneflies mean that poor water quality threatens the health of aquatic ecosystem. The absence of Plecoptera indicates the water quality degradation and physical alteration.

In the present studies, the absence of Plecoptera during present study clearly indicates the water quality degradation and physical alteration. They usually prefer stream environment, where there is low temperature.

**Trichoptera:** The larvae of caddisfly are useful as biological indicator organisms for assessing water quality. Extensive use of them has been made for this purpose because larvae of different species vary in sensitivity to various types of pollution (Resh and Unzicker, 1975; Resh, 1993; Dohet, 2002) and because the taxonomy of the group is relatively well known. Their life cycle is completed before monsoon period and adults emerge, so at that time their abundance can be seen in the aquatic ecosystem.

In the present studies there is absence of Trichoptera across all the sites of selected lake. This clearly indicates that they are sensitive to pollution.

## V. CONCLUSION

Conservation of natural resources and biodiversity has become urgent issues in recent years for attaining an environmentally sustainable future. While a lack of data has historically excluded the use of many taxa as possible indicators (Sahlen and Ekestubbe, 2001). Growing number of studies on the habitats and distributional pattern of certain insects is making their use increasingly suitable. The improvement and development of existing and new biomonitoring tools using aquatic insects are a major effort among aquatic entomologists (Carter and Resh, 2001). Aquatic insect fauna of Madhya Pradesh is rather poorly documented and limited numbers of studies have been carried out on the ecological aspects of aquatic entomofauna.

## REFERENCES

- [1] Abell, R. (2002). Conservation biology for biodiversity crisis: Fresh water follow up. *Conservation Biology*, 16 : 1435-1437.
- [2] Azrina, M.Z., Yap, C.K., Ismail, A.R., Ismail, A. and Tan, S.G. (2006). Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River Peninsular Malaysia. *Ecotoxicology and Environmental Safety*, 64 : 337-347.
- [3] Balaram, P. (2005). Insect of tropical streams. *Current Science* 89 : 914.
- [4] Barbour, M. T., Gerritsen, J., Snyder, B.D. and Stribling, J. B. (1999). *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers*, Office of Water, U.S. Environmental Protection Agency, Washington. *Periphyton, Benthic Macroinvertebrates and Fish*, 2nd Ed : EPA 841-B-99- 002.
- [5] Bath, K. S. and Kour, H. (1998). Seasonal distribution and population dynamics of aquatic insects in Harika reservoir (Punjab). *Ecobiology*, 10 (1) : 160-165.

- [6] Bauernfeind, E. and Moog, O. (2000). Mayflies (Insecta : Ephemeroptera) and the assessment of ecological integrity: a methodological approach. *Hydrobiologia*, 423 : 71- 83.
- [7] Bried, J. T. and Ervin, G. N. (2005). Distribution of Adult Odonata among localized Wetlands in East- central Mississippi. *Southeastern Naturalist*, 4 (4) : 731-744.
- [8] Bried, J. T. and Ervin, G. N. (2006). Abundance patterns of dragonflies along a wetland buffer. *Wetlands*, 26 (3) : 878-883.
- [9] Bried, J. T., Herman, B. D. and Ervin, G. N. (2007). Umbrella potential of plants and dragonflies for wetland conservation, a quantitative case study using the umbrella index. *Journal of Applied Ecology*, 44 : 833-842.
- [10] Briers, R. A. and Biggs, J. (2003). Indicator taxa for the conservation of pond invertebrate diversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 13: 323-330.
- [11] Carter, J. L. and Resh, V. H. (2001). After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by US state agencies. *Journal of the North American Benthological Society*, 20 (4) : 658-682.
- [12] Cheng, L. (1985). Biology of Halobates (Heteroptera: Gerridae). *Annual review of entomology*, 30 : 111-135.
- [13] Clark, T.E. and Samways, M.J. (1996). Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. *Journal of Applied Ecology*, 33 : 1001-1012.
- [14] Clausnitzer, V. (2003). Dragonfly communities in coastal habitats of Kenya: indication of biotope quality and the need of conservation measures. *Biodiversity and Conservation*, 12 : 333-356.
- [15] Cibrowski, J. J. H., and Corkum, L. D. (2003). United Earth Fund. Appendix 9: Sediment- zoobenthos interactions. In *Evaluating Ecosystem Results of PCB Control Measures within the Detroit River–Western Lake Erie Basin* : 78-82.
- [16] Corbet, P.S. (1999). *Dragonflies: Behaviour and Ecology of Odonata*. Comstock Publishing Associates, Ithaca, New York.
- [17] Cummins, K. W. (1973). Trophic relations of aquatic insects. *Annual Review of Entomology*, 18 : 183–206.
- [18] D'Amico, F., Darblade, S., Avignon, S., Blanc-Manel, S. and Ormerod, S. J. (2004). Odonates as Indicators of Shallow Lake Restoration by Liming: Comparing Adult and Larval Responses. *Restoration Ecology*, 12 (3) : 439-446.
- [19] Daly, H. E. (1998). The return of Lauderdale's paradox. *Ecol. Econ.*, 25 : 21–23.
- [20] Dohet, A. (2002). Are caddis flies an ideal group for the biological assessment of water quality in streams? *Nova supplementa Entomologica. Proceedings of 10th International Symposium on Trichoptera*. 15 : 507-520.
- [21] Francis, O., Arimoro and Wilhelmine, J. M. (2010). Mayfly (Insecta : Ephemeroptera) community structure as an indicator of the ecological status of stream in the Nigeria delta area of Nigeria. *Environmental Monitoring and Assessment*, 166 : 581-594.
- [22] Glausiusz, Josie (1997). The Ecology of Language. Link between Rainfall and language diversity, *Discover*, 18 (8) : 30.
- [23] Glausiusz, (2004). When life was Hell. *Discover*, 23 : 10.
- [24] Hickey, C. W. and Clements, W. H. (1998). Effects of heavy metals on benthic macroinvertebrate communities in New Zealand streams. *Environmental Toxicology and Chemistry*, 17 : 2338–2346.
- [25] Hubbard, M. D. and Peters, W. L. (1978). Environmental requirements and pollution tolerance of Ephemeroptera. EPA- Environmental Protection Agency, Cincinnati, OH, VI, U.S. : 600-4-78-061.
- [26] IUCN (1990). The 1990 IUCN red list of threatened animals. IUCN, Gland, Switzerland and Cambridge, UK.
- [27] Jansson, A. (1987). Micronectinae (Heteroptera, Corixidae) as indicators of water quality in Lake Vesijaervi, southern Finland, during the period of 1976-1986. *Lake Paeijaenne Symposium* : 119-128.
- [28] Kaur, H., Dhillon, S.S., Bath, K. S., Kaur, K. and Mander, G. (1995). Invertebrate fauna of fresh water bodies existing in and around Patiala. *Environmental Pollution*, 22(4) : 163-167.
- [29] Kerans, B. L. and Karr, J.R. (1994). A benthic index of biotic integrity (B-ibi) for rivers of the Tennessee valley. *Ecological Applications*, 4 : 768–785.
- [30] Khan, R.A. and Ghosh, L.K. (2001). Faunal diversity of aquatic insects in freshwater wetlands of South Eastern West Bengal. *Zoological Survey of India, Kolkata* : 104.
- [31] Krishnan, et. al. (1988). Ionic Alkylleads in Salt Marsh Periwinkles ( *Littorina irrorata*) *Environmental Science and Technology*, 22 : 806.
- [32] Krebs, C.J. (2001). *Ecology: The Experimental Analysis of Distribution and Abundance*. (5th Edition). Benjamin Cummings of Addison Wesley Longman Inc. San Francisco, CA.
- [33] Langdon, P.G., Ruiz Z., Brodersen K.P. and Foster I.D.L. (2006). Assessing lake eutrophication using chironomids: understanding the nature of community response in different lake types. *Freshwater Biology*, 51 : 562–577.
- [34] Lawrence, et. al. (1982). Digestion in Echinoderm, Nutrition, Balkema, Rotterdam, the Netherlands.
- [35] Lenat, D. R. (1988). Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. *Journal of the North American Benthological Society*, 7 : 222–233.
- [36] Majumder, J., Goswami R., and Agarwala, B. K. (2011). A preliminary study on the insect community of Phytotelmata, an ephemeral ecosystem in Tripura, Northeast India. *Nebio*, 2 : 23-31.
- [37] Mackay, R.J. and Wiggins. G. B (1978). Ecological diversity in the Trichoptera. *Annual Review of Entomology*, 24 : 185-208.
- [38] Madenjian, C. P., Schloesser, D.W and Krieger, K. A. (1998). Population models of burrowing mayfly recolonization in western Lake Erie. *Ecological Applications*, 8 : 1206–1212.
- [39] Malick, M. (2010). Case building as a primary defense behavior in larval caddisflies (Tricophtera). [Http://www.Colostate.edu/Depts./Entomology/courses/en 507/papers-1995 Malick.html](http://www.Colostate.edu/Depts./Entomology/courses/en 507/papers-1995 Malick.html).
- [40] Merritt, R.W., Cummins, K.W. and Berg, M.B. (2008). *An introduction to the Aquatic insect of North America*. 4<sup>th</sup> Ed. : 1158.
- [41] Mitra, A. (2002). The study on the dragonfly (Odonata : Insecta) fauna of the district Trashigang, East Bhutan, Environment and life support system of the Bhutan Himalaya, 1 : 30-70.
- [42] Moog, O., Bauernfeind, E. and Weichselbaumer, P. (1997). The use of Ephemeroptera as saprobic indicators in Austria. In: *Ephemeroptera and Plecoptera, Biology, Ecology, Systematics*. Landolt, P. and M. Sartori Fribourg (Eds.) Mauron, Tinguely and Lachat SA, : 254-260.
- [43] Morin, E (1984). *Ciencia con conciencia*, Barcelona, Anthopos. Originally published in French as: *Science avec conscience*, Coll. Points : 1990.
- [44] Needham, J.G., Westfall, M. J. Jr., May, M.L. (2000). *Dragonflies of North America*. Scientific Publishers, Gainesville, FL : 189.
- [45] Neri- Barbosa, J.F., Quiroz-Martinez, H., Rodriguez-Tovar, M. L., Tejada, L.O and Badii, M.H. (1997). Use of Bactimos registered briquets (B.t.i. formulation) combined with the backswimmer *Notonectida irrorata* (Hemiptera : Notonectidae) for control of mosquito larvae. *Journal of the American Mosquito Control Association*, 13 (1) : 87-89.
- [46] Ohba, S. and Nakasuji, F (2006). Dietary items of predacious aquatic bugs (Nepoidea: Heteroptera) in Japanese wetlands. *Limnology*, 7 : 41-43.

- [47] Otto, C. (1987b). Behavioural adaptations by *Agrypni apagetana* (Trichoptera) larvae to cases of different value. *Oikos* 50 : 191-196.
- [48] Papacek, M. (2001). Small aquatic and ripicolous bugs (Heteroptera : Nepomorpha) as predators and prey: The question of economic importance. *European Journal of Entomology*, 98 (1) : 1-12.
- [49] Ramade, F. (2002). Dictionnaire encyclopedique de I, ecologieet des science de I, environment. Encyclopedic dictionary of ecology and environment sciences. 2n edition, Dunot, Paris.
- [50] Resh, V. H. (1993). Recent trends in the use of trichoptera in water quality monitoring. In proceeding of the 7th International symposium on Trichoptera (C. Otto. ed.). Backhuys publishers, Leiden, Netherlands.
- [51] Resh, V. H. and Unzicker, J. D. (1975). Water quality monitoring and aquatic organisms: the importance of species identification. *Water Pollution Controller Federation*, Washington, 47 (1): 9-19.
- [52] Rowlands, M. L. J. and Hansell, M. H. (1987). Case design, construction and ontogeny of building in *Glyptotaelius pellucidus* (caddisfly) larvae. *Journal of Zoology*, 211 : 329- 356.
- [53] Runck, C. and Blinn, D. W. (1994). Role of *Belestoma bakerbi* (Heteroptera) in the trophic ecology of a fishless desert spring. *Limnology and Oceanography*, 39 (8) : 1800-1812.
- [54] Saether, O. (1975). Chironomid communities as water quality indicators. *Holarctic Ecology*, 2 : 65-74.
- [55] Saha, N., Aditya, G., Bal, A. and Saha, G. K. (2007). Comparative study of functional response of common hemipteran bugs of east Calcutta wetlands, India. *International Review of Hydrobiology*, 92 : 242-257.
- [56] Sahlen, G. and Ekestubbe, K. (2001). Identification of dragonflies (Odonata) as indicators of general species richness in boreal forest lakes. *Biodiversity and Conservation*, 10 : 673-690.
- [57] Saunders, D. L., Meeuwing, J. J. and Vincent, A. C. J. (2002). Freshwater protected areas : strategies for conservation. *Conservation Biology* 16 : 30-41.
- [58] Stewart, D. A. B. and Samways, M. J. (1988). Conserving dragon fly (odonata) assemblages relative to river dynamics in an African Savannah game reserve. *Conservation Biology*, 12 : 683-692.
- [59] Tachet, H., Richoux, P., Bourneau, M. and Usseliopolatera, P. (2003). Invertebrates' caudouce; systematique, biologie, ecologie. Fresh water invertebrates; systematic, biology, ecology. CNRS edition, Paris.
- [60] Varma, M.C. and Pratap, R. (2006). Haematology and Ecotoxicology, 1 (1) : 13-20.
- [61] Vasuki, V. (1996). Insect growth regulator: Its impact on some predatory arthropods of mosquito immatures. *Entomon*. 21 (3-4): 217-220.
- [62] Vazirani, T.G. (1977). Catalogue of oriental Dytiscidae. Records of the Zoological Survey of India, Miscellaneous Publications, Occasional papers 6 : 111.
- [63] Vinson and Hawkins, (1998). Biodiversity of stream insects. Variations at local, Basin and regional scales. *Annual review of entomology*, 43 : 271-293.
- [64] Voshell, J.R. (2002). A Guide to Common Freshwater Invertebrates of North America. McDonald and Woodward Publishing Co., Blacksburg, Virginia : 442.
- [65] Watson, J.A.L., Arthington, A.H. and Cornick, D.L. (1982). Effects of sewage effluent on dragonflies (odonata) of Bulimba Creek, Brisbane. *Australian Journal of Marine and Freshwater Resources*, 33:517-528.
- [66] Winnell, M.H., and White, D.S. (1985). Trophic status of Southeastern Michigan based on the Chironomidae (Diptera). *Journal of Great Lakes Research*, 11:540-548.
- [67] Wollmann, K. (2001). Corixidae (Hemiptera, Heteroptera) in acidic mining lakes with pH  $\leq$  3 in Lusatia, Germany. *Hydrobiologia*, 433(3) : 181-183.