INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 9, No. 4, p. 286-298, 2016
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Seasonal and annual variation of aquatic beetles abundance in different wetlands of Manipur

M. Bhubaneshwari Devi*, O. Sandhyarani Devi, Leiphon Wanghengbam

Department of Zoology, D. M. College of Science, Imphal, Manipur, India

Article published on October 30, 2016

Key words: Seasonal, Wetland, Abundance, Aquatic beetles, Manipur, India

Abstract

The studies aimed to record the seasonal influence in occurrence and abundance of aquatic beetles (Order-Coleoptera) in different wetlands of Manipur. The wetlands were visited monthly from September 2007 to August 2008 to sample aquatic insects using D-pond nets. The research was conducted at 9 wetlands in 9 districts of Manipur during pre-monsoon (March to May) 2015, monsoon (June to August) 2015, Post monsoon (September to November 2015) and winter (December to February) 2015- 2016. The data on the physical factors of each location sites were recorded at the time of collection of water beetles. A total of 55 water beetles species were recorded belonging to order Coleoptera under 11 families viz. Dytiscidae, Noteridae, Hydrophilidae Curculionidae, Hydrochidae, Haliplidae, Staphylinidae, Scirtidae, Dryopidae and Hydraneidae during the study period.

***Corresponding Author:** M. Bhubaneshwari Devi ✉ mbhubaneshwari@yahoo.com

Introduction

The wetlands of Manipur are supposed to represent the least disturbed environments in the India due to their remote location with relatively low industrialization and direct human impacts. Manipur, typically, observes moderate climate throughout the year. Depending upon the altitude, the climate ranges from tropical to temperate. Though the state enjoys all the four seasons of summers, winters, monsoons and post monsoon; precipitation dominates the valley for most of the year. Summers prevail from the month of March till May, when temperature reaches to the max of 32°C. It is never too hot in Manipur. Monsoons formally arrive in the month of June and drench the state with heavy rain showers up to September. Manipur receives an annual rainfall of 1500mm. The months of post monsoon (October and November), more or less, remain dry. The winter season extends from December to February, when the temperature usually drops down to 0°C. The unpredictable monsoon and seasonal rainfall affects the diversity and abundance of aquatic beetles in Manipur.

The rainfalls dictated many features of the wetland and play major role in changes of the benthic community (Robinson & Minshall, 1986). Rainfall varies with an annual seasons to some extent the quantity of rainfall which enters the streams is extremely variable (Hynes, 1970). Rainfall in mountainous regions can increase water flow in lotic environments (Oliveira & Froehlich, 1997). At the advent of the rains, headwater streams respond rapidly and can change from quiet, trickling streams to torrents in an hour or two (Payne, 1986). During the periods of high water, the invertebrate fauna in streams tend to be low (Dudgeon, 2008).

Aquatic beetles possess a range of attributes needed for the evaluation of the conservation status of wetlands. Beetles occupy the complete range of wetland habitat from headwater, where they can be dominant life form, to sub marshes and coastal area of the lakes. They are non-specialist predators confined to special habitat more by their size, shape and swimming ability than by association with particular food plants or prey. Among the macroinvertebrates, water beetles are often suggested as bio-indicators of habitat quality and are used for selecting areas for conservation and management of freshwater habitats (Painter, 1999, Oertli *et al.*, 2005, Sanchez-Fernandez *et al.*, 2006). Due to their ecological demands and physiological features (feeding, microhabitat preferences, body size, flying capacity, etc.), many species are sensitive to changes in environmental conditions (Hebauer 1986, Fairchild *et al.*, 2000, 2003), resulting in rapid changes in their assemblages. They occur in most aquatic habitats in considerable abundance compared to other macroinvertebrate taxa (Ribera and Foster, 1992), and the group is taxonomically well-known.

The importance of seasonal dynamics of water beetles has been highlighted by several authors (Bosi, 2001, Fairchild *et al.*, 2003); thus we evaluated seasonal dynamics of beetle assemblages in view of the important role played by the water beetles in the ecosystem.

In this study we selected 9 different wetlands in 9 districts of Manipur. The wetlands with vegetation of aquatic plants had a positive effect on the abundance and diversity of aquatic beetle assemblages due to enhanced plant colonization and the association of aquatic beetles with the presence of aquatic vegetation. In addition, we investigated the hypothesis that seasonal differences between the wetland treatment types were also important due to the phenology of aquatic beetles.

Temporary and permanent standing waters represent the most important habitats for aquatic beetles groups. Today the diversity assessment and preparation of the water beetles inventories are considered as essential task due to the importance of wetland in the conservation planning and endeavors. In view of the important role played by the water beetles in the ecosystem, the present work was conducted to determine the occurrence, seasonal influence in the diversity,

abundance and species composition of aquatic beetles in the 9 different wetlands of Manipur, North-Eastern part of India. This study would be very helpful in the temporal variability of beetles' community and needs consideration in order to establish reliable conservation programs.

Materials and methods

Study area and Sampling Sites

Manipur is a small state in the North-Easternmost part of India. It lies between 23°83'N-25°68' N; 93°03'E-94° 78'E.The state comprises of nine districts, five in the hills and four in the valley. From the 9 districts of Manipur 9 collection sites were selected as sampling sites for collection of water beetles.

The geographical data for the study sites selected were comprised of wetlands and some lentic locations with their respective typical habitat illustrated for each site was given in. The geo-coordinates profiles of the 9 different sites of Manipur were provided herein (Table 1). The geographical coordinates were noted using a GPS recorder.

Table 1. Description of the 9 collection sites of 9 districts of Manipur.

Code	Location of collection sites	Substrate type
LL 1	Porompat/Imphal East	Yellow to red sandy loams more depths with some aquatic plants
LL 2	Lamphelpat/Imphal West	Yellow to red sandy loams more depths with some aquatic plants
LL 3	Lousipat/Thoubal	Yellow to red sandy loams more depths with some aquatic plants
LL 4	Loktak Lake, Bishnupur	Sandy, silt and clay with some aquatic plants
LL 5	Leimaram/Senapati	Poor sand, silt clay and some aquatic plants
LL 6	Thawai village/Ukhrul	Poor sand, silt, clay, some aquatic plants
LL 7	Noney/Tamenglong/Senapati	Poor sand, silt, clay, some aquatic plants
LL 8	Moreh/Chandel	Sand, silt, clay. Some aquatic plants.
LL 9	Sagang and Tuibong/Churachanpur	Sand, silt, clay. Some aquatic plants.

Weather data

The climate of the state varies with its land elevations. Normally the weather of plain is similar to the other state of India but the regions of hilly area receive a low temperature and dry weather in winter season. The weather characters of Manipur mainly depend on the wind flows of Bay of Bengal and it produces a heavy rainfall during the monsoon season. The climate season of the state can be divided into four divisions namely, summer, winter and monsoon and post monsoon.

Weather in summer**:** Normally the summer season of Manipur is continued from mid of March to May. The average temperature during this season is 28°C. Weather in winter**:** Normally the winter season of Manipur is continued from December to February and the average temperature during this season is about 8°C. But some region of hilly areas temperature drops in freezing point.

Weather in monsoon**:** Normally the monsoon season of Manipur is continued from June to August and the average annual rainfall of the state is approximately 147 cm.

Weather in post monsoon: Normally this season is in transition between the monsoon and winter season and continued from September to November.

Aquatic insect sampling and identification

Aquatic beetles were collected from the 9 collection sites through an extensive survey during January 2015 to August 2016 for one hour at each site to standardize sampling effort per site. The insects were collected using D-Frame net, Pond net, Kicking net as well as triangular dip net and circular net with a mesh size of 0.5mm and dragged around the vegetation for one minute and such three drags constituted a sample. The number of individual was noted down. The large sized insects were captured using bottle traps in horizontal position and also vertical position. After two days the bottle traps were removed and trapped insects were preserved in 70% alcohol and brought back to the laboratory of Entomology, P.G. Department of Zoology, D.M. College of Science, Imphal and identified with the help of standard identification manuals and published literature **(**Andersen *et al.*, 2004; Bal *et al.* 1994a, b; Bouchard, 2004; Epler, 2010; Westfall *et al.*, 1996).

Identification of adults and immature stages was done using Smith & Smith (2003), Subramanian & Sivaramakrishnan (2007). A number of identified insects were confirmed in the division of Entomology, IARI, Pusa, New Delhi.

The illustrations and photographs were based on the examination of the material collected in this study. Male genitalia were removed from specimens that were first relaxed in lightly boiling water for 10 minute. An insect pin with a bent apex was inserted into the abdominal cavity to hook the base of the genital capsule. The entire capsule was then removed from the abdomen and placed in alcohol to dissect and examine. Male genitalia were then glued to a point and placed on the pin beneath the specimen.

Data Analysis

Data collected from the study were tested for normality. Data which failed normality were not used for further analysis.

Species diversity (Shannon- Weiner index), component of dominance (Simpson dominance index) and Berger-Parker dominance were determined for each site. Comparison in species composition between different sites was estimated using single linkage cluster based on Bray-Curtis similarity. Species recorded in this study were ranked on the basis of relative abundance of individual species. Data of species richness counts of one year from the five sites were pooled to get rarefaction curves for comparison of estimated species richness between the sites. Biodiversity Pro version 2 was used to determine diversity indices, cluster analysis, rarefaction curves, species richness estimates and also used for rank abundance diagram. Pearson Correlation coefficient (r) was used to determine the interdependence of the parameters where seasonal changes were correlated with themselves and abundance of insect species (Table 2).

Table 2. Pearson's correlation values between the four season at nine different sites of Manipur.

	Post Monsoon	Winter	Summer	Monsoon
Post Monsoon	1.	*	*	*
Winter	0.7636	1.	*	*
Summer	0.845	0.7672	1.	*
Monsoon	0.5428	0.5092	0.5526	1.

Results

Survey of aquatic beetles from the identified sites

During the study period from the 9 different collection sites in 9 Districts of Manipur 55 water beetles species were recorded belonging to order Coleoptera.

Among these species, 25 species belonging to family Dytiscidae, 18 species belonging to family Hydrophilidae, 3 species belonging to family Noteridae, 2 species belonging to family Haliplidae and 1 species each belonging to family Hydraneidae, Curculionidae, Hydrochidae, and Chrysomelidae, Dryopidae, Staphylinidae respectively. Out of 55 species, 19 species were reported as new record from Manipur. 7 species from the family Hydrophilidae, viz, *Amphiops mirabilis, Laccobius* sp., *Tropisternus* sp., *Helochares atropiceus, Enochrus nigropiceu, *Chasmogenus abnormalis, Paracymus* sp., 5 species from the family Dytiscidae viz, *Leiodytes nicobaricus, Hydruvatus acuminatus, Hydrovatus bonvoulouri, Copelatus irinus*, *Graphodesus* sp. 2 species from Noteridae viz, *Neohydrocoptus subvittulus, Hydrocanthus guinuoti*,. 1 species each from Dryopidae, Scirtidae, Staphylinidae Hydraneidae, Curculionidae and Chrysomelidae, viz, *Elmomophes brevicornis, Scitid, Paedrus, Hydraena*, *Notiode* sp. and *Donacia* spp. respectively were reported for the first time from the Manipur. Out of this nineteen new record from Manipur 6 species i,e *Elmomophes brevicornis, Enochrus nigropiceus, Helochares atropiceus, Chasmogenus abnormalis, Paracymus* sp. *and Hydrocanthus guinuoti* were reported as first record from India and list of species and seasonal abundance of aquatic beetles recorded in different in each month were noted in (Table 3).

Table 3. List of species and seasonal abundance of aquatic beetles recorded in different sites of Manipur.

i. Dytiscidae	Species	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug
	Cybister sugillatus	1	1	2	2	3	2	2	2	1	1	2	1
	Cybister tripunctatus	2	1	2	3	2	3	3	2	1	2	2	1
	Leiodytes nicobaricus	8	3	2	16	15	12	9	4	3	5	6	7
	Laccophilus purvulus	16	5	2	20	10	13	6	8	2	3	4	2
	Laccophilus flexuosus	14	6	3	10	12	9	5	4	3	1	2	2
	Laccophilus chinensis	3	4	2	25	8	5	3	3	2	2	5	4
	Laccophilus anticatus	2	3	1	13	10	4	2	1	3	1	2	1
	Laccophilus sp.1	3	1	1	3	2	2	2	1	2	2	1	2
	Laccophilus sp.2	4	2	1	2	3	4	1	1	3	1	2	1
	Laccophilus sp.3	5	1	0	4	10	7	2	2	1	3	2	1
	Hydroglyphus flammulatus	15	10	9	14	10	15	10	14	13	2	2	4
	Dytiscus sp.	0	0	0	2	1	3	1	0	2	1	0	1
	Hydroglyphus inconstans	5	3	2	12	11	12	9	10	6	3	2	2
	Copelatus sp.1	0	0	0	1	0	0	2	4	1	0	0	0
	Copelatus sp.2	0	0	1	5	2	3	2	1	1	3	1	0
	Copelatus sp.3	2	3	2	7	4	1	0	0	0	1	2	1
	Hydrovatus acuminatus	25	10	13	15	18	13	15	7	5	3	4	5
	Hydrovatus bonvouloiri	20	13	5	20	8	6	10	9	6	5	2	1
	Rhantus suturalis	10	8	2	12	10	5	5	4	1	1	2	1
	Graphodesus sp.	5	5	8	13	15	8	3	4	1	3	2	1
	Hydaticus satoi	3	1	0	7	2	1	1	2	1	2	2	1
	Hydaticus sp.	0	0	0	0	0	0	3	2	1	1	0	0
	Hyphydrus birmanicus	0	0	0	12	0	0	0	0	0	3	2	1
	Agabus amoenus sinuaticolis	0	2	1	1	1	2	1	0	0	0	0	1
ii. Noteridae	*Hydrocanthus guignoti*	30	20	10	40	18	20	13	21	15	13	8	6
	Neohydrocoptus subvittulus	15	7	2	16	5	8	3	2	1	4	2	1
	Canthydrus incosistant	2	1	1	3	10	4	1	2	1	2	1	2
iii. Hydrophilidae	**Tropisternus sp.*	5	2	4	10	16	12	1	2	3	1	1	2
	Laccobius sp.	0	0	0	1	0	0	0	0	0	0	0	0
	Hydrophilus olivaceous	1	2	1	2	4	1	2	1	4	1	2	1
	Regimbartia attenuata	4	5	3	4	5	8	2	1	1	2	1	1
	Amphiops sp.	10	3	6	5	3	2	1	2	1	1	2	4
	Amphiops mirabilis	3	1	2	2	2	1	1	2	1	0	0	1
	Coelostoma stultum	0	1	2	5	3	2	1	2	1	1	2	4
	Helochares anchoralis	5	2	3	17	10	12	5	5	4	2	2	1
	Helochares crenatus	7	8	4	5	7	4	5	4	3	2	1	5
	Helochares atropiceus	5	6	4	18	8	10	8	7	6	3	5	2
	Enochrus esuriens	10	5	3	30	16	13	5	6	2	1	2	2
	Berosus indicus	3	2	1	3	2	1	1	2	1	1	0	1
	Berosus pulchellus	5	2	1	1	2	5	4	2	1	1	2	1
	Enochrus nigropiceus	8	4	3	13	8	4	3	2	1	1	1	0
	Enochrus sp.	0	0	0	1	0	0	0	0	0	0	0	0
	Paracymus sp.	1	3	2	5	22	3	2	1	3	0	0	0
	**Chasmogenus abnormalis*	1	3	2	5	2	2	3	2	1	3	0	0
	Cercyon sp.	2	2	1	3	3	2	2	3		0	2	0
iv. Chrysomelidae	*Donacia* sp.	1	3	2	2	1	8	1	2	8	4	3	1
v. Curculionidae	*Notiodes* sp	3	4	2	6	2	1	1	2	1	8	4	5
vi. Hydrochidae	*Hydrochus sp.*	10	5	2	3	8	10	2	8	5	0	2	2
vii. Haliplidae	*Haliplus* sp.	0	1	0	0	2	2	1	2	0	0	0	4
	Haliplus manipurensis	2	0	1	0	2	2	1	1	2	3	1	2
viii. Staphylinidae	*Paederus* sp.	2	3	3	5	8	4	4	3	2	0	0	0
ix. Scirtidae	*Scitid* sp.	1	1	0	0	2	3	1	0	2	0	0	1
x. Dryopidae	*Elmomophes brevicornis*	0	0	0	0	0	0	0	0	0	5	15	1
xi. Hydraneidae	*Hydraena* sp.	0	0	1	2	1	2	0	2	1	3	1	1

Seasonal diversity of aquatic beetles

During different four season of Manipur, viz., pre-monsoon (March to May) 2015, monsoon (June to August) 2015, Post monsoon (September to November - 2015) and winter (December to February) 2015 -2016. A total of 2429 individual and 55 water beetles species were recorded belonging to order Coleoptera under 11 families viz. Dytiscidae, Noteridae, Hydrophilidae, Curculionidae, Hydrochidae, Haliplidae, Staphylinidae, Scirtidae, Dryopidae and Hydraneidae were collected from the 9 collection sites of Manipur during the study period (Table 4). In the study the maximum number of beetles was collected in winter season and minimum were collected during the monsoon season.

Overall, wetlands of Manipur have been found more aquatic beetles abundance regardless of season. More species diversity were found in the wet season (1034 individuals) compared with the rainy season (311 individuals). The highest diversity was recorded in the winter season (53 taxa) compared with 48 taxa recorded in post monsoon season from all sites.

Hydrovatus acuminatus and *Hydrocanthus guignoti* were present in maximum number and representing the dominant species with respect to species diversity and abundance as they almost found in all the season and *Enochrus* sp., La*ccobius* sp., were present in minimum number (Only one individual each). Base on the Shannon-Wiener index (1.585) winter season was the most diverse season followed by summer season (1.555). Monsoon (1.58) and post monsoon (1.518). Hills diversity index indicated that winter season was the richest (53 species) followed by summer (50 species), monsoon and post monsoon (with 49 and 48 species each).

Berger parker dominance indicated that the winter (13.25 species) was the most species rich season followed by monsoon (11.5 species), summer and post monsoon.

The aquatic insect population and abundance are presented in Table 5. Number of aquatic beetles and their diversity were low during monsoon season primarily because of water dynamics high volume which did not allow the beetles to grow and propagate in spite of nutrient input to the lakes from catchment areas. Contrary to this, in winter, though nutrient input from surrounding areas were reduced but water stagnancy resulted appropriate utilization of available nutrient followed by growth and reproduction thereby increasing in number and diversity of aquatic insect population.

The high aquatic beetles' diversity was mainly possible due to a higher habitat stability and availability (Table 6 &7).

The richest substrates (in general, litter) during this season are less affected by water flow allowing a greater period for colonization and processing of benthic organic matter by macro invertebrates.

The community established in stony substrates also becomes more stable serving a refuge for younger organisms. Although there was an occupation in all substrates, there was clear preference for one or two specific substrates, litter in riffle and stony substrate. Litter substrates were preferred by many taxa, because they offered best shelter and feeding conditions due to the high habitat heterogeneity and a rich periphytic flora.

Table 4. List of species and seasonal abundance of aquatic beetles recorded in different sites of Manipur.

i. Dytiscidae	Species	Post Monsoon	Winter	Summer	Monsoon
	Cybister sugillatus	4	7	5	4
	Cybister tripunctatus	5	8	6	5
	Leiodytes nicobaricus	13	43	16	18
	Laccophilus purvulus	23	43	16	9
	Laccophilus flexuosus	23	31	12	5
	Laccophilus chinensis	9	38	8	11
	Laccophilus anticatus	6	27	6	4
	Laccophilus sp.1	5	7	5	5
	Laccophilus sp.2	7	9	5	4
	Laccophilus sp.3	6	21	5	6
	Hydroglyphus flammulatus	34	39	37	8
	Dytiscus sp.	0	6	3	2

	Hydroglyphus inconstans	10	35	25	7
	Copelatus indicus	10	13	6	0
	Copelatus sp.1	0	1	7	0
	Copelatus sp.2	1	10	4	4
	Copelatus sp.3	7	12	0	4
	Hydrovatus acuminatus	48	36	27	12
	Hydrovatus bonvouloiri	38	34	24	8
	Rhantus suturalis	20	27	10	4
	Graphodesus sp.	18	36	8	6
	Hydaticus satoi	4	10	4	5
	Hydaticus sp.	0	0	6	1
	Hyphydrus birmanicus	0	12	0	6
	Agabus amoenus sinuaticolis	3	4	1	1
	Hydrocanthus guignoti	60	78	49	27
ii. Noteridae	*Neohydrocoptus subvittulus*	24	29	5	7
	Canthydrus incosistant	4	17	4	5
iii. Hydrophilidae	**Tropisternus* sp.	11	38	6	4
	Laccobius sp.	0	1	0	0
	Hydrophilus olivaceous	4	7	7	4
	Regimbartia attenuata	12	17	4	4
	Amphiops sp.	19	10	4	7
	Amphiops mirabilis	6	5	4	1
	Coelostoma stultum	3	10	4	7
	Helochares anchoralis	10	39	14	5
	Helochares crenatus	19	16	12	8
	Helochares atropiceus	15	36	21	10
	Enochrus esuriens	18	59	13	5
	Berosus indicus	6	6	3	2
	Berosus pulchellus	8	8	7	4
	Enochrus nigropiceus	15	25	6	2
	Enochrus sp.	0	1	0	0
	Paracymus sp.	6	30	6	0
	**Chasmogenus abnormalis*	6	9	6	3
	Cercyon sp.	5	8	5	2
iv. Chrysomelidae	*Donacia* sp.	6	11	11	8
v. Curculionidae	*Notiodes* sp.	9	9	4	17
vi. Hydrochidae	*Hydrochus* sp.	17	21	15	4
vii. Haliplidae	*Haliplus* sp.	1	4	3	4
	Haliplus manipurensis	3	4	4	6
viii. Staphylinidae	*Paederus*	8	17	9	0
ix. Scirtidae	*Scitid*	1	5	3	1
x. Dryopidae	*Elmomophes brevicornis*	0	0	0	21
xi. Hydraneidae	*Hydraena*	1	5	3	4

Table 5. Diversity indices for aquatic beetles in different season of Manipur.

Index	Post Monsoon	Winter	Summer	Monsoon
Shannon H' Log Base 10.	1.518	1.585	1.555	1.58
Shannon Hmax Log Base 10.	1.681	1.724	1.699	1.69
Shannon J'	0.903	0.919	0.915	0.935
Berger-Parker Dominance (d)	0.102	0.075	0.103	0.087
Berger-Parker Dominance (1/d)	9.85	13.256	9.755	11.519
Berger-Parker Dominance (d%)	10.152	7.544	10.251	8.682
Simpsons Diversity (1/D)	25.639	32.391	27.61	32.949
Simpsons Diversity (D)	0.039	0.031	0.036	0.03
Margaleff M Base 10.	19.483	17.913	20.154	21.663

Table 6. Distribution profile of aquatic beetles' insect fauna at nine different sites of Manipur.

Sample	Mean Individuals	Variance	Standard Deviation	Standard Error	Total Individuals	Total Species	Mini mum	Maxi mum	Mean Confidence Interval
Post Monsoon	10.745	145.193	12.05	1.625	591	48	0	60	38.373
Winter	18.8	269.83	16.426	2.215	1034	53	0	78	71.312
Summer	8.691	84.847	9.211	1.242	478	50	0	49	22.424
Monsoon	5.655	27.378	5.232	0.705	311	49	0	27	7.236

Table 7. Distribution profile of aquatic beetles insect fauna in each month at nine different sites of Manipur.

Sample	Mean Individuals	Variance	Standard Deviation	Standard Error	Total Individuals	Total Species	Minim um	Maxim um	Mean Confidence Interval
Sept	5.255	42.23	6.498	0.876	289	43	0	30	11.161
Oct	3.236	13.665	3.697	0.499	178	44	0	20	3.611
Nov	2.273	6.832	2.614	0.352	125	43	0	13	1.806
Dec	7.836	68.251	8.261	1.114	431	50	0	40	18.038
Jan	6.073	30.883	5.557	0.749	334	49	0	22	8.162
Feb	5.073	21.958	4.686	0.632	279	49	0	20	5.803
Mar	3.164	10.991	3.315	0.447	174	49	0	15	2.905
April	3.2	13.941	3.734	0.503	176	47	0	21	3.684
May	2.382	8.389	2.896	0.39	131	47	0	15	2.217
Jun	2.018	4.944	2.224	0.3	111	43	0	13	1.307
Jul	1.982	5.87	2.423	0.327	109	41	0	15	1.551
Aug	1.673	2.78	1.667	0.225	92	44	0	7	0.735

Table 8. Distribution profile of aquatic beetles fauna of Manipur.

Species	Variance	Mean	Chi-sq	d.f.	Probability
Cybister sugillatus	2	5	1.2	3	0.756582
Cybister tripunctatus	2	6	1	3	0.8039588
Leiodytes nicobaricus	191	22.5	25.4667	3	2.13E-005
Laccophilus purvulus	214.9167	22.75	28.3407	3	6.4E-006
Laccophilus flexuosus	132.9167	17.75	22.4648	3	7.65E-005
Laccophilus chinensis	207	16.5	37.6364	3	1E-007
Laccophilus anticatus	118.25	10.75	33	3	9E-007
Laccophilus sp.1	1	5.5	0.5455	3	0.9086444
Laccophilus sp.2	4.9167	6.25	2.36	3	0.504096
Laccophilus sp.3	59	9.5	18.6316	3	0.0004017
Hydroglyphus flammulatus	209.6667	29.5	21.322	3	0.000125
Dytiscus sp.	6.25	2.75	6.8182	3	0.0765457
Hydroglyphus inconstans	172.25	19.25	26.8442	3	1.19E-005
Copelatus indicus	31.5833	7.25	13.069	3	0.0046789
Copelatus sp.1	11.3333	2	17	3	0.0008207
Copelatus sp.2	14.25	4.75	9	3	0.0289077
Copelatus sp.3	25.5833	5.75	13.3478	3	0.0041321
Hydrovatus acuminatus	230.25	30.75	22.4634	3	7.65E-005
Hydrovatus bonvouloiri	178.6667	26	20.6154	3	0.0001697
Rhantus suturalis	104.9167	15.25	20.6393	3	0.0001679
Graphodesus sp.	188	17	33.1765	3	9E-007
Hydaticus satoi	8.25	5.75	4.3043	3	0.229038
Hydaticus sp.	8.25	1.75	14.1429	3	0.0029012
Hyphydrus birmanicus	33	4.5	22	3	9.34E-005
Agabus Amoenus sinuaticolis	2.25	2.25	3	3	0.3927475
Hydrocanthus guignoti	455	53.5	25.514	3	2.09E-005
Neohydrocoptus subvittulus	144.9167	16.25	26.7538	3	1.24E-005
Canthydrus incosistant	40.3333	7.5	16.1333	3	0.001202
**Tropisternus* sp.	248.9167	14.75	50.6271	3	0
Laccobius sp.	0.25	0.25	3	3	0.3927475
Hydrophilus olivaceous	3	5.5	1.6364	3	0.6554352
Regimbartia attenuata	40.9167	9.25	13.2703	3	0.0042774
Amphiops sp.	42	10	12.6	3	0.0057677
Amphiops mirabilis	4.6667	4	3.5	3	0.3206452
Coelostoma stultum	10	6	5	3	0.1699867
Helochares anchoralis	228.6667	17	40.3529	3	0
Helochares crenatus	22.9167	13.75	5	3	0.1699867
Helochares atropiceus	127	20.5	18.5854	3	0.0004099

Species	Variance	Mean	Chi-sq	d.f.	Probability
Enochrus esuriens	580.9167	23.75	73.379	3	0
Berosus indicus	4.25	4.25	3	3	0.3927475
Berosus pulchellus	3.5833	6.75	1.5926	3	0.6653315
Enochrus nigropiceus	104.6667	12	26.1667	3	1.58E-005
Enochrus sp.	0.25	0.25	3	3	0.3927475
Paracymus sp.	177	10.5	50.5714	3	0
**Chasmogenus abnormalis*	6	6	3	3	0.3927475
Cercyon sp.	6	5	3.6	3	0.3076974
Donacia sp.	6	9	2	3	0.5762582
Notiodes sp.	28.9167	9.75	8.8974	3	0.0302667
Hydrochus sp.	52.9167	14.25	11.1404	3	0.0110782
Haliplus sp.	2	3	2	3	0.5762582
Haliplus manipurensis	1.5833	4.25	1.1176	3	0.7760784
Haliplus manipurensis	1.5833	4.25	1.1176	3	0.7760784
Paederus	48.3333	8.5	17.0588	3	0.0007998
Scitid	3.6667	2.5	4.4	3	0.2199118
Elmomophes brevicornis	110.25	5.25	63	3	0

The variation among the four seasonal sampling periods is shown in In this study the substrate litter in riffle had its highest richness and abundance numbers at the winter season. The low insect abundance in depositional areas in the dry season is probably due to high rainy water flow and high temperature.

DISCUSSION

During the study period from the 9 different collection sites in 9 districts of Manipur 2429 individual and 55 water beetles species were recorded belonging to order Coleoptera. More species diversity were found in the wet season (1034 individuals) compared with the rainy season (311 individuals). Maximum numbers of beetles (431 individuals) were collected during December and minimum numbers of beetles (92 individuals) were collected in the month of August. Although Malhotra *et al.*, (1990) reported the highest aquatic organisms in August till February in Lake Mansar, Jammu.

In terms of species richness and abundance high species (50 Species) were found in the month of December and minimum in the month of July (41 species). However in earlier observation regarding insect abundance both in quality (26 sps. of insects) during colder months and quantity during summer seasons in pond water were reported by Kaushik *et al.*, (1990) at Gwalior (M.P.). Number of aquatic beetles and their diversity were low during monsoon season primarily because of water dynamics high volume which did not allow the beetles to grow and propagate in spite of nutrient input to the lakes from catchment areas.

Contrary to this, in winter, though nutrient input from surrounding areas were reduced but water stagnancy resulted appropriate utilization of available nutrient followed by growth and reproduction thereby increasing in number and diversity of aquatic insect population.

The high aquatic beetles' diversity was mainly possible due to a higher habitat stability and availability (Table 6 & 7). Thakare and Zade (2011) studied the diversity, abundance and species composition of water beetles in Kolkas Region of Melghat Tiger Reserve, Central India and collected 13 species of water beetles. Kiyak *et al.*, (2006) collected 31 aquatic beetles from the province Denizli, Aydin, Ispark and Antalya in South west Mediterranean region of Turkey. Percentage contribution of family Dysticidae was maximum 45% with 25 species, family Hydrophilidae contributed 32% with 18 species and the family Noteridae contributed 5% with 3 species, family Haliplidae 2 species 3% and remaining family Chrysomelidae, Curculionidae, Hydrochidae, Staphylinidae, Scirtidae, Dryopidae and Hydraneidae 1% each with only 1 species each. Similar observations regarding the preponderance of Dytiscidae over Hydrophilidae was observed by Jana *et al.*, (2009) who worked on diversity and community structure of aquatic insects in a pond in Midnapore town, West Bengal, India. They recorded 20 species of aquatic insects from a weed infested pond belonging to three orders Odonata, Hemiptera and Coleoptera.

The preponderance of Dytiscidae over Hydrophilidae and Noteridae indicates the ecological condition of wetland. Devi *et al.*, (2016) studied the aquatic insect diversity of the Loktak Lake and reported that Coleoptera constituted 41.60%, prevalence of Dytiscidae was the indicative of the ecological health of studied lake. Dytiscidae and Noteridae generally preferred leaves of submerged aquatic vegetation in clear freshwater lake and are predacious in nature. On the contrary, Hydrophilidae are water scavenger beetles and generally occur in shallower regions of wet land with abundant macrophytes and feed mainly on detritus, algae and decaying vegetative matter (Khan and Ghosh, 2001, Jana *et al.*, 2009). Suhaila *et al.*, (2014) reported the higher.

Season variation have formed changes in the environmental characteristics diversity in the dry season (29 taxa) compared with 25 taxa recorded in wet season from all rivers in Gunung Jerai Forest Reserve, Malaysia and thus influenced the number of individual and diversity of EPT at Gunung Jerai Forest Reserve, rivers.

According to Hassall & Thompson (2008) climate change brings with it unprecedented rates of increase in environmental temperature, which will have major consequences for the earth's flora and fauna. A range of behaviors are likely to be affected which will, in turn, influence other parts of the aquatic ecosystem, primarily through trophic interactions. Temperature may influence changes in geographical distributions, through a shifting of species' fundamental niches, changes in the distribution of suitable habitat and variation in the dispersal ability of species. Finally, such a rapid change in the environment results in a strong selective pressure towards adaptation to core and the inevitable loss of some potentially species insects populations. Aquatic Coleoptera (beetles) play a key role in freshwater ecosystems and are considered as a suitable bioindicator (Dong *et al.*, 2014). Aquatic macro invertebrates play significant role in responding to a variety of environmental conditions of rivers and streams and therefore may be used as bio-indicators for water quality assessment.

In the past, biological communities like plankton, periphyton, microphytobenthos, macrozoobenthos, aquatic macrophytes, fishes etc. have been used for the assessment of water quality of rivers and streams, but now the use of benthic macro invertebrates as bio-indicators is gaining importance as these can be easily caught and seen with naked eyes and the method is less costlier and less time consuming compared to other methods.

Substrate and Stream Order Abundance and Richness Patterns

The variation among the four seasonal sampling periods is shown in Table 4. In this study the substrate litter in riffle had its highest richness and abundance numbers at the winter season. The low insect abundance in depositional areas in the dry season is probably due to high rainy water flow and high temperature. Oliveira (1996), Kikuchi and Uieda (1998) recorded similar results in the distribution and abundance of aquatic insect populations in Brazilian streams.

In the present study, diversity analysis showed higher species diversity (more than 1.5) indicating finely distributed individuals of the different species. This agreed the observation of Smith (1977). In the present study higher species diversity in winter season was an indication of stable environmental condition for the growth of the aquatic beetles.

Importance in conservation of wetlands

In Manipur the wetlands are of different types. The studied 9 different wetlands have the different diversity of beetles. More diversity of beetles was found in more planted wetlands regardless of season. An important consequence for conservation is that the smaller, shallow temporary wetlands play a crucial role in the preservation of biodiversity. Therefore, they have to be considered as important for the management and conservation of these wetland complexes as by several authors (Wood *et al.*, 2003, Nicolet *et al.*, 2004). During the spring, temporary wetlands play an especially important role in maintaining aquatic beetle diversity by providing breeding sites. The presence of the different types of wetlands increases the landscape heterogeneity which is an important factor in conserving aquatic macro invertebrate diversity (Verberk *et al.*, 2006).

Species richness of aquatic beetles in surface flow wetlands was highest in spring, while the abundance was lower in the planted surface flow wetlands than in the unplanted surface flow wetland. Planted surface flow wetlands had a slightly higher diversity of beetles than that of the unplanted surface flow wetland (A´kos Molna´r *et al*., 2009).On the other hand, in sand substrates the instability of the substrate and the low organic matter availability lead to a low diversity and richness numbers (Hawkins, 1984). Thus the habitat heterogeneity is a very important factor influencing macro invertebrates distribution in streams (Vinson and Hawkins 1998).

Acknowledgement

The authors are thankful to the Council of Scientific and Industrial Research (CSIR), PUSA, New Delhi for giving financial assistance during the course of the work. Thanks are also due to the Principal and Head, P.G. Department of Zoology, D.M. College of Science, Imphal for providing laboratory facilities.

References

Andersen NM, Weir TA. 2004. Australian water bugs. Their Biology and Identification (Hemiptera-Heteroptera, Gerromorpha & Nepomorpha*). CSIRO Publishers*, Australia.

Baili dong. 2014**.** Aquatic Coleoptera response to environmental factors of freshwater ecosystems in Changbai Mountain, northeast China.

Bal A, Basu RC. 1994a**.** Insecta: Hemiptera: Belostomatidae, Nepidae, Notonectidae and Pleidae. State Fauna Series3: Fauna of West Bengal, Part **5,** 535-558.

Bal A, Basu RC. 1994b. Insecta: Hemiptera: Mesovellidae, Hydromatridae, Veliidae and Gerridae. State Fauna Series3: Fauna of West Bengal, Part **5,** 511-534.

Bosi G. 2001. Abundance, diversity and seasonal succession of dytiscid and noterid beetles (Coleoptera: Adephaga) in two marshes of the Eastern Po Plain (Italy). Hydrobiologia **459,** 1-7.

Bouchard RW, Jr. 2004. Guide to aquatic macroinvertebrates of the Upper Midwest.Water Resources Centre, University of Minnesota, St. Paul, MN. 208 pp.

Devi BM, Devi SO Singh DS. 2016. Aquatic insect fauna and diversity in five different sites of Loktak Lake of Manipur, North East India. Bugs R All Newslatter of the Invertebrate Conservation and Information Network of South Asia (ICINSA) No. **22,** 30-36.

Dudgeon, D. 2008. Tropical Stream Ecology. California: Elsevier Inc.

Epler JH. 2010. The Water Beetles of Florida: An Identification Manual for the Families Chrysomelidae, Curculionidae, Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Helophoridae, Hydraenidae, Hydrochidae, Hydrophilidae, Noteridae, Psephenidae Ptilodactylidae, Scirtidae. Florida Department of Environmental Protection, Tallahassee 414pp.

Fairchild GW, Faulds AM, Matta JF. 2000. Beetle assemblages in ponds: effects of habitat and site age. Freshwater Biology **44,** 523-34.

Fairchild GW, Cruz J, Faulds AM, Short AEZ, Matta JF. 2003. Microhabitat and landscape influences on aquatic beetle assemblages in a cluster of temporary and permanent ponds. Journal of the North American Benthological Society **22,** 224-40.

Hassall, C. & Thompson, D. J. 2008**.** The impacts of environmental warming on odonata: a review. International Journal of Odonatology, **11,** 131-153.

Hawkins CP, Sedell JR. 1998. Longitudinal and seasonal-changes in functional-organization of macroinvertebrate communities in 4 Oregon streams. Ecology **62,** 387-397.

Hebauer F. 1986. Ka¨ fer als Bioindikatoren dargestellt am O¨kosystem Bergbach. Laufener Seminarbeitrage: Ausgewa¨ hlte Referate zum Arteschutz **7,** 55-65.

Hynes HBN. 1970. The Ecology of Running Waters. Toronto, Canada: University of Toronto Press.

Jana S, Pahari PR, Dutta TK, Bhattacharya T. 2009. Diversity and community structure of aquatic insects in a pond in Midnapore town,West Bengal. India. J. Environ. Biology **30(2),** 283-287.

Kaushik S, Sharma S, Saxena MN, Saxsena DN. 1990. Abundance of insects in relation to physicochemical characteristics of pond water at Gwalior (M.P.). Proceedings of the National Academy of Sciences, India Vol. LX PartII.

Khan RA, Ghosh LK. 2001. Faunal diversity of aquatic insects in fresh water wetlands of South Eastern West Bengal. Z.S.I. Kolkata p. 104.

Kikuchi RM, Uieda VS, 1998, Composição da comunidade de invertebrados de um ambiente lótico tropical e sua variação espacial e temporal, pp. 157-174. *In*: J. L. Nessimian & A. L. Carvalho (eds.), *Ecologia de insetos aquáticos*. Series Oecologia Brasiliensis, Vol. V. PPGE-UFRJ, Rio de Janeiro, Brasil.

Kiyak S, Canbulat S, Darilmaz A. 2006. Additional notes on aquatic coleopteran fauna of Turkey with a new record (Helophoridae, Hydrophilidae) Munis Entomology and Zoology **1(2),** 273-278.

Malhotra YR, Gupta K, Khajuria A. 1990. Seasonal variations in the population of Macrozoobenthos in relation to some physicochemical parameters of Lake Mansar, Jammu. J. Freshwater Biol **2(2),** 123-128.

Molna´r A, Csabai Z, To´thme´re´sz B. 2000. Influence of flooding and vegetation patterns on aquatic beetle diversity in a constructed wetland complex. WETLANDS **29(4),** 12141223.

Nicolet PJ, Biggs G, Fox M, Hodson J, Reynolds C, Whitfield M. Williams P. 2004. The wetland plant and macroinvertebrate assemblages of temporary ponds in England and Wales. Biological Conservation **120,** 261-78.

Oertli BD, Joye A, Castella E, Juge R, Lehmann A, Lachavanne J. 2005. PLOCH: a standardized method for sampling and assessing the biodiversity in ponds. Aquatic Conservation: Marine and Freshwater Ecosystems **15,** 665-79.

Oliveira LG. 1996. Aspectos da biologia de comunidades de insetos aquáticos da ordem Trichoptera Kirby, 1813, em córregos de cerrado do município de Pirenópolis, Estado de Goiás. Tese de Doutorado, Universidade de São Paulo, São Paulo, 120p.

Oliveira LG, Froehlich CG. 1997. The Trichoptera (Insecta) fauna of a Cerrado stream in Southeastern Brazil. Naturalia **22,** 183-197.

Painter D. 1999. Macroinvertebrate distribution and the conservation value of aquatic Coleoptera, Mollusca and Odonata in the ditches of traditionally managed and grazing fen at Wicken Fen, UK. Journal of Applied Ecology **22,** 224-40.

Payne AI. 1986. The Ecology of Tropical Lakes and Rivers. Chichester: John Wiley and Sons.

Robinson CT, Minshall GW. 1986. Effects of disturbance frequency on stream benthic community structure in relation to canopy cover and season. Journal of the North American Benthological Society **5,** 237-248.

Sa´nchez-Ferna´ndez D, Abella´n P, Mellado A, Velasco J, Milla´n A. 2006. Are water beetles good indicators of biodiversity in Mediterranean aquatic ecosystems? The case of the Segura river basin (SE Spain). Biodiversity and Conservation **15,** 4507-20.

Smith DL, Smith S. 2003. Proceedings of the Ninth symposium on the Natural History of the Bahamas. Gerace Research Center San Salvator, Bahamas.

Subramanian, KA, Sivaramakrishnan KG. 2007. Aquatic insects of India- A Field Guide Ashoka Trust for Research in Ecology and Environment (ATREE).

Suhaila AH, Che Salmah MR, Nurul Huda A. 2014. Seasonal abundance and diversity of aquatic insects in rivers in Gunung Jerai Forest Reserve, Malaysia. Sains Malaysiana **43(5),** 667-674.

Thakare GV, Zade SV. 2011. Diversity, Abundance and species composition of water beetles (Coleopteran: Dytiscidae, Hydrophilidae and Gyrinidae) in Kolkas Region of Melghat Tiger Reserve, Central India. Academic Journal of Entomology **4(2),** 64-71.

Verberk WCEP, van GA, Duinen AMT, Brock RS, Leuven H, Siepel PF, Verdonschot EW, van der M, Velde G, Esselink H. 2006. Importance of landscape heterogeneityfor the conservation of aquatic macroinvertebrate diversity in bog landscapes. Journal of Nature Conservation **14,** 78-90.

Westfall MJ, Jr Tennessen KJ. 1996. An introduction to the Aquatic Insect of North America-3rd Edition. Kendell/Hunt publishing Company. Dubuque, Lowa. Odonata164-211.

Wood PJ, Greenwood MT, Agnew MD. 2003. Pond biodiversity and habitat loss in the UK. Area **35,** 206-16.