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Nepomorpha and Gerromorpha (Hemiptera) community in the agricultural fields of Barak Valley, Assam, North East India

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ABSTRACT

Nepomorpha and Gerromorpha are infraorders of order Hemiptera comprising aquatic and semiaquatic bugs. Besides being predators they are particularly important in agricultural fields as bio-control agents and bioindicators. Studies on diversity of aquatic and semi aquatic Hemiptera bugs in agricultural fields are very rare in India. The study area Barak Valley though included in Indo Burma biodiversity hotspot region lacks documentation of hemipterans. Thus a study on their diversity and abundance in the large and old agricultural fields of Cachar (AF1), Karimganj (AF2) and Hailakandi (AF3) districts of Barak Valley were taken up. Collections were made seasonally by standard methods except when the systems were dry. A total of 30 species, 19 genera and 11 families were recorded with the dominance of mostly Nepomorpha bugs. In AF1 and AF2 the preponderance of semi -tolerant species of Micronectidae, Notonectidae and Pleidae implied disturbances in the field water to some extent. Whittaker plot, k-dominance plot, rarefaction curves figured out the temporal variation in the taxa richness and their assemblage in the three sites. Among all the sites, AF3 showed more stable habitat with highest species richness and lowest dominance.

Key words: Aquatic and semiaquatic Hemiptera; Engelmann's Scale; Heteroptera; k-dominance plot; Rarefaction curve; Whittaker plot

INTRODUCTION

Nepomorpha and Gerromorpha are infraorders of suborder Heteroptera under order Hemiptera. Although studies on evolutionary history of these Hemiptera bugs are still in dispute, it is reported that, Nepomorpha diverged earliest as one of the seven infraorders of order Heteroptera in early Triassic period followed by its superfamilies and families from middle Triassic to late Cretaceous period. On the other hand the infraorder Gerromorpha diverged during late Triassic and its superfamilies had their origin in Jurassic period. The aquatic habitat was colonized by Nepomorpha in the Triassic and the Gerromorpha adapted to the semi-aquatic habitat in the early Jurassic period (Li *et al*., 2012). Thus infraorder Nepomorpha includes all truly aquatic bugs. Gerromorpha are found on the water surface or associated with the water margin. It is also presumed that all families and possibly most subfamilies of water bugs were present long before the break-up of Gondwanaland (Hebsgaard *et al*., 2004; Damgaard & Zettel, 2014). Unlike other aquatic insects, nymphs and adults of these true bugs occupy the same habitat. They have characteristic mouth part, called rostrum and their hemelytral wings which is half lathery on the base and membranous on the apical part. They are mostly predatory. They use their grasping forelegs to catch their pray and through their rostrum inject enzymes to poison it and suck the soft fluid materials out of the pray leaving behind the exoskeleton. They are found feeding on dipteral larvae, other insects, tadpoles etc. and thus act as an important bio-control agents (Ambrose *et al*., 1993); (Ohba & Nakasuji, 2006). They are also known as bioindicators Skern *et al*., 2010); (Chessman, 2003); (Hodkinson & Jackson, 2005). Among the aquatic insects, aquatic Hemiptera are the most numerous in the tropical region utilizing an exceptionally broad range of habitat and many species exhibit striking morphological adaptations for survival in their aquatic environment (Polhemus & Polhemus, 2007). Nepomorpha and Gerromorpha are found inhabiting all types of aquatic systems, lotic and lentic which are either perennial or temporary. They are also found in water filled agricultural fields but are mostly ignored (Lawler, 2001).

Barak Valley, situated in the southern part of Assam is included in the Indo-Burma biodiversity hotspot, well known for its species diversity and endemism. Being one of the most biologically important region on this planet, this hotspot is also reported as one of the most threatened biodiversity hotspots in the world due to higher rate of resource exploitation and habitat loss (Chitale *et al*., 2014) resulting into biodiversity loss (Tordoff *et al*., 2012). In spite of its importance, documentation on freshwater biodiversity in Indo -Burma hotspot region is still in its infancy, mostly restricted to Fishes, Reptiles, Amphibians and Odonata (Tordoff *et al*., 2012). Barak Valley region comprising three districts of Assam is blessed with several wetlands and low lying areas which are also used as agricultural fields for paddy cultivation. Paddy is the major crop cultivated in this region. The insect fauna in these agricultural fields are composed of the resident, migratory and aquatic

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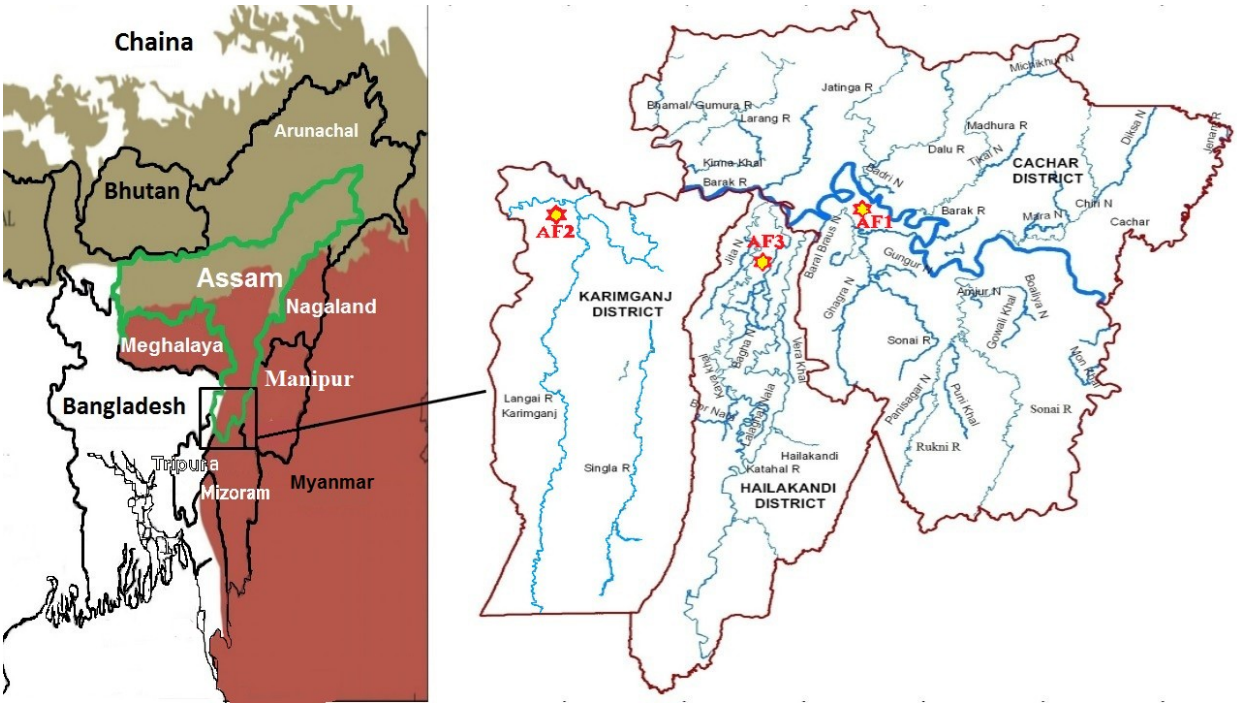

Figure 1. Part of Indo-Burma Biodiversity Hotspot in Northeast India (Tordoff *et al*., 2012) and map of Barak Valley region (Saha and Gupta, 2018) showing three study sites AF1, AF2 and AF3

species (Kiritani, 2000) and based on their feeding strategy they are grouped as grazers/decomposers, collectors and predators (Dudgeon, 1999). In spite of their ecological (Whiteman & Sites, 2008); (Boda *et al*., 2015) and economic importance (Papacek, 2001) there is lack of information and documentation of these bugs in the agricultural fields of Barak Valley. Thus in this paper we have inventoried the Nepomorpha and Gerromorpha species in agricultural fields of three districts of Barak Valley. Further we have investigated the spatial and temporal variations in the diversity and abundance of these bugs during the study period.

MATERIALS AND METHODS

Study sites

Barak Valley region comprising three districts viz. Cachar, Karimganj and Hailakandi is situated in the southern part of Assam. Three large and old agricultural fields from the three districts were selected for this study (Figure 1). **AF1** is the site from Arunachal, Cachar District (24˚51′28.95″ N and 92˚44′31.61″ E), **AF2** is the site from Akbarpur, Karimganj district (24°51′54.98″ N and 92°18′32.70″ E) and **AF3** is the site from Chiparsangan, Hailakandi district (24°48′61.6″ N and 92°35′83.4″ E). AF1 depends entirely on rainfall for irrigation whereas AF2 is found connected to a narrow channel and AF3 is located near by a wetland that gets connected after rainfall. During the collection period AF1 and AF2 were found devoid of macrophytes as they are cleared regularly by the owners but in AF3 weeds and some aquatic macrophytes were visible.

Sampling method and Identification

The sampling of Nepomorpha and Gerromorpha was done during pre-monsoon (March to May), monsoon (June to August) and post-monsoon (September to November) seasons during 2013 to 2014. Abbreviations used for seasons in this study are M13= monsoon 2013; PS13= post-monsoon2013; PR14= pre-monsoon 2014; M14= monsoon 2014 and PS14= post-monsoon2014. During winter 2013 and 2014 (December to February) and pre-monsoon 2013 systems were completely dry and thus collection could not be done. A D-shaped nylon net (mesh opening: 500 µm; diameter: 60 cm; depth: 50 cm) with adjustable handle was used for the collection. Aquatic insects were searched vigorously by disturbing the aquatic vegetation and the net was swept through it for 1 minute. The effort in sampling was standardized by restricting the collection for 3 minutes for one replicate. Three such replicates constitute one sample. The sorted samples were then preserved in 70% ethanol (Subramanian & Sivaramakrishnan, 2007).

Identification of the collected specimens were done under a stereozoom-trinocular microscope using standard taxonomic keys (Bouchard, 2004); (Cheng, *et al*., 2001); (Nieser, 2004); (Nieser & Chen, 2005); (Winterbourn & Gregson, 1981); (Polhemus & Polhemus, 2013) and consulted the checklists (Thirumalai, 1989; 1994; 1999; 2002; 2007); (Thirumalai & Radhakrishnan, 1999).

Data analyses

Diversity indices namely, Shannon Wiener Diversity index, Evenness index and Berger Parker index of dominance were computed and compared. Accumulation curve, k- dominance curve and rarefaction curves were used for understanding their diversity, richness and abundance. The infraorder level and family level relative abundance (RA) were studied using RA of the Nepomorpha and Gerromorpha species. Dominance status was determined using the Engelmann's Scale (Engelmann, 1978).

Table1. Distribution of Nepomorpha and Gerromorpha (Order: Hemiptera) community in the three agricultural fields of Barak Valley, Assam

	Families	Species	AF1	AF2	AF3
NEPOMORPHA	Micronectidae	***Micronecta scutellaris scutellaris*** (Stål, 1858)	√	√	√
		Micronecta siva (Kirkaldy,1897)	√	√	√
		Micronecta haliploides (Horvath, 1904)	√	√	√
		Micronecta ludibunda (Breddin, 1905)	√	√	√
	Corixidae	***Sigara paivai*** (Lundblad,1928)	√	√	-
	Notonectidae	***Anisops niveus*** (Fabricius, 1775)	√	√	√
		Anisops breddini (Kirkaldy, 1901)	√	√	√
		Anisops kuroiwae (Matsumura, 1915)	√	√	-
		Anisops bouvieri (Kirkaldy, 1904)	-	√	√
		Nychia sappho (Kirkaldy, 1901)	√	-	√
	Nepidae	***Ranatra varipes*** (Stal, 1861)	√	√	√
		Ranatra gracilis (Dallas , 1850)	√	√	√
		Ranatra longipes (Stal, 1861)	√	√	√
		Ranatra spinifrons (Montandon, 1905)	√	√	-
		Laccotrephes ruber (Linnaeus, 1764)	-	√	√
	Belostomatidae	***Diplonychus rusticus*** (Fabricius, 1781)	√	√	-
	Helotrophidae	***Tiphotrephes indicus*** (Distant, 1910)	-	√	-
	Pleidae	***Paraplea liturata*** (Fieber, 1844)	√	√	√
		Paraplea frontalis (Fieber , 1844)	-	√	√
GERROMORPHA	Gerridae	***Gerris adelaidis*** (Dohrn, 1960)	√	√	√
		Neogerris parvula (Stal, 1859)	-	√	√
		***Trepobates* sp.**	√	√	√
		Rhagadotarsus anomalus (Breedin, 1905)	√	-	-
		Limnogonus nitidus (Mayr, 1865)	√	-	√
	Hydrometridae	***Hydrometra greeni*** (Kirkaldy, 1898)	-	-	√
	Mesoveliidae	***Mesovelia horvathi*** (Lundblad, 1934)	-	-	√
		Mesovelia vittigera (Horvath, 1895)	√	-	√
	Veliidae	***Microvelia* sp.**	√	√	√
		***Baptista* sp.**	√	-	√
		Pseudovelia lundbladi	√	√	√

RESULTS

A total of 30 species belonging to 19 genera and 11 families of Heteroptera were recorded during the study period that included 19 Nepomorpha species belonging to 9 genera, 7 families, and 11 Gerromorpha species belonging to 10 genera and 4 families. Among the three agricultural fields, highest number of taxa was found in AF3 with 25 species, 15 genera and 8 families. AF1 recorded 23 species 15 genera and 9 families and AF2 recorded 23 species, 13 genera and 9 families (Table 1). The seasonal and temporal variations in the taxa richness of these aquatic and semiaquatic Hemiptera and rainfall in the three agricultural fields are shown in Figure 2. Temporally and spatially, taxa richness was found higher in AF3 in all the season except during pre-monsoon 2014. The highest richness was recorded during monsoon 2013. AF1 also recorded higher taxa richness during monsoon 2013. In contrary, AF2 recorded higher species richness during monsoon 2013 and higher genera and family richness during post-monsoon 2014. Similar to AF3, AF2 also recorded lower taxa richness during pre-monsoon 2014, whereas in AF1, taxa richness was lowest during post monsoon 2013.

The relative abundance (RA) values of the two infraorders and different families of Hemiptera (Figure 3) showed the dominance of Gerromorpha only in AF1 during post-monsoon2013 and in AF3 during monsoon 2013 and post-monsoon 2013. Among the three agricultural fields, AF3 was found to inhabit higher Gerromorpha population during these two seasons of 2013 whereas in rest of the seasons of 2014 dominance of Nepomorpha were recorded. In contrast, AF2 recorded the dominance of Nepomorpha throughout the collection. The presence of family Micronectidae was common in all the sites and seasons. According to the Engelmann's scale (Engelmann, 1978), if RA is more than 31.7%, the taxon is interpreted as the eudominant taxon in that system.

The temporal and spatial variations in the RA of all the recorded species during the study period is shown in Figure 4. The eudominant species recorded in the three agricultural fields during the study are shown in Figure 5. In AF1 Micronecta *siva, Anisops breddini* and *Micronecta scutellaris* were found eudominant during

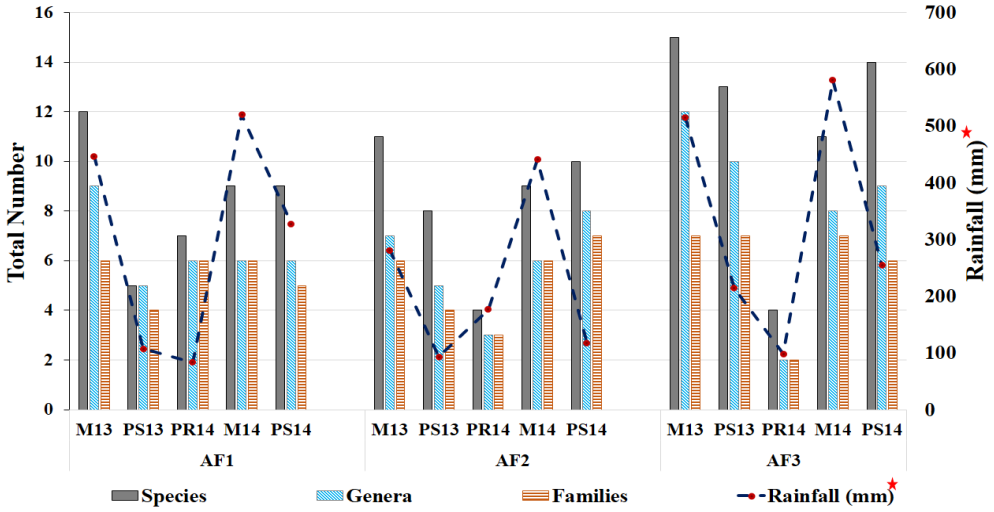

Figure 2. Temporal and spatial variations in taxa-richness of Nepomorpha and Gerromorpha (Hemiptera) in AF1, AF2 and AF3 with rainfall data in secondary axis, during M13=monsoon 2013; PS13=post-monsoon2013; PR14= pre-monsoon 2014; M14=monsoon 2014; PS14=post-monsoon 2014.

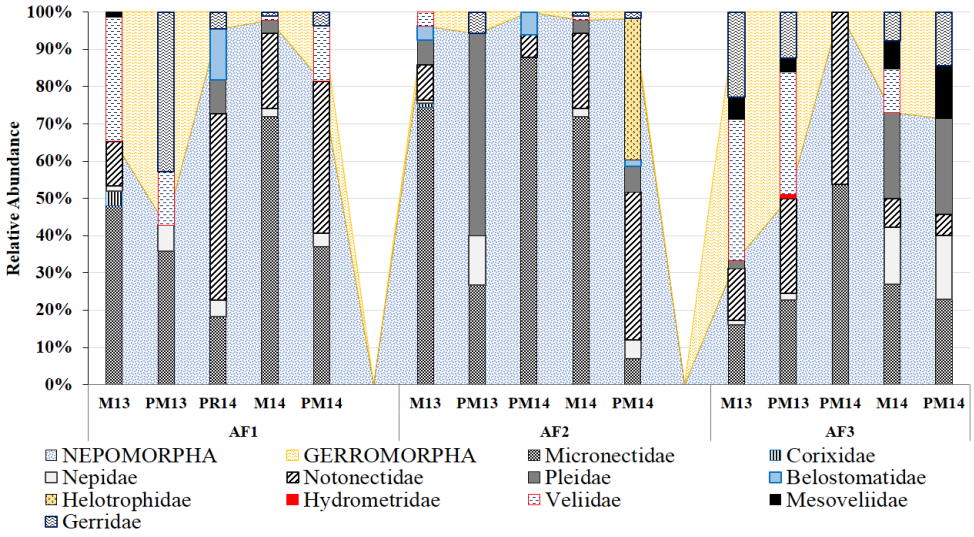

Figure 3. Temporal and spatial variations in the relative abundance of the two infraorders and different families belonging to them in AF1, AF2 and AF3 duringM13=Monsoon 2013; PS13=Post-monsoon 2013; PR14= pre-monsoon 2014; M14=Monsoon 2014; PS14=Post-monsoon 2014.

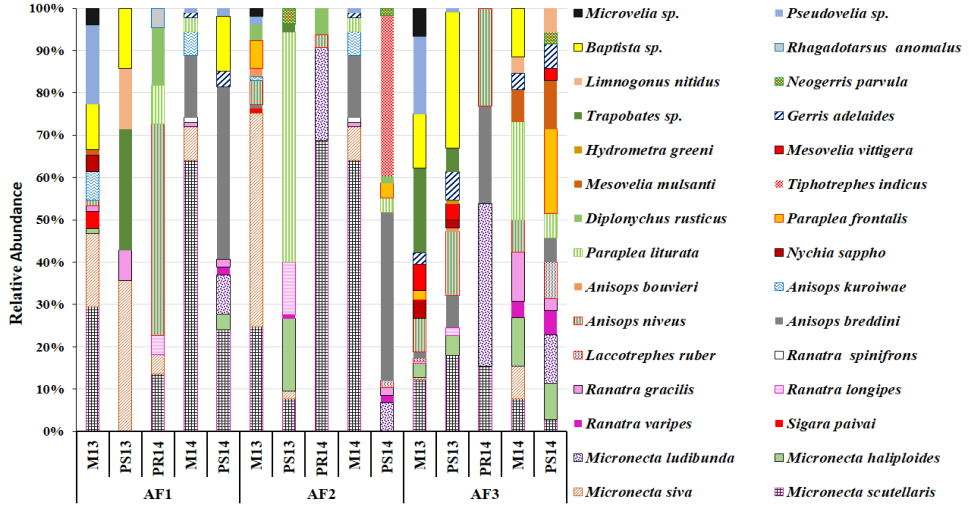

Figure 4. Temporal and spatial variations in the relative abundance of Nepomorpha and Gerromorpha species in AF1, AF2 and AF3 duringM13=Monsoon 2013; PS13=Post-monsoon 2013; PR14= pre-monsoon 2014; M14=Monsoon 2014; PS14=Post-monsoon 2014.

Figure 5. Eudominant species recorded in the three agricultural fields of Barak Valley throughout the collection period. A) *Micronecta scutellaris*; B) *Micronecta siva*; C) *Micronecta ludibunda*; D) *Paraplea liturata;* E) *Anisops breddini;* F) *Baptista* sp.

post-monsoon 2013, 2014 and monsoon 2014, respectively. In AF2, *Micronecta siva, Micronecta scutellaris, Paraplea liturata* and *Anisops breddini* were found eudominant during monsoon 2013, 2014 and post-monsoon 2013, 2014 respectively. Similarly, *Baptista* sp. and *Micronecta ludibunda* were recorded eudominant in the AF3 during post-monsoon 2013 and pre-monsoon 2014 respectively. Among these six eudominant species, *Baptista* sp. belongs to infraorder Gerromorpha and the rest belong to infraorder Nepomorpha. Most strikingly AF2 shows highest number of eudomiant species and all belonging to infraorder Nepomorpha.

Temporal and spatial variations in the various diversity indices are shown in Figure 6. Shannon H′ was highest in AF3 during post-monsoon 2014 and was higher in all the seasons except pre-monsoon 2014 while it was lowest in AF2 during pre-monsoon 2014. Index of Evenness was found highest in AF3 during pre-monsoon 2014 and the lowest in AF2 during monsoon 2014. Berger parker index of dominance was higher in AF1 and AF2 in comparison to AF3. It was highest in AF1 during monsoon 2014 and the lowest in AF3 during monsoon 2013 and post-monsoon 2014. Thus among the three agricultural fields, AF3 showed the highest and satisfactory values of Shannon H′ and evenness and lowest Berger –Parker index of dominance.

Temporal rank abundance curve was produced based on temporal variations in the relative abundance of the species and their respective rankings. This curve, also known as Whittaker plot in Figure 7 clearly figured out the temporal variations in the species richness in the three agricultural fields of Barak Valley. Stiff slopes were observed in AF1 during monsoon 2014; in AF2 during monsoon and post-monsoon 2013 and monsoon 2014. Curves in AF3 during monsoon and post-monsoon 2013 were seen with relatively gradual slopes. Similar gradual slopes were also seen in AF1 during monsoon and post-monsoon 2013 and in AF2 during pre-monsoon and post-monsoon 2014. Shallow slopes were produced in AF1 during post-monsoon 2013 and pre-monsoon 2014, and in AF3 during pre-monsoon, monsoon and post-monsoon 2014. The k-dominance plot shows the temporal variation in the cumulative RA in relation to species rank in the three agricultural fields (Figure 8). Here all the curves in the three agricultural fields showed much shallower slopes in the study period except during pre-monsoon 2014 in AF3. Temporal variations in rarefaction curves of the aquatic and semi-aquatic Hemiptera assemblage of the three agricultural fields are shown in Figure 9. All the three agricultural fields produced gentle elongated curves in all the seasons except pre-monsoon2014 where the curves are comparatively small and poorly produced.

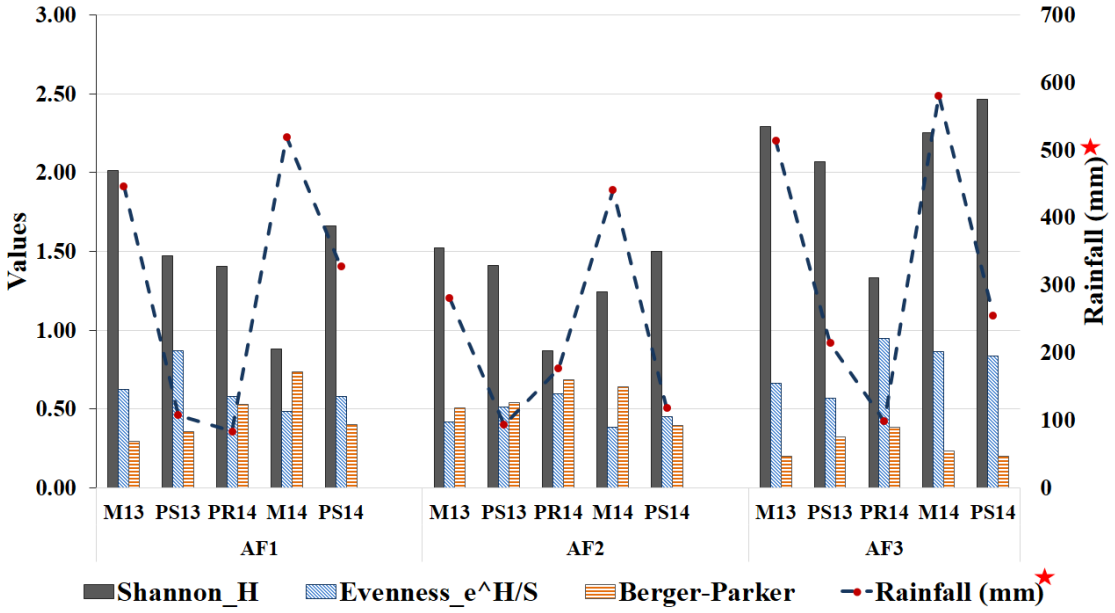

Figure 6. Temporal and spatial variations in Shannon diversity index, Evenness index and Berger-Parker index of dominance of total Nepomorpha and Gerromorpha species in AF1, AF2 and AF3 during M13= monsoon 2013; PS13=post-monsoon2013; PR14= pre-monsoon2014; M14= monsoon 2014; PS14=post-monsoon2014 with rainfall data in secondary axis.

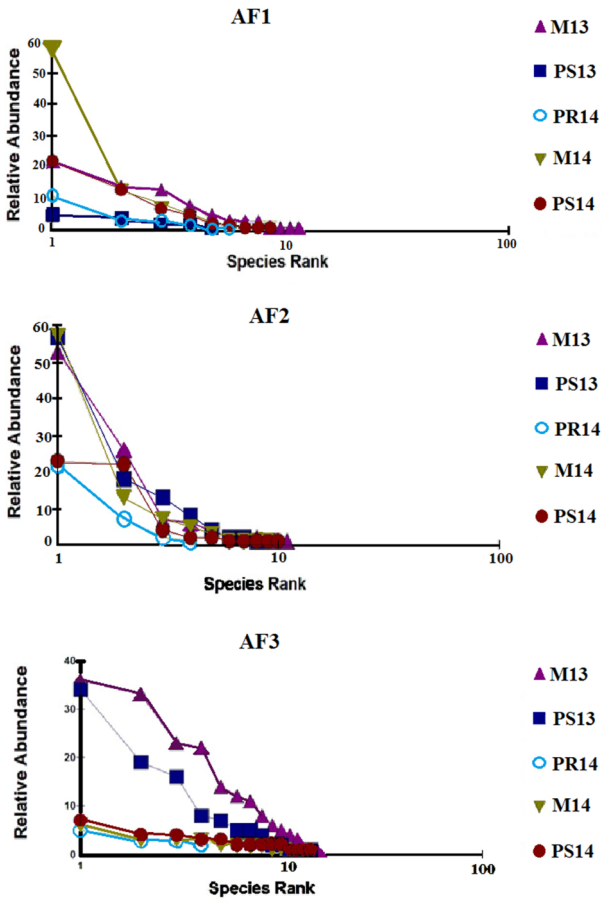

Figure 7. Temporal variations in the Whittaker plot of Nepomorpha and Gerromorpha species in AF1, AF2 and AF3 during M13= monsoon 2013; PS13= post-monsoon 2013; PR14= pre-monsoon 2014; M14= monsoon 2014; PS14= post-monsoon 2014.

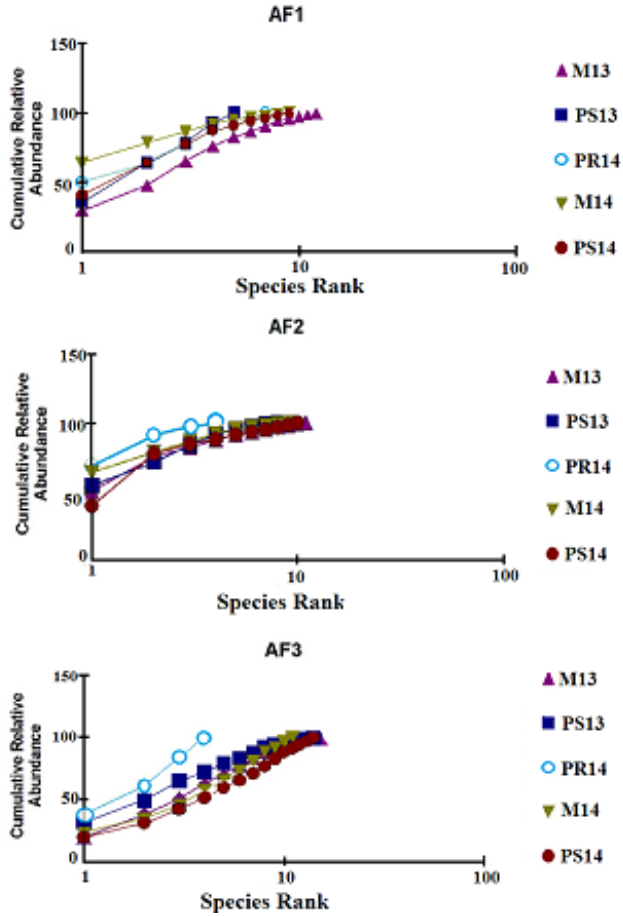

Figure 8. Temporal variation in the K- dominance plot of Nepomorpha and Gerromorpha species in AF1, AF2 and AF3 during M13= monsoon 2013; PS13= post-monsoon 2013; PR14= pre-monsoon 2014; M14= monsoon 2014; PS14= post-monsoon 2014.

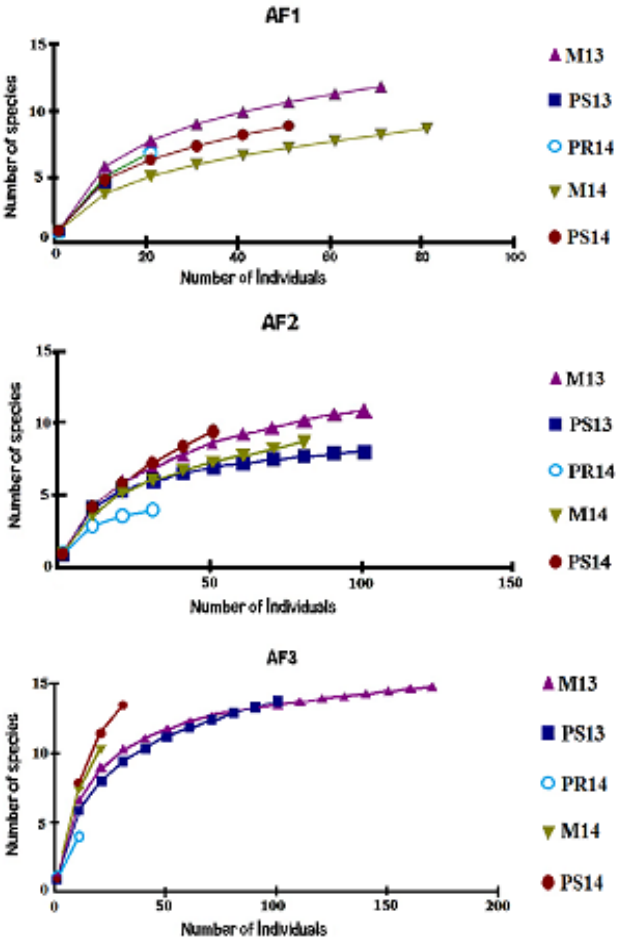

Figure 9. Temporal variations in the Rarefaction curves of Nepomorpha and Gerromorpha species in AF1, AF2 and AF3 during M13= monsoon 2013; PS13= post-monsoon 2013; PR14= pre-monsoon 2014; M14= monsoon 2014; PS14= post-monsoon 2014.

Among the three agricultural fields, AF3 produced the longest rarefaction curve during monsoon 2013. In comparison to other two sites curves in AF1 were much constricted, with the longest curve during monsoon 2014. Similarly in AF2, longer curves were seen during monsoon 2013 and post-monsoon 2013.

DISCUSSION

Studies on diversity of aquatic and semi aquatic Hemiptera bugs in agricultural fields are very rare mainly confined to South India. The results of present study exceeded the record of a similar studies on these bugs in the agricultural fields by Ponraman *et al*. (2016) and Kandibane *et al*. (2007). The former had recorded of 7 genera belonging to 6 families and the latter had recorded 6 species of these aquatic and semiaquatic Hemiptera belonging to 5 genera and 5 families of order Hemiptera. The higher diversity of these bugs in the agricultural fields of Barak Valley confirmed the importance of the study site located in a biodiversity hotspot. This also inferred that these systems played a significant role in maintaining the diversity of these predatory Nepomorpha and Gerromorpha community.

During the study period, higher taxa richness was recorded during the monsoon and post-monsoon seasons. In the first year it was observed that species richness was in the peak during monsoon 2013 in all the three agricultural fields. In the next season during post-monsoon2013, taxa richness decreased in AF1 with decrease in rainfall. Although in AF2 and AF3, the taxa richness was recorded lowest during pre-monsoon 2014. This contrast between AF1 and other two agricultural fields might be due to the fact that AF1 is a rain fed agricultural field that solely depends on monsoon rain that soon got depleted with the sharp decline in rainfall during post-monsoon 2013. But in the second year, as rainfall was much higher during monsoon 2014 and a short decline during post-monsoon 2014 helped this site to retain water and also the population and richness of the Nepomorpha and Gerromorpha hemipterans. On the other hand, AF2 and AF3 which were found connected to other water sources, can retain sufficient amount of water till post-monsoon seasons. Thus these two sites could retain their richness. During winter the systems dried up. With the fresh rainfall during pre-monsoon 2014, these aquatic and semiaquatic hemipterans appeared back with lower richness which soon got higher during monsoon 2014.

As these sites completely dries up during the winter seasons the aquatic and semi aquatic hemipterans were also found disappeared from the system. These bugs are known for their association with water and are reported to colonise new suitable habitat by short flights and some are known that undergo hibernation during adverse conditions (Barber,1913); (Fairbairn & Butler, 1990). When these dry agricultural fields receive fresh new water during pre-monsoon and monsoon seasons, these bugs recolonize these sites. Availability of fresh rainwater in the systems increases their food availability and space to provide these bugs better opportunity to colonise and to proliferate (Santana *et al*. 2015). Flooded rice fields get rich in organic matter which increase the population of several detritivores, plankton feeders and intern predators also (Mustow, 2002). It also showed that water availability governs the occurrence of Nepomorpha Gerromorpha bugs in agricultural fields.

The lower relative abundance of Gerromorpha in these agricultural fields except in AF3 during monsoon 2013 is an indication of disturbance in water quality. Gerromorpha as surface dwellers depend on surface tension and any alteration in water quality influencing the surface water tension do not allow the surface dwellers to skate over the water (Wilson *et al*., 2008). Insecticides and pesticides are well-known for negatively effecting the surface-dwelling predators like Veliidae, Mesoveliidae and Hydrometridae (Mustow, 2002) and for reducing invertebrate biodiversity within the rice fields (Wilson *et al*., 2008). For monitoring different types of systems, Biological Monitoring Working Party tolerance value and score (BMWP) is used. BMWP provides numerical values to specific "indicator" organisms at a particular taxonomic level (Armitage *et al*., 1983). The preponderance of the Nepomorpha bugs belonging to the family Micronectidae, Notonectidae and Pleidae which are known to be semi-tolerant to polluted water (BMWP tolerance value=5), also implies disturbances in the field

water to some extent (Mustow, 2002). Among all the three sites AF3 showed highest Shannon H′, highest Evenness and lowest Berger parker index of dominance.

The Whittaker plot, K-dominance plot and Rarefaction curves clearly showed seasonal variation in the dominance status, the evenness in the distribution, diversity and rarity among these Nepomorpha and Gerromorpha bugs (Magurran, 2003). Highly stiff Whittaker slope during monsoon 2014 in AF1 and during monsoon and post-monsoon 2013, and monsoon 2014 in AF2 imply higher dominance and lack of evenness in the systems. In contrast, the shallow slopes in AF3 during pre-monsoon 2014, monsoon 2014 and post-monsoon 2014 inferred higher evenness. Again, gradually declining slopes in AF3 during monsoon 2013 and post-monsoon 2013 have inferred higher species richness with almost even distribution (Magurran, 2003) of these Nepomorpha and Gerromorpha bugs. Thus, Whittaker plot produced a clear picture regarding the Nepomorpha and Gerromorpha bugs in the three agricultural fields. It statistically confirmed the higher evenness in AF3 in comparison to the other two agricultural fields with no or low dominance. K-dominance plot curves statistically infers how diverse a system is. As, the more the elevation in the curve, the less diverse is the system. Here all the curves in the three agricultural fields showed much shallower slopes in the study period except during pre-monsoon 2014 in AF3. It infers that these three agricultural fields of Barak Valley region harbours a diverse assemblage of these Nepomorpha and Gerromorpha bugs.

Rarefaction curves is used to compare the estimated number of species in relation to the number of individuals sampled from the system (Magurran, 2003). This provided a statistical information regarding the richness of the Nepomorpha and Gerromorpha bugs in the three agricultural fields that counts taxa richness as well as number of individuals. According to Maguran, 2003 the more elongated the Rarefaction curves are, the higher is the statistical richness of the system. Thus AF3 during monsoon 2013 with the longest rarefaction curve confirmed the highest richness of the bugs among the three agricultural fields. Spatially and temporarily rarefaction curves of AF1 were much shorter throughout the collection with the longest curve during monsoon 2014 although taxa richness was found higher during monsoon 2013. In AF2, longer curves were seen during monsoon 2013 and post-monsoon 2013 implying higher richness. Thus, richness was recorded higher in the monsoon seasons in all the three agricultural fields. Shortest rarefaction curve produced in AF1 during post-monsoon 2013 confirms lowest richness of these Nepomorpha and Gerromorpha bugs. Similarly, curves were shortest in AF2 and AF3 during pre-monsoon 2014. AF3 which was found to be disconnected from the nearby wetland during pre-monsoon 2014, produced very poor curve indicating very less number of taxa and absence of most of the species. Thus we can state that, wetland which was found directly connected to AF3 during monsoon and post-monsoon seasons has helped the agricultural field to maintain the higher population of these Nepomorpha and Gerromorpha bugs with higher species richness and evenness.

Also the presence of higher relative abundance of the Gerromorpha bugs that depends on the water surface tension implies that the wetland has helped AF3 in restoring the diversity of these bugs and has balanced the natural water condition of the agricultural field.

CONCLUSIONS

This study finds that the old and permanent agricultural fields of Barak Valley have the potential of harbouring diverse population of Nepomorpha and Gerromorpha. High availability of semi tolerant species of Nepomorpha and occurrence of relatively less number of Gerromorpha species in AF1 and AF2 indicated stressed condition of the system. The study revealed that among all the three agricultural fields the AF3 had the most stable habitat with highest species richness, higher species evenness, and lowest dominance associated with higher number of Gerromorpha species. The study also showed the positive impact of a wetland that helped the agricultural field to restore and maintain the natural condition in the AF3. This study also provided a primary data of aquatic and semiaquatic hemipterans of agricultural fields of this region for further investigation in future. Further, considering the ecological and economic importance of these Nepomorpha and Gerromorpha bugs as bioindicators and pest control agents, conservation of these predatory bugs may lead to a stable and robust system.

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REFERENCES

Ambrose, T., Mani, T., Vincent, S., Cyril, L., Kumar, A. and Mathews, K.T. 1993. Biocontrol efficacy of Gerris (A) spinolae, *Laccotrephes griseus* and *Gambusia affinis* on larval mosquitoes. Indian J. Malariol. 30: 187-92.

Armitage, P.D., Moss, D., Wright, J.F. and Furse, M.T. 1983. The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res. 17(3), 333–347. https://doi:10.1016/0043-1354(83)90188-4

Barber, H. 1913. Aquatic Hemiptera. Jour. New York ent. Soc., 21(1), 29-32.

Boda, P., Bozoki, T., Vasarhelyi, T., Bakonyi, G. and Varbiro, G. 2015. Revised and annotated checklist of aquatic and semiaquatic Heteroptera of Hungary with comments on biodiversity patterns. ZooKeys. 501: 89–108. https://doi:10.3897/zookeys.501.8964

Bouchard, R.W. 2004. Guide to aquatic macro invertebrates of the upper Midwest, water resources centre. University of Minnesota, St. paul, M N.

Cheng, L., Yang, C. M. and Polhemus, J.T. 2001. Guide to aquatic Heteroptera of Singapore and Peninsular Malaysia: Introduction and key to families. Raffles Bull. Zool. 49(1): 121-127

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.

Chitale, V.S., Behera, M.D. and Roy, P. S. 2014. Future of Endemic Flora of Biodiversity Hotspots in India. PLoS ONE. 9(12): 1-15 e115264. https://doi.org/10.1371/journal.pone.0115264

Damgaard, J. and Zettel, H. 2014. The water bugs (Hemiptera-Heteroptera: Gerromorpha and Nepomorpha) of New Caledonia: Diversity, ecology and biogeographical significance. In Guilbert E, Robillard T, Jourdan H, Grandcola P. (eds) Zoologia Neocaledonica 8: Biodiversity studies in New Caledonia. Muséum national d'Histoirenaturelle, Paris: 219-238 Mémoires du Muséum national Histoirenaturelle 206.

Dudgeon, D. 1999. Tropical Asian Streams-Zoobenthos, Ecology and Conservation. Hongkong University Press. Hongkong.

Engelmann H. D. 1978. Untersuchungen zur Erfassung predozoogener componenten im definierten. Okosystem. Forschungen. Staatl. Mus. Naturkde., Gorlitz.

Fairbairn, D. J. and Butler T. C. 1990. Correlated traits for migration in the Gerridae (Hemiptera, Heteroptera): a field test. Ecol Entomol. 15(2):131–142. https://doi:10.1111/j.1365-2311.1990.tb00794.x

Hebsgaard, M. B., Andersen, N. M., and Damgaard, J. 2004. Phylogeny of the true water bugs (Nepomorpha: Hemiptera-Heteroptera) based on 16S and 28S rDNA and morphology. Systematic Entomology. 29(4): 488–508. https://doi:10.1111/j.0307-6970.2004.00254.x

Hodkinson, I. D. and Jackson, J. K. 2005. Terrestrial and Aquatic Invertebrates as Bioindicators for Environmental Monitoring, with Particular Reference to Mountain Ecosystems. Environmental Management. 35(5):649-666. https://doi:10.1007/s00267-004-0211-x

Kandibane, M., Raguraman, S. and Mahadevan, N.R. 2007. Diversity and Community Structure of Aquatic Arthropods in an Irrigated Rice Ecosystem of Tamil Nadu, India. Asian J. Plant Sci. 6: 741-748. https://doi: 10.3923/ajpss.2007.741.748

Kiritani, K. 2000. Integrated biodiversity management in paddy fields: shift of paradigm from IPM toward IBM. Integrated Pest Management Reviews. 5:175–183. https://doi:10.1023/A:1011315214598

Lawler, S.P. 2001. Rice fields as temporary wetlands: a review. Israel Journal of Zoology. 47(4) 513-528. https://doi: 10.1560/X7K3-9JG8-MH2J-XGX1

Li, M., Tian, Y., Zhao, Y. and Bu, W. 2012. Higher Level Phylogeny and the First Divergence Time Estimation of Heteroptera (Insecta: Hemiptera) Based on Multiple Genes. PLoS ONE. 7(2), e32152. https://doi:10.1371/journal.pone.0032152

Mustow S. E. 2002. Biological monitoring of rivers in Thailand: use and adaptation of the BMWP score. Hydrobiologia. 479:191-229. https://doi:10.1023/a:102105592631

Magurran, A.E. 2003. Measuring biological diversity. Blackwell Publishing, Oxford. UK 18-71.

Nieser, N. 2004. Guide to aquatic Heteroptera of Singapore and peninsular Malaysia III Pleidae and Notonectidae. Raffles Bull. Zool. 52(1): 79-96

Nieser, N. and Chen, P. 2005. The water bugs (Hemiptera: Nepomorpha and Gerromorpha) of Vanuatu. Tijdschrift voor Entomologie. 148: 307-327

Ohba, S. and Nakasuji, F. 2006. Dietary items of predacious aquatic bugs (Nepoidea: Heteroptera) in Japanese wetlands. Limnology. 7(1), 41–43. https://doi:10.1007/s10201-006-0161-5

Papacek, M. 2001. Small aquatic and ripicolous bugs (Heteroptera: Nepomorpha) as predators and prey: the question of economic importance. European Journal of Entomology. 98: 1–12. https://doi: 10.14411/eje.2001.001

Polhemus, J.T and Polhemus, D.A. 2007. Global diversity of true bugs (Heteroptera; Insecta) in freshwater. In: Balian E.V., Lévêque C., Segers H., Martens K. (eds) Freshwater Animal Diversity Assessment. Developments in Hydrobiology, vol 198. Springer, Dordrecht.

Polhemus, D.A. and Polhemus, J.T. 2013. Guide to the aquatic Heteroptera of Singapore and Peninsular Malaysia. X. Infraorder Nepomorpha—Famlies Belostomatidae and Nepidae. Raffles Bull. Zool. 61(1): 25–45

Ponraman, G., Anbalagan, A. and Dinakaran, S. 2016. Diversity of aquatic insects in irrigated rice fields of South India with reference to mosquitoes (Diptera: Culicidae). JEZS. 4(4): 252-256.

Santana, H. S., Silva, L.C.F., Pereira, C.L, Simiao, F. J and Angelini, R. 2015. The rainy season increases the abundance and richness of the aquatic insect community in a Neotropical reservoir. Braz. J. Biol. 75(1): 144-151. https://doi: 10.1590/1519-6984.09213

Saha, A. and Gupta, S. 2018. Aquatic and semi aquatic Hemiptera community of Sonebeel, the largest wetland of Assam, northeastern India. JoTT. 10 (13): 12792-12799. https://doi.org/10.11609/jott.3440.10.13.12792-12799.

Skern, M., Zweimüller, I. and Schiemer, F. 2010. Aquatic Heteroptera as indicators for terrestrialisation of floodplain habitats. Limnologica 40(3), 241–250. https://doi:10.1016/j.limno.2009.09.002

Subramanian, K.A. and Sivaramakrishnan, K.G. 2007. Aquatic Insects for Biomonitoring Freshwater Ecosystems- A Methodology Manual. Ashoka

Trust for Ecology and Environment (ATREE), Bangalore, India.

Tordoff, A.W., Bezuijen, M.R., Duckwor, J.W., Fellowes, J.R., Koenig, K., Pollard, E.H.B. and Royo, A.G. 2012. Ecosystem Profile: Indo-Burma Biodiversity Hotspot, 2011 Update. Critical Ecosystem Partnership Fund, Washington, DC.

Thirumalai, G. 1989. Aquatic and semi aquatic Hemiptera (Insecta) of Javadi Hills, Tamilnadu. Rec. Zool. Surv. India, Occ. Paper. 18: 63.

Thirumalai, G. 1994. Aquatic and semi aquatic hemiptera (Insecta) of Tamilnadu-1. Dharampuri and Pudukkatai districts. Rec. Zool. Surv. India, Occ. Paper. 165:45

Thirumalai, G. 1999. Aquatic and semi-aquatic Heteroptera of India. Publication No.7. Hyderabad: Indian Association of Aquatic Biologists.

Thirumalai, G. and Radhakrishnan C. 1999. Aquatic Hemiptera (Insecta) of Kasaragode District, Kerala State. Rec. Zool. Surv. India. 97(3): 123-139.

Thirumalai. G. 2002. A checklist of Gerromorpha (Hemiptera) from India. Rec. Zool. Surv. India. 100 (1-2): 55-97.

Thirumalai G. 2007. A synoptic List of Nepomorpha (Hemiptera: Heteroptera) from India. Rec. Zool. Surv. India, Occ. Paper. 273: 1-84

Whiteman, N. K. and Sites, R.W. 2008. Aquatic insects as umbrella species for ecosystem protection in Death Valley National Park. J Insect Conserv. 12:499–509. https://doi:10.1007/s10841-007-9090-9

Wilson, A.L., Watts, R. J. and Stevens, M.M. 2008. Effects of different management regimes on aquatic macroinvertebrate diversity in Australian rice fields. Ecol Res. 23: 565–572.

Winterbourn, M. J. and Gregson, K.L.D. 1981. Guide to the aquatic insects of New Zealand. Bulletin of the Entomological Society of New Zealand, 5:1-8