Tropical Ecology **56**(2): 245-255, 2015 ISSN 0564-3295

www.tropecol.com

Ecology of Monabeel, a floodplain ecosystem of Cachar, Assam with special reference to aquatic insect community

PINKI PURKAYASTHA & SUSMITA GUPTA*

Department of Ecology and Environmental Science, Assam University, Silchar 788011, India

Abstract: Present study was carried out to investigate the composition, diversity and distribution of aquatic insects in relation to the physico-chemical properties of the water of Monabeel, a floodplain ecosystem. This study reported that the ecological quality of the system is mainly governed by dissolved oxygen, rainfall, free carbon dioxide and nitrate. Average Score Per Taxon (ASPT), Stream Invertebrate Grade Number - Average Level (SIGNAL), Trophic Rate Score (TRS) and Biological Monitoring Working Party (BMWP) Score reported from the study reflected good ecological potential as well as slightly impacted nature of the water body. Input of nutrients during connectivity might be one of the important reasons for mesotrophic nature of the system. However for drawing a concrete conclusion intensive sampling and thorough investigations are necessary.

Resumen: El presente estudio se llevó a cabo con el fin de investigar la composición, la diversidad y la distribución de insectos acuáticos en relación con las propiedades físico-químicas del agua en Monabeel, un ecosistema de planicie de inundación. Este estudio reportó que la calidad ecológica del sistema está regida principalmente por el oxígeno disuelto, la lluvia, el dióxido de carbono libre y el nitrato. La Puntuación Media por Taxón (ASPT), el Nivel Promedio del Número Gradual Invertebrados de la Corriente (SIGNAL), la Puntuación de la Tasa Trófica (TRS) y la Puntuación del Grupo de Trabajo de Monitoreo Biológico (BMPW; todas las siglas por sus nombres en inglés) reportadas a partir de este estudio reflejaron el buen potencial ecológico, así como la naturaleza ligeramente impactada del cuerpo de agua. La entrada de nutrientes durante la conectividad podría ser una de las causas importantes de la naturaleza mesotrófica del sistema. Sin embargo, para poder llegar a una conclusión concreta hacen falta un muestreo intensivo y una investigación exhaustiva.

Resumo: Este estudo foi realizado para investigar a composição, diversidade e distribuição de insetos aquáticos em relação às propriedades físico-químicas da água de Monabeel, um ecossistema inundável de várzea. Este estudo mostrou que a qualidade ecológica do sistema é regidaprincipalmente pelo oxigénio dissolvido, as chuvas, o dióxido de carbono livre e o nitrato. A Pontuação Média Por Taxon ASPT), o grau do fluxo de Invertebrados - nível médio (SIGNAL), Taxa de Contagem Trófica (TRS) e Contagem Reportada pelo Grupo de Trabalho de Acompanhamento Biológico (BMWP) a partir do estudo, reflete um bom potencial ecológico, bem como a natureza ligeira do impacto do corpo de água. A entrada de nutrientes durante a conectividade pode ser uma das razões importantes para a natureza mesotrófica do sistema. No entanto, para chegar a uma conclusão concreta, são necessárias uma amostragem intensiva e uma investigação aprofundada.

Key words: Aquatic insects, diversity, distribution, floodplain ecosystem, physico-chemical properties, trace elements.

**Corresponding Author*; e-mail: susmita.au@gmail.com

Introduction

Rightly called nature's kidney (James 1995), aquatic ecosystems are among the most important ecosystems on planet earth. These are highly productive ecosystems occupying about 6 % of the world's land surface (WWF 2006). Freshwater ecosystems are colonized by a diverse array of aquatic organisms (Sharma 2011). Floodplain ecosystems provide feeding, breeding and nesting ground to a large number of organisms. Monabeel is one such floodplain ecosystem in Barak Valley, Assam that provides home to a large number of plankton, macrophytes, aquatic insects, fishes and migratory birds. Species abundance and the distribution of organisms in any community is one of the important aspects of community ecology. Such studies provide information on the number and the relative abundance of the species encountered in a sample from a given community, both of which are important for understanding the impact, as well as possible mitigation of global environmental changes (Das *et al.* 2013). Aquatic insects are a group of arthropods that live or spend part of their life cycle in water bodies. They are also considered to be very good indicators of water quality since they have a range of environmental disturbance tolerant levels (Arimoro & Ikomi 2008; Pennak 1978). Some are highly vulnerable and sensitive to pollution, while others can live and proliferate in disturbed and extremely polluted waters (Merritt & Cummins 1996). Aquatic insects are used for assessing water quality and provide information to environmental managers and decisions makers to take accurate and justifiable actions in regard to the state and quality of water bodies (Arimoro & Ikomi 2008).

Chatla wetland is situated to the south-west of Silchar town of Cachar district of Assam at a distance of 18 kilometers from Silchar town. It is located at 24° 42′ 697″ N Latitude and 92° 46′ 264″ E Longitude. Chatla has a maximum depth of around 10 m and water spread area of 1,750 hectares when inundated. The Chatla floodplain contains almost 1500 fishery ponds and 12 large water bodies, locally known as *Beels*. Monabeel is one of them. *Beel* is a term used for a pond (wetland) with static water, formed by inundation of low lying lands during flooding, where some water remains trapped after floodwater recedes back from the floodplains. *Beels* may also be formed by filling up of low lying areas during rain. Several hydrobiological studies have been conducted in the rivers, fisheries, ponds and lakes of Cachar district including Chatla floodplain (Bhuiyan & Gupta 2007; Das 2001, 2002; Das & Gupta 2010; Das & Gupta 2012; Duttagupta *et al.* 2004; Laskar & Gupta 2009; Purkayastha & Gupta 2011; Purkayastha & Gupta 2012) however, none of these have focused on Monabeel, which is a rich aquatic ecosystem providing habitat to large number of aquatic organisms and migratory birds, and which supports different types of food chains and food web, providing livelihood to local fishing communities. In this study we investigated the diversity and density of aquatic insects and physico-chemical properties of water of Monabeel.

Materials and methods

Study area

Monabeel is a natural aquatic ecosystem of Chatla floodplain, Cachar, Assam (Fig. 1) covering an area of 12.36 ha (approx). Topography of the area is fenland type with small hillocks strewn among large stretches of lowland. Monabeel holds water throughout the year and during periods of high rainfall, it links with the neighboring lentic and lotic ecosystems of Chatla floodplain. The surface water contains only 10 % mud and there is no continuous movement of water and wind flow. Vegetation type around the ecosystem is mainly grassland type. Among the tree species found around the ecosystem the most important one is *Barringtonia acutangula* (locally known as 'Hijol'), a common swamp forest species which can withstand prolonged water logging in association with *Calamus tenuis*, a rattan species. Other dominant tree species found in and around are *Lagerstroemia flos reginae, Vitex nigundo, Artocarpus chaplasha, A. heterophyllus* etc. Reeds like *Erianthus ravennae, Phragmites karka* and *Imperata cylindrica* are abundant in this system. There are also some bamboo species like *Bambusa polymorpha, B. tulda, Melocanna baccifera* in this area and several macrophytes such as *Azolla pinnata, Lemna minor, Nymphoides cristata, Vallisneria spiralis, Ipomoea aquatica and Hygroryza aristata* are also found. Water from Monabeel is used for fishing, drinking, bathing, cleaning and by a brick factory. Monabeel also provides habitat to large number of aquatic organisms and migratory birds.

Sampling

Water and aquatic insect samples were collected seasonally in three replicates from October 2010 to August 2011. Aquatic insects per unit

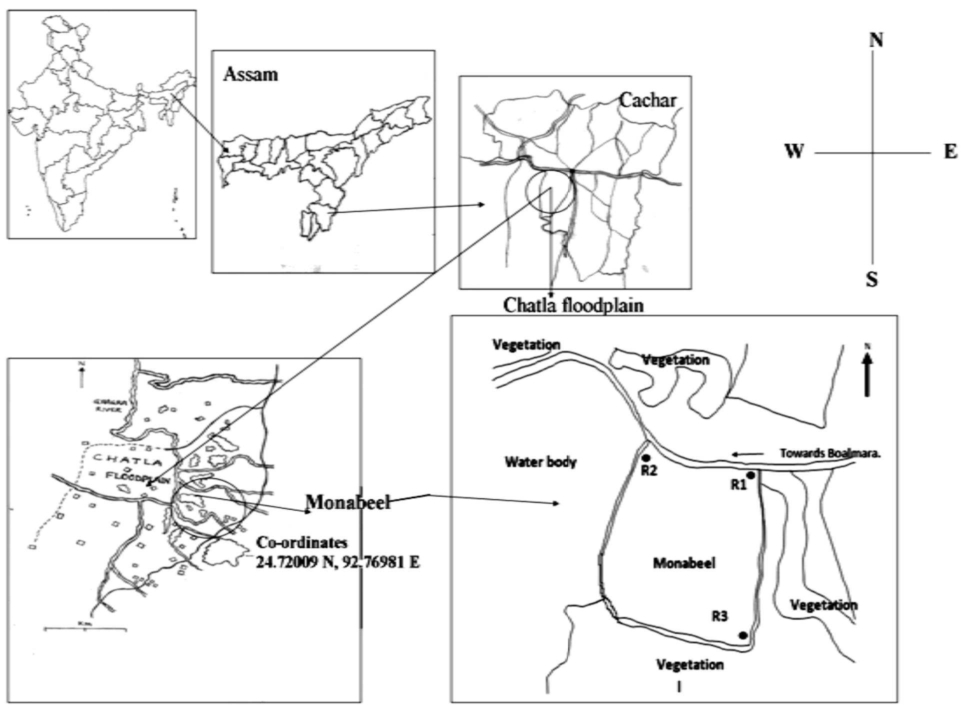

Fig. 1. Map of the site studied.

time were collected by the kick method whereby the vegetation was disturbed and the circular net (mesh size 60 µm) was dragged around the vegetation for one minute (Brittain 1974; Subramaniam & Sivaramakrishnan 2007**)**. Three such drags were conducted per sample.

Physico-chemical parameters of water

Physico-chemical parameters such as air temperature (AT), water temperature (WT), pH, conductivity (EC) and transparency (Trans) of water samples were analyzed by using thermometer (Model: Mercury Bulb Thermometer), pH meter (Model: Digital pH Meter MK VI), conductivity meter (Conductivity-TDS Meter 308) and secchi disc, respectively. Dissolved oxygen (DO), Free carbon dioxide (CO_2), Total alkalinity (TA) of water samples were analyzed by standard titrimetric methods (APHA 2005). Nitrate (NO_3), Nitrite (NO_2), Phosphate (PO_4) and Ammonium (NH_4) ions in water samples were analyzed by phenoldisulphonic acid method, Griess-Ilosyay method, Ascorbic Acid-Molybdate method and Colorimetric method respectively, using Spectrophotometer (Helios 3 : Thermo Spectronic) (Michael 1984; APHA 2005). Concentrations of trace elements such as Copper (Cu), Iron (Fe), Chromium (Cr) and Zinc (Zn) in water samples were analyzed by standard methods using Perkin - Elmer 3110 Spectrometer (Abolude *et al.* 2009).

Aquatic insects and indices used

Collected insects were immediately sorted and preserved in 70 % ethyl alcohol. They were later identified using Dewinter advanced stereozoom microscope with the help of standard keys (Bae & Park 1997; Bal & Basu 1994 a,b; Bouchard 2004; Kumar 1973 a,b; Thirumalai 1989, 1994; Westfall & Tennessen 1996; ZSI 2004). Identification was confirmed in the entomological laboratory of Zoological Survey of India. Diversity indices like Shannon diversity, Evenness, Berger-Parker Dominance were calculated using Biodiversity professional version 2 for Windows. *Average Score Per Taxon* (*ASPT*), Stream Invertebrate Grade Number - Average Level (SIGNAL), Trophic Rate Score (TRS) and The Biological Monitoring Working Party (BMWP) Score were determined by standard methods (Chessman 2001, 2003; Hawkes 1998; Jackson 2009).

Table 1. Seasonal variation in physico-chemical parameters as well as concentration of trace elements in the study area (N=3).

Parameters	Post monsoon	Winter	Pre monsoon	Monsoon
	Mean ±S.E.M	Mean ±S.E.M	Mean ±S.E.M	Mean ±S.E.M
AT (°C)	25.33 ±0.34	20.33±0.34	28.67 ±0.32	28±0.29
WT (°C)	23 ±0	20.47±0.03	26.83±1.09	25.33±1.84
pH	6.96 ±0.45	6.89±0.40	6.53±0.04	6.51±0.01
RF (mm)	291.33 ±199.42	4±2.00	186.67±134.08	426.67±78.82
EC (ms ppt^{-1})	3.94 ±0.30	5.92±0.02	8.34±0.18	4.43±0.01
Trans (cm)	22.17 ±2.03	13.08±0.36	6.58±0.46	25.08±1.96
DO (mg l^{-1})	7.33 ±0.24	9.27±0.35	6.8±0.42	6±0.66
FCO_2 (mg l^{-1})	5.99 ±0.57	5.99±2.31	7.66±0.66	8.1±0
TA (mg l^{-1})	10 ±0	12.67±1.77	22.67±1.33	18.3±0
PO_4 (mg l^{-1})	0.56 ±0.05	0.38±0.17	1.76±0.01	1.60±0.02
NO_3 (mg l^{-1})	0.17 ±0.01	0.47±0.03	2.04±0.24	1.14±0.02
NO_2 (mg l^{-1})	0.00 ±0	0.02±0.01	0.10±0	0.11±0
NH_4 (mg l^{-1})	0.13 ±0	0.18±0.02	0.12±0	0.19±0
Cu (mg l^{-1})	0.001 ±0	0.001±0	0	0.002±0
Fe(mg l^{-1})	0.10±0.03	0.33±0.19	1.02±0.06	0.28±0.05
Cr (mg l^{-1})	0.001±0	0.002±0	0	0.001±0
Zn (mg l^{-1})	0.15±0.01	0.06±0.03	0.05±0.01	0.03±0

AT = Air temperature; WT = Water temperature; RF = Rainfall; EC = Transparency; DO = Dissolved oxygen; FCO_2 = Free carbon dioxide; TA = Total alkalinity; PO_4 = Phosphate; NO_3 = Nitrate; NO_2 = Nitrite; NH_4 = Ammonium; Cu = Copper; Fe = Iron; Cr = Chromium; Zn = Zinc.

Table 2 (a). Test of variance (t-test for independent samples) showing level of significance in seasonal variation in physico-chemical parameters.

t-Test (independent sample)						
	t	df	Sig. (2-tailed)	Mean Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
AT (°C)	13.48	3	0.00*	25.53	19.51	31.56
WT(°C)	17.16	3	0.00*	23.86	19.43	28.29
pH	56.62	3	0.00*	6.67	6.30	7.05
RF (mm)	3.93	3	0.03*	16.68	3.19	30.17
EC (ms ppt^{-1})	5.67	3	0.01*	5.61	2.46	8.75
Trans (cm)	3.93	3	0.03*	16.68	3.19	30.17
DO (mg l^{-1})	10.49	3	0.00*	7.30	5.09	9.51
FCO_2 (mg l^{-1})	12.45	3	0.00*	6.89	5.12	8.64
TA (mg l^{-1})	5.58	3	0.01*	15.86	6.82	24.90
PO_4 (mg l^{-1})	2.91	3	0.06	1.03	-0.09	2.15
NO_3 (mg l^{-1})	2.18	3	0.12	0.90	-0.41	2.22
NO_2 (mg l^{-1})	0.27	3	0.81	0.01	-0.08	0.09
NH_4 (mg l^{-1})	5.98	3	0.01*	0.11	0.05	0.16
Cu (mg l^{-1})	-120.03	3	0.00*	-0.05	-0.05	-0.05
Fe (mg l^{-1})	1.89	3	0.16	0.38	-0.26	1.03
Cr (mg l^{-1})	-120.02	3	0.00*	-0.05	-0.05	-0.05
Zn (mg l^{-1})	0.85	3	0.46	0.02	-0.06	0.11

For acronyms see footnote of Table 1.

*Significant at $P < 0.05$.

Table 2 (b). Test of variance (t-test for independent sample) showing level of significance in seasonal variation in physico-chemical parameters .

T-Test (independent sample)						
	t	df	Sig. (2-tailed)	Mean Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
AT (°C)	13.50	3	0.00**	25.57	19.55	31.60
WT (°C)	17.18	3	0.00**	23.90	19.47	28.32
pH	56.96	3	0.00**	6.71	6.34	7.09
RF (mm)	3.94	3	0.03	16.72	3.23	30.21
EC (ms ppt^{-1})	5.71	3	0.01	5.65	2.50	8.79
Trans(cm)	3.94	3	0.03	16.72	3.23	30.20
DO (mg l^{-1})	10.54	3	0.00**	7.34	5.13	9.55
FCO_2 (mg l^{-1})	12.52	3	0.00**	6.93	5.17	8.68
TA (mg l^{-1})	5.60	3	0.01	15.90	6.86	24.94
PO_4 (mg l^{-1})	3.02	3	0.06	1.07	-0.06	2.19
NO_3 (mg l^{-1})	2.28	3	0.11	0.95	-0.37	2.26
NO_2 (mg l^{-1})	1.71	3	0.19	0.05	-0.04	0.14
NH_4 (mg l^{-1})	8.26	3	0.00**	0.15	0.09	0.20
Cu (mg l^{-1})	-22.05	3	0.00**	-0.01	-0.01	-0.01
Fe (mg l^{-1})	2.09	3	0.13	0.42	-0.22	1.07
Cr (mg l^{-1})	-22.05	3	0.00**	-0.01	-0.01	-0.01
Zn (mg l^{-1})	2.35	3	0.10	0.06	-0.02	0.15

For acronyms see footnote of Table 1.

**Significant at $P < 0.01$.

Statistical analyses

Data on physico-chemical parameters were subjected to t-test (independent samples) for tasking the differences among seasonal means. Pearson correlation coefficients among physico-chemical parameters, species richness and density of aquatic insects were also calculated. All statistical analyses were done by using the software SPSS 10.

Results and discussion

Analysis of different physico-chemical parameters (AT, WT, Trans, pH, EC, DO, Free CO_2, TA, PO_4, NO_3, NO_2, NH_4), concentration of trace elements (Cu, Zn, Cr and Fe) in water of the ecosystem during post monsoon 2010 to monsoon 2011 (Table 1) depicted its water quality status. Trace elements play important role in physiology of aquatic organisms and are essential elements for most species (Watanabe *et al*. 1997). Parameters such as temperature, pH, DO, EC, TA, NO_3, NO_2, NH_4 as well as trace elements like Cu, Zn, and Cr content of water samples were found within permissible limit (CPCB website, BIS website, Kumar & Puri 2012). During pre monsoon and monsoon, concentration of PO_4 was found slightly higher than the standard and Fe concentration was found higher in pre monsoon. According to Jacobson (1991), slightly high concentration of PO_4 supports algal growth and indicates moderate level of pollution. Test of variance (t-test for independent samples) for physico-chemical parameters revealed highly ($P < 0.01$) significant seasonal variation in AT, WT, pH, EC, Trans, DO, FCO_2, TA, NH_4, Cu and Cr whereas RF and Trans showed significant variation at $P < 0.05$ only (Table 2a & 2b). We found significant correlations among different physico-chemical parameters, species richness and density of aquatic insects (Table 3). Four aquatic insect orders, Hemiptera, Odonata, Ephemeroptera and Coleoptera, seven families, Notonectidae, Gerridae, Corixidae, Mesoveliidae, Baetidae, Coenagrionidae, and Dytiscidae, eleven species viz. *Rhagodotarsus anomalus, Gerris lepcha, Limnogonus nitidus, Neogerris par-*

Table 3. Significant correlations among physico-chemical parameters, species richness and density of aquatic insects.

Parameters	Correlation	Parameters	Correlation
Species richness Vs. RF	-0.96*	Species richness Vs. DO	0.99*
Density Vs. NO_2	0.97*	Density Vs. FCO_2	0.98*

*Correlation is significant at the 0.05 level (2-tailed).

vula, Enithares fusca, Mesovelia vittigera, Anisops barbata, Micronecta scutellaris, Enallagma cyathigerum, Dytiscus fasciventris and Cloeon sp. occurred in the study site. ASPT, SIGNAL, TRS and BMWP scores for the aquatic ecosystem are shown in Table 4. Dominance status of each of the eleven species reported during each of the four seasons is shown in Table 5 and values of Shannon diversity index, evenness and Berger - Parker index of dominance are depicted in Table 6. Shannon diversity index (Shannon H' $\log_{10}$) values ranged from 0.16 to 0.75 (highest in winter), evenness from 0.27 to 0.83 (highest in winter) and Berger - Parker dominance (d) from 0.37 to 0.92 (lowest in winter). H' value being less than 1 (0.16 - 0.75) in each of the four seasons indicated perturbed nature of the ecosystem (Turkmen & Kazanci 2010). Although presence of insect order Ephemeroptera, which is included in the EPT (Ephemeroptera, Plecoptera and Trichoptera) i.e. sensitive group of insects, is an indication of good water quality (Rosenberg & Resh 1993); the family Baetidae and, particularly, the genus *Cloeon* of this order are known to survive in moderately polluted water (Alba - Tercedor *et al.* 1991). In the present study highest densities of aquatic insects were recorded during monsoon (Fig. 2). A clear picture of seasonal variation was observed in the relative abundance of aquatic insect order, family and species (Figs. 3, 4 & 5). During the post monsoon, winter and pre monsoon, the order Hemiptera showed the highest relative abundance, whereas during the monsoon the order Coleoptera showed the highest relative abundance. Although highest numbers of aquatic insect families were reported during pre monsoon, the highest numbers of aquatic insect species were recorded during winter. In this season, water gets confined to a particular area, and the entire water body is more stable with macrophytes and aquatic vegetation. This may at least partially explain the taxon richness. According to Engelmann Scale (1973), *Micronecta scutellaris* (Family Corixidae) was eudominant during winter (37.29 %) and pre-monsoon (40.22 %), *Mesovelia vittigera* (Family Mesoveliidae) was eudominant (50.00 %) during post monsoon while *Dytiscus fasciventris* (Family Dytiscidae) was eudominant (91.94 %) during monsoon. Semi-aquatic Mesoveliid bugs occur in well vegetated stagnant water such as permanent and temporary ponds with water lilies or in billabongs and pools in river beds with algal growth (MDFRC Website). Ecological relationships between macrophytes and insects are reciprocal and manifold. Hydrophytes provide anchorage, natural hiding places, protection from rapid disturbances of water, provide more oxygen and afford suitable sprawling niche (Bisht & Das 1979; Pandit *et al.* 1985).

Table 4. ASPT, SIGNAL, TRS and BMWP scores of the study site.

ASPT score	BMWP score	TRS	SIGNAL
5	35	7.75	2.58

ASPT = Average Score Per Taxon; BMWP = Biological Monitoring Working Party Score; TRS = Trophic Rate Score; SIGNAL = Stream Invertebrate Grade Number - Average Level.

Cloeon sp. belonging to the family Baetidae, order Ephemeroptera was recorded only in pre monsoon and was found eudominant (39.13 %). This might be because of their preference for mild movement of water and their short developmental life cycle (Nakanwe 2009). Absence of *Dytiscus fasciventris* (Family: Dytiscidae) during post monsoon and winter and their eudominance (91.94 %) during monsoon indicated that they preferred high spate conditions. Nakanwe (2009) suggested that alternating periods of flooding and drought could affect Dytiscid populations. Presence of one eudominant, two dominant, four subdominant and one recedent species in winter (Table 5) as revealed by Engelmann Scale (Engelmann 1973), indicated more or less even distribution of species

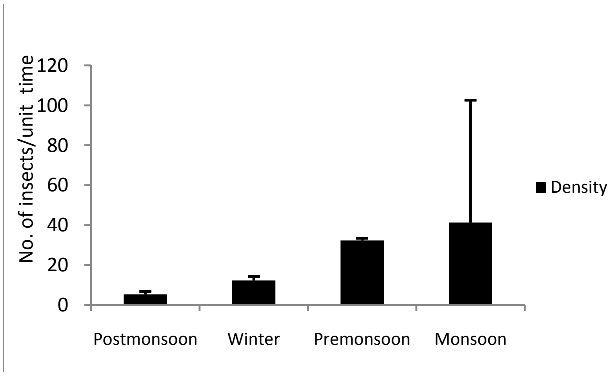

Fig. 2. Seasonal variation in density of aquatic insects (no . of insects per minute per season) in Monabeel.

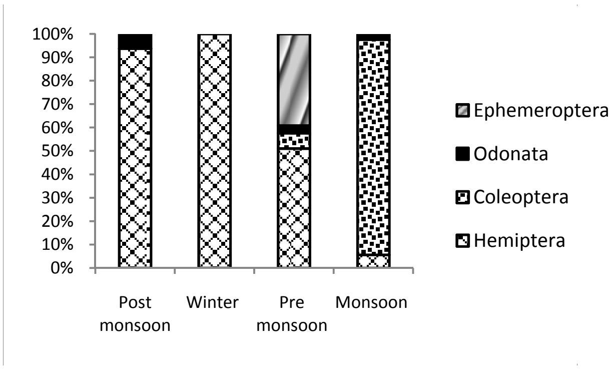

Fig. 3. Relative abundance of aquatic insect orders in Monabeel.

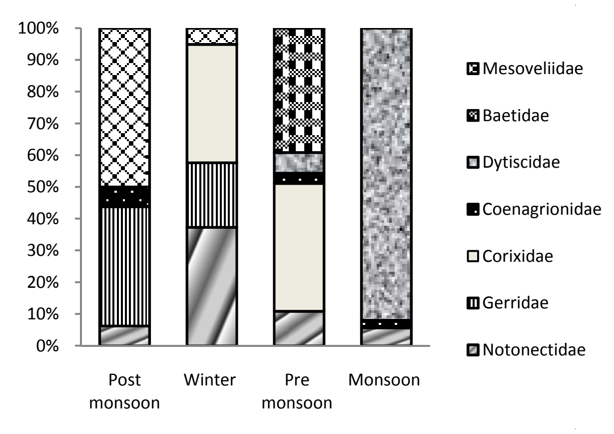

Fig. 4. Relative abundance of aquatic insect families in Monabeel.

during that season. This is supported by the highest evenness (Shannon J, 0.827) during winter. Highest relative abundance or eudominance of *Dytiscus fasciventris* during monsoon is supported by highest Berger Parker Dominance in the same season. Among all the species only *Anisops barbata* (Family Notonectidae) of order Hemiptera was recorded during all seasons. A significant positive correlation of species richness with DO is in agreement with the fact that the water bodies with consistently high levels of dissolved oxygen are usually considered healthy and stable ecosystems, capable of supporting diverse forms of aquatic life (Popoola & Otalekor 2011). Significant negative correlation of species richness with RF could be attributed to the fact that during monsoon the system became linked with all the inlets of Chatla floodplain lake which brought in pollutants from the surrounding areas such as tea gardens, agricultural fields, etc. thus rendering the system unsuitable for many aquatic insects. Brewin *et al.* (2000) proposed that flooding reduces abundance and taxon richness of macroinvertebrates and causes condition-dependent alterations to community structure. Another reason might be that the input of large volume of water causes destruction of aquatic insect habitats and their functional organization (Nicole *et al.* 2004; Snyder & Johnson 2006).

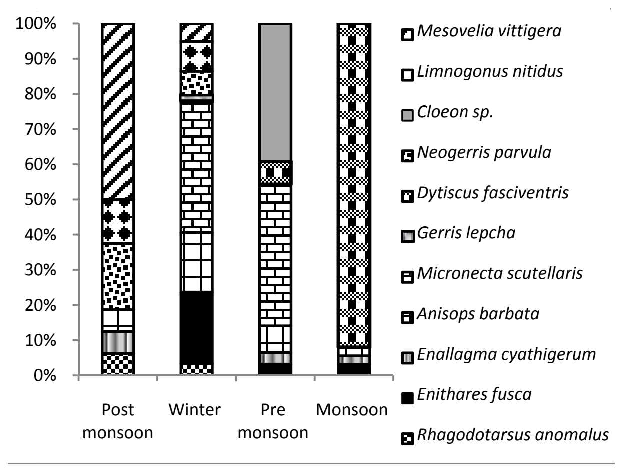

Fig. 5. Relative abundance of aquatic insect species in Monabeel.

Fishing practices, such as the use of fine mesh nets as was observed in the study area also has negative impact on diversity. However, highest density of aquatic insects found in the present study during the seasons of high rainfall confirms the fact that each species of aquatic insect responds differently to disturbance as evidenced by the highest relative abundance of *Dytiscus fasciventris* in monsoon. Moreover, it is known that species capable of withstanding extreme condition

Table 5. Dominance status of aquatic insects recorded from the study site according to Engelmann's Scale

Species	Post monsoon		Winter		Pre Monsoon		Monsoon	
	Relative abundance (%)	Status of Dominance	Relative abundance (%)	Status of Dominance	Relative abundance (%)	Status of Dominance	Relative abundance (%)	Status of Dominance
Rhagodotarsus anomalus	6.25	Sub-dominant	3.39	Sub-dominant	-	-	-	-
Enithares fusca	-	-	20.34	Dominant	3.26	Sub-dominant	3.23	Sub-dominant
Enallagma cyathigerum	6.25	Sub-dominant	0	-	3.26	Sub-dominant	2.42	Recedent
Anisops barbata	6.25	Sub-dominant	16.95	Dominant	7.61	Sub-dominant	2.42	Recedent
Micronecta scutellaris	-	-	37.29	Eu-dominant	40.22	Eu-dominant	-	-
Gerris lepcha	-	-	1.69	Recedent	-	-	-	-
Dytiscus fasciventris	-	-	0	-	6.52	Sub-dominant	91.94	Eu-dominant
Neogerris parvula	18.75	Dominant	6.78	Sub - dominant	-	-	-	-
Cloeon sp.	-	-	-	-	39.13	Eu-dominant	-	-
Limnogonus nitidus	12.50	Dominant	8.47	Sub-dominant	-	-	-	-
Mesovelia vittigera	50.00	Eu-dominant	5.08	Sub-dominant	-	-	-	-

Relative abundance <1 = Subrecedent; 1.1-3.1 = Recedent; 3.2-10 % Subdominant; 10.1-31.6 = Dominant and >31.7 % = Eudominant

Table 6. Seasonal variation in Shannon diversity , Evenness and Berger-Parker dominance index values for aquatic insects recorded from the study site

Index	Post monsoon	Winter	Pre monsoon	Monsoon
Berger-Parker Dominance (d)	0.50	0.37	0.40	0.92
Shannon H' Log Base 10	0.63	0.75	0.58	0.16
Evenness Index (Shannon J')	0.80	0.83	0.74	0.27

like flood or drought reproduce well (Hendricks *et al.* 1995). The significant positive correlation of density of aquatic insects with free CO_2 and NO_2 could be attributed to the fact that free CO_2 in water is mostly from respiration of aquatic organisms (Dhakal 2006). Furthermore NH_4, NO_2 and NO_3 are the most common forms of dissolved inorganic nitrogen in aquatic ecosystems (Wetzel 2001; Rabalais 2002) playing an important role in net primary production (Wetzel 2001; Dodds *et al.* 2002) and in turn the secondary production. An ASPT score greater or equal to the value of 4.5 indicate a good ecological potential of water body (AWBS 2008). In this study, computation of ASPT score revealed that the study site has good ecological potential (GEP). BMWP score calculated from the study site reported a value of 35 (Table 4). BMWP score within the range of 11 - 40 indicates impacted nature of water bodies (Bartram & Balance 1996). This condition of water body is also supported by the Shannon $H^{/}$ values < 1. Shannon $H^{/}$ values < 1 indicate perturbed nature of the system (Turkmen & Kazanci 2010). SIGNAL value of the system was recorded as 2.58. SIGNAL values of less than 5.5 in lotic systems suggest pollution (Chessman 2001). Some of the macroinvertebrate orders that have the highest SIGNAL sensitivity grades are naturally rare in wetlands, for example stoneflies and, to a lesser extent, mayflies and caddis flies. Therefore, wetlands are likely to have naturally lower scores than streams in the same region (Chessman 2003). In the present study the SIGNAL score is much lower indicating moderately polluted nature of water. The mesotrophic nature of the water body is also supported by the TRS value (7.75) (Palmer & Roy 2001). Trophic Ranking Scores (TRS) are numerical expressions of the DOME codes. DOME codes reflect the occurrence of plants in the various site types and give a measure of the strength of the association. Macrophytes confined to nutrient-poor waters have low TRS scores (3.0 - 4.0), those confined to eutrophic waters have high scores (8.5 - 10.0), whilst plants characteristic of mesotrophic conditions or with a wide tolerance of trophic states have intermediate scores (Palmer & Roy 2001).

Conclusions

This study revealed that Monabeel is a mesotrophic system, as supported by the values of biological indices and scores which indicated perturbed and moderately polluted nature of the water body. Higher concentration (beyond the permissible limit) of PO_4 during pre- monsoon and monsoon and of Fe during pre monsoon indicated that the input of nutrients during connectivity might be an important fuel for mesotrophic nature of the system. These results present a first view of aquatic insect diversity in this dynamic system. It is therefore necessary that a more intensive sampling campaign is put in place in order to draw more concrete conclusions because floodplains are dynamic ecosystems where nutrient transformations occur within a very short period.

Acknowledgements

Authors are thankful to University Grants Commission, New Delhi, for financial support through Major Research Project. Authors are also thankful to the Head, Dept. of Ecology and Environmental Science for providing laboratory facilities.

References

Abolude, D. S., O. A. Davies & A. M. Chia. 2009. Distribution and concentration of trace elements in Kubanni reservoir in northern Nigeria. *Research Journal of Environmental and Earth Sciences* **1**: 39-44.

Alba-Tercedor, J., C. Zamora-Munoz, A. Sanchez- Ortega & I. Guisasola. 1991. Mayflies and stone flies from the RioMonachil (Sierra, Nevada Spain) (Ephemeroptera and Plecoptera). pp. 529-538. *In*: J. Alba-Tercedor & A. Sanchez Ortega (eds.) *Overview and Strategies of Ephemeroptera and Plecoptera*. Sand-Hill Crane Press Inc.

APHA. 2005. *Standard Methods for the Examination of Water and Wastewater*. 19th edn. American Public Health Association, 1015, Fifteen Street, NW Washington, D.C. 20 R.C.0015.

Arimoro, F. O. & R. B. Ikomi. 2008. Ecological integrity of upper Warri River, Niger Delta using aquatic insects as bioindicators. *Ecological Indicators* **395**: 1-7.

AWBS. 2008. *Interim Report on Ecological Classification for Ireland's AWBs 2*. The Surface Water Status Group, Ireland.

Bae, Y. J. & S. Y. Park. 1997. Taxonomy of Cloeon and Procloeon (Ephemeroptera: Baetidae) in Korea. *Korean Journal of Systematic Zoology* **13**: 303-314.

Bartram, J. & R. Balance. 1996. *Water Quality Monitoring*. UNEP and WHOE and FN Spon. London, UK.

Bal, A. & R. C. Basu. 1994. Insecta: Hemiptera: Mesovellidae, Hydrometridae, Veliidae and Gerridae. *State Fauna Series 5*: *Fauna of West Bengal, India* 511-534.

Bhuiyan, J. R. & S. Gupta. 2007. A comparative hydrobiological study of a few ponds of Barak valley, Assam, and their role as sustainable water resources. *Journal of Environmental Biology* **28**: 799-802.

BIS (Bureau of Indian Standards) http://www.bis.org.in/

Bisht, R. S. & S. M. Das. 1979. Aquatic insects in relation to coldwater fisheries of Kumaon lakes. *Environment India* **2**: 49-50.

Bouchard, R. W. Jr. 2004. *Guide to Aquatic Macroinvertebrates of the Upper Midwest*. Water Resources Center, University of Minnesota, St. Paul, MN.

Brewin, P. A., S. T. Buckton & S. J. Ormerod. 2000. The seasonal dynamics and persistence of stream macroinvertebrates in Nepal: do monsoon floods represent disturbance? *Freshwater Biology* **44**: 581-594.

Brittain, J. E. 1974. Studies on the lentic Ephemeroptera and Plecoptera of Southern Norway. *Norsk Entomologisk Tidsskrif* **21**: 135-151.

Chessman, B. 2001. *SIGNAL 2: A Scoring System for Macro-Invertebrates ('Water Bugs') in Australian Rivers User Manual.* Department of the Environment Heritage, Commonwealth of Australia.

Chessman B. 2003. *SIGNAL 2-A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers. Monitoring River Heath Initiative Technical Report No. 31.* Commonwealth of Australia, Canberra.

CPCB (Central Pollution Control Board): Water quality criteria http://cpcb.nic.in/Water_Quality_Criteria.php

Das, D. J. 2002. *Ecological Studies and Assessment of Capture Fishery Potential in Chatla Floodplain Wetland, Cachar, Assam.* M.Phil. Thesis. Assam University, Silchar, Assam.

Das, K. & S. Gupta. 2010. Aquatic Hemiptera community of agricultural and rain pools in Cachar district, Assam, Northeast India. *Assam University Journal of Science and Technology: Biological and Environmental Sciences* **6**: 123-128.

Das, K. & S. Gupta. 2012. Seasonal variation of Hemiptera community of a temple pond of Cachar District, Assam, northeastern India. *Journal of Threatened Taxa* **4**: 3050-3058.

Das, P., S. Joshi, J. Rout & D. K. Upreti. 2013. Impact of anthropogenic factors on abundance variability among lichen species in southern Assam, north east India. *Tropical Ecology* **54**: 67-72.

Das, T. 2001. *A Study on the Limnology and Capture Fisheries of River Barak, Assam.* M.Phil. Thesis, Assam University, Silchar.

Dhakal, S. 2006. *Study on Physiochemical Parameters and Benthic Macroinvertibrates of Balkhu Khola in Kathmandu Valley, Central Nepal.* Management of Water, Wastewater and Environment: Challenges for the Developing Countries, Kathmandu.

Dodds, W. K., V. H. Smith & K. Lohman. 2002. Nitrogen and phosphorus relationships to benthic algal biomass in temperate streams. *Canadian Journal of Fisheries and Aquatic Sciences* **59**: 865-874.

Duttagupta, S., S. Gupta & A. Gupta. 2004. Euglenoid blooms in the floodplain wetlands in Barak Valley, Assam, Northeastern India. *Journal of Environmental Biology* **25**: 369-373.

Engelmann, H. D. 1973. *Untersuchungen zur Erfassung Predozoogener Komponenten im Definierten, Okosystem*. Forschungsergebnisse Staatliche Museum Naturkunde, Gorlitz.

Hawkes, H. A. 1998. Origin and development of the biological monitoring working party score system. *Water Research* **32**: 964-968.

Hendricks, A. C., L. D. Willis & C. D. Snyder.1995. Impact of flooding on the densities of selected aquatic insects. *Hydrobiologia* **299**: 241-247.

Jackson, R. 2009. *Ecological Survey of Ponds on Sites Belonging to Northumbrian Water Limited.* Tees Valley Wildlife Trust.

Jacobson, C.1991. *Water, Water Everywhere: Water Quality Factors.* Reference Unit, 2nd edn., Hach Co., Loveland.

James, E. J. 1995. Managing the wetlands and their watersheds. *Yojana* **1**: 43-50.

Kumar, A. 1973a. Description of the last instar larvae of Odonata from Dehra Dun Valley (India) with notes on biology. I. Suborder Zygoptera. *Oriental Insects* **7**: 83-118.

Kumar, A.1973b. Description of the last instar larvae of Odonata from Dehra Dun Valley (India) with notes on biology. II. Suborder Anisoptera. *Oriental Insects* **7**: 291-331.

Kumar, M. & A. Puri. 2012. A review of permissible limits of drinking water. *Indian Journal of Occupational and Environmental Medicine* **16**: 40-44.

Laskar, H. S. & S. Gupta. 2009. Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, North East India - A seasonal study. *Journal of Environmental Biology* **30**: 1007-1012.

Merritt, R. W. & K. W. Cummins. 1996. *An Introduction to the Aquatic Insects of North America.* 3rd edn. Kendall Hunt Publishing Co., Debuque, IA.

MDFRC (Identification and ecology of Australian invertebrates: Mesoveliidae) http://www.mdfrc.org.au/bugguide)

Michael, P. 1984. *Ecological Methods for Field and Laboratory Investigations.* Tata Mc. Graw-Hill Publishing Company Ltd. New Delhi .

Nakanwe, S. N. 2009. *Developing a Monitoring Framework for the Aquatic Flora and Fauna of the Ishana Sub-basin in the Cuvelai Basin.* Internal Report file no 20/12/2/8/4, Water Environment Division, Department of Water Affairs and Forestry, Ministry of Agriculture, Water and Rural Development, Windhoek.

Nicole, K. M., W. H. Clements, L. S. Guevara & B. F. Jacobs. 2004. Resistance and resilience of stream insect communities to repeated hydrologic disturbances after a wildfire. *Freshwater Biology* **49**: 1243-1259.

Palmer, M. A. & D. B. Roy. 2001. *An Estimate of the Extent of Dystrophic, Oligotrophic, Mesotrophic and Eutrophic Standing Fresh Water in Great Britain.* JNCC Report No. 317, Peterborough.

Pandit, A. K., S. N Pandit & V. Kaul. 1985. Ecological relation between invertebrates and submerged macrophytes in two Himalayan lakes. *Pollution*

Research **4**: 53-58.

Pennak, R. W. 1978. *Fresh Water Invertebrates of the United States.* John Wiley and Sons, New York.

Popoola, K. O. K. & A. Otalekor. 2011. Analysis of aquatic insects' communities of awba reservoir and its physico-chemical properties. *Research Journal of Environmental and Earth Sciences* **3**: 422-428.

Purkayastha, P. & S. Gupta. 2011. Ecology of a few shallow ponds of Chatla floodplain with special referece to aquatic insect community. *Assam University Journal of Science and Technology: Biological and Environmental Sciences* **8**: 48-55.

Purkayastha, P. & S. Gupta. 2012. Insect diversity and water quality parameters in two ponds of Chatla wetland, Barak valley, Assam. *Current World Environment* **7**: 243-250.

Rabalais, N. N. 2002. Nitrogen in aquatic systems. *Ambio* **31**: 102-112.

Rosenberg, D. M. & V. H. Resh. 1993. *Freshwater Biomonitoring and Benthic Invertebrates.* New York, Chapman and Hall.

Sharma, B. K. 2011. Zooplankton communities of Deepor Beel (a Ramsar site), Assam (N. E. India): ecology, richness, and abundance. *Tropical Ecology* **52**: 293-302.

Snyder, C. D. & Z. B. Johnson. 2006. Macroinvertebrate assemblage recovery following a catastrophic flood and debris flows in an Appalachian mountain stream. *Journal of the North American Benthological Society* **25**: 825-840.

Subramanian, K. A. & K. G. Sivaramakrishnan. 2007. *Aquatic Insects for Biomonitoring Fresh Water Ecosystems: A Methodology Manual.* Trust for Ecology and Environment (ATREE), Bangalore, India.

Thirumalai, G. 1989. *Aquatic and Semi Aquatic Hemiptera (Insecta) of Javadi Hills, Tamilnadu.* Zoological Survey of India **18**: 1-63.

Thirumalai, G. 1994. *Aquatic and Semi Aquatic Hemiptera (Insecta) of Tamilnadu-1, Dharampuri and Pudukkatai Districts.* Zoological Survey India **165**: 1-45.

Turkmen, G. & N. Kazanci. 2010. Applications of various biodiversity indices to benthic macroinvertebrate assemblages in streams of a national park in Turkey. *Review of Hydrobiology* **3:** 111-125.

Watanabe, T., V. Kiron & S. Satoh. 1997. Trace minerals in fish nutrition. *Aquaculture* **151**: 185-207.

Westfall M. J. Jr. & K. J. Tennessen. 1996. Odonata. pp. 164-169 *In*: R. W. Merritt & K. W. Cummins (eds.) *An Introduction to the Aquatic Insects of North America, Dubuque* . Kendall Hunt Publishing, IA3.

Wetzel, R. G. 2001. *Limnology of Lake and River Ecosystems.* 3rd edn. Academic Press, San Diego, CA. 1006.

WWF. 2006. *Living Planet Report.* Global Footprint Network.

ZSI. 2004. *State Fauna Series 10: Fauna of Manipur (Part-2)-Insects.* Zoological Survey of India, Kolkata, India.

(Received on 20.02.2013 and accepted after revisions, on 13.10.2013)