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# Diversity Analysis of Aquatic Hemipterans in Southern Western Ghats, Kerala, India

**L.S.Bismi[1*] and Vattavila Vijayakumar[2]**

[1]Dept. of Zoology, Christian College, Kattakada, Kerala, INDIA
[2]Dept. of Zoology, VTMNSS College, Dhanuvachapuram, Kerala, INDIA

## ABSTRACT

The hemipterans are recognised as the fifth largest group of insects. These half-winged aquatic insects are most diverse group with interesting morphological and biological features and adapted to any habitat. The hotspot regions like Western Ghats are yet to be exploited in connection with aquatic hemiptera especially in the unique habitats like shola forests. The three Shola forests in Idukki district were chosen for the study. Diversity of aquatic hemiptera across altitude and seasonal diversity across the Shola during two years were the objectives. These were assessed using Shannon-Weiner diversity index, richness index, dominance index and evenness index.

**KEYWORDS**: Shola forest, Western Ghats, Hemiptera, Diversity, PAST

***Corresponding author**

**Dr. Bismi L.S.**

Department of Zoology,

Christian College

Kattakada, Thiruvananthapuram,

Kerala, INDIA

Email: bismisathya@gmail.com, Mob No- 9497470877

## INTRODUCTION

Aquatic insects are insects which are invaded in every type of aquatic biotope. The insects associated with aquatic habitats all of their life cycle belongs to the sub-order Heteroptera. The aquatic and semi-aquatic Heteroptera are grouped into two monophyletic in fraorders such as Gerromorpha and Nepomorpha. They constitue 92% of the aquatic and semi-aquatic species and the remaining species belonging to more or less water dependant Leptopodomorpha (Polhemus and Polhemus 1988)[1]. Nepomorpha are aquatic; living submerged and breathes atmospheric air. They periodically swimming to the surface or they have a long or short breathing tube. Parsons (1970,1972)[2,3] studied the plastron breathers and internal air carriers among the heteropterans generally. Most bugs belong to Gerromorpha are semi-aquatic (live on the water surface) and they feed while moving across the surface tension layer of the water. Most species of Nepomorpha and Gerromorpha have spiracle protecting layer of tiny setae which is hydrophobic in nature. Most of the hemipterans are predators (Domínguez and Fernández, 2009) [4]. They feed mainly upon other organisms with their modified feeding organs. Hemipterans of the family notonectidae use their beak-like structure called rostrum during feeding. Here, the maxillary stylets protrude from the rostrum tip through which, the bug injects poison (digestive enzyme or toxic saliva) into the prey and consume their tissue by sucking out the fluid (Cheng, 1966; Andersen, 1982)[5,6]. Water striders use its sensitivity to motion and water vibration to locate its food and capture prey by using their raptorial legs (Mazzucconi*et al.* 2009) [7]. Species of the families such as Belostomatidae, Nepidae, Naucoridae and Aphelocheiridae attack other animals in the same habitat of their own size such as tadpoles, frogs, juvenile fish, molluscs and other invertebrates (Keffer, 2000; Polhemus and Polhemus, 1988) [8, 1]. In ecosystems, predators play a very important role as energy transferors and thereby they control the population of other organisms (Oberndorfer *et al.* 1984; Cooper *et al*. 1990) [9, 10]. Hence the study of aquatic heteroptera is also important.

## LITERATURE REVIEW

A noteworthy study on Gerromorpha is of Andersen (1982) [6]. His study revealed that gerromorphan bugs are well known for their ability to walk (pleustonic) on water surface, and are seen on all kinds of lentic and lotic water bodies (Mesoveliidae, Hebridae, Paraphrynoveliidae, Macroveliidae,Gerridae, Veliidae, Hydrometridae and Hermatobatidae). Damgaard (2008 a, b) [11, 12] presented the molecular aspect of Gerromorphan phylogeny with the help of DNA. Thirumalai (2002) [13] reported that this infraorder consists of 138 species belonging to 44 genera in India so far. He (2007) [14] prepared a synoptic list of Nepomorpha from India which enlisted 153 species under 34 genera of aquatic bugs found in India. Two new species of the Genus *Anisops* Spinolae from lower

Western Ghats, Kerala (Thirumalai, 1983) [15]; Thirumalai (1986) [16] studied on Gerridae and Notonectidae (Heteroptera: Hemiptera: Insecta) from Silent Valley, Kerala etc. are the noteworthy studies of Nepomopha in India and or Kerala. In 2014, a detailed study on Hydrometra spp. from India was conducted by Jehamalar[18] and Chandra and reported two new species. Her contribution to science is *Strongylovelia lillyae* (Jehamalar, 2015) [19]. In another work, Thirumalai, and Radhakrishnan, (1999) [20] studied the aquatic Hemiptera of Kasaragode district in Kerala.

## MATERIALS AND METHODS

### *Study Sites*

Aquatic insects were collected during March 2012 to May 2014 from the water bodies of three altitudinal ranges throughout the Shola forests located in three areas in Idukki District. The Sholas were Mathikettan Shola National Park, Pampadum Shola National Park and Anamudi Shola National park with altitudinal range of 1000 to 1900m (>1000, 1200 and 1900), 1900 to 2200msl (1900, 2000 and 2200) and 1600 to 2400msl (1600, 2000 and 2400) respectively (Fig. 2 a,b and c). Details of study sites including altitude, latitude and longitude are given in Appendix 1.

***Collection***: Aquatic insect communities were sampled from hill streams of three habitats: runs, riffles and pools of the shola forests. The insects were collected using D-nets, kicknets and 'all-out-search' method (Subramanian and Sivarama krishnan 2007) [21]. At each shola, three important habitats - riffle, pool and small streams were selected for collection of aquatic insects. In the riffle area, insects were trapped in kick-net having 1 x 1 m area with a mesh size of 500 µm. Insects were collected in pool habitat with "D" frame pond net. The edges, on the vegetation area or strewn with rocks etc. and difficult for application of any net method, were randomly surveyed using appropriate collection methods.

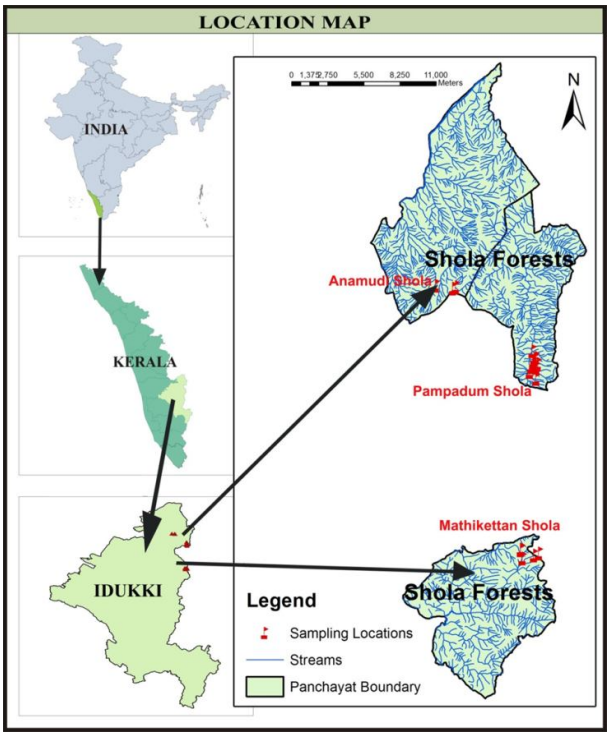


**Figure 1 Map of Kerala showing study sites**

**Figure 2 Collection Sites Showing Shola Forests – a).Mathikettan Shola National Park b). Pampadum Shola National Park c).Anamudi Shola National Park**

***Data Analysis*:** Species diversity indices such as Shannon-Weiner, Simpson's, Evenness, and Margalef were computed to understand the biotic community of each Shola.

Shannon-Weiner diversity index (H) (Magurran, 1988)[22] helps to assess the relative abundance of species in a given area. It is calculated from the equation: $\mathbf{H' = - \Sigma\ pi^{*}\ ln\ pi}$ Where pi is the proportion of individuals found in the $i^{th}$ species. In a sample the true value of pi is unknown and is estimated as ni/N (the maximum likelihood estimator).

Simpson's diversity index points towards abundance of the most common species (dominance measure) since they are weighted towards the abundances of the commonest species (Magurran, 1988)[22]. It can be calculated as: $\mathbf{D = \Sigma\ (ni\ (ni-1)/N\ (N-1))}$ Where ni is the number of individuals found in the $i^{th}$ species and N= the total number of individuals.

Evenness index is used for the degree to which the abundances are equal among the species present in a sample or community. Margalef index is having a good discriminating ability and is sensitive to sample size; it is a measure of the number of species present for a given number of individuals. The software used for statistical analysis was PAST (Hammer, 2001)[23].

## RESULTS

### *Biodiversity Indices*

The biodiversity of aquatic insects of shola forests in Idukki district was assessed using Shannon-Weiner diversity index, richness index, dominance index and evenness index.

Diversity indices analysis of hemipteran families across shola: The biodiversity indices of hemipteran families of Shola forests in Idukki district is presented in Table 1. The Shannon-Weiner diversity index of the hemipteran families recorded highest value of 1.507 in MNP and the Margalef species richness was 0.665 in PNP with a slight difference from MNP of 0.654. The values of Evenness index (0.9025) showed lesser even distribution of species, with relatively more value for dominance index.

**Table 1. "Biodiversity indices of hemipteran families across the shola forests in Idukki district, Kerala"**

| Shola | Individuals | Shannon_H | Margalef | Evenness_e^H/S |
|---|---|---|---|---|
| MNP | 453 | 1.507 | 0.654 | 0.9025 |
| PNP | 408 | 1.151 | 0.6654 | 0.6323 |
| ANP | 206 | 1.023 | 0.5631 | 0.6952 |

### *Diversity indices analyses of hemipteran families across seasons:*

The biodiversity indices of hemipteran families of shola forests across seasons during first year of the study period in Idukki district is presented in Table 2. The Shannon-Weiner diversity index of the hem ipteran families recorded highest value of 1.373 duringpre-monsoon in first year and the Margalef species richness was highest in pre-monsoon (0.843). The values of Evenness index

showed highest even distribution of species during monsoon with less number of individuals (98). The lowest Shannon value was recorded during monsoon and lowest Margalef index was recorded during monsoon itself. The lowest even distribution was plotted during post-monsoon in the first year of the study period with the highest number of individuals (211) compared with other seasons.

**Table 2: " Seasonal diversity of aquatic hemipteransacross three shola forests during 2012-2013"**

| Season | Individuals | Shannon_H | Margalef | Evenness_e^H/S |
|---|---|---|---|---|
| PrM | 115 | 1.373 | 0.843 | 0.7897 |
| M | 98 | 1.219 | 0.6543 | 0.8459 |
| PoM | 211 | 1.265 | 0.7474 | 0.7083 |

## *Diversity indices analyses of hemipteran families across seasons during second year (2013-2014) of the study period:*

The biodiversity indices of hemipteran families of shola forests across seasons during second year of the study period in Idukki district is presented in Table 3. The Shannon-Weiner diversity index of the hemipteranfamilies recorded highest value of 1.395 during post-monsoon in second year and the Margalef species richness was highest in post-monsoon (0.758). The values of Evenness index showed highest even distribution of species during post-monsoon with less number of individuals (195). The lowest Shannon value was recorded during pre-monsoon (1.188) and the lowest Margalef index was recorded during monsoon (0.7373) itself. The lowest even distribution was plotted during pre-monsoon (0.655) in the second year of the study period

**Table 3 :" Seasonal diversity of Aquatic hemipterans in three shola forests during second year of the study period"**

| Season | Individuals | Shannon_H | Margalef | Evenness_e^H/S |
|---|---|---|---|---|
| PrM | 221 | 1.188 | 0.741 | 0.6558 |
| M | 227 | 1.264 | 0.7373 | 0.7079 |
| PoM | 195 | 1.395 | 0.7586 | 0.8069 |

Diversity indices analyses of hemipteran families during the study period: The biodiversity indices of hemipteran families of Shola forests during the study period in Idukki district is presented in Table 4. The family Gerridae shows highest Shannon-Weiner diversity index (1.232) during the study period and the Margalef species richness was highest in the family Naucoridae (0.562). The values of Evenness index showed the highest even distribution of species in the family Gerridae (0.857) with 668 number of individuals. The lowest Shannon value was recorded in the family veliidae (0.803) and the lowest Margalefrichness index was recorded in the family veliidae (0.430) itself. The lowest even distribution was plotted in the family corixidae (0.734) during the study period.

**Table No. 4: " Diversity analyses of hemipteran families in three sholas"**

| Hemipteran families | Individuals | Shannon_H | Margalef | Evenness_e^H/S |
|---|---|---|---|---|
| Gerridae | 668 | 1.232 | 0.461 | 0.857 |
| Veliidae | 104 | 0.803 | 0.430 | 0.744 |
| Notonectidae | 934 | 1.223 | 0.438 | 0.849 |
| Corixidae | 268 | 1.078 | 0.536 | 0.734 |
| Naucoridae | 208 | 1.179 | 0.562 | 0.812 |

## *Diversity indices analysis of hemipteran species in threes sholas*

Diversity indices analyses of hemipteran species during the study period: The biodiversity indices of hemipteran species of Shola forests during the study period in Idukki district is presented in Table 5. The species *Enithares* showed highest number of individuals in three sholas (254) and *Limnogonus sp*. showed the least (28).During the study period,*Metrocorissp*showed highest Shannon-Weiner diversity index (1.091) among the others and the lowest was recorded by *Perittopus sp*. (0.22) during the study period. TheMargalef species richness was highest in the species *Limnometra*(0.4885) and the lowest value was shown by the species *Perittopus* (0.2531). The values of Evenness index showed the highest even distribution of species *Metrocoris sp*. (0.9929) and the lowest Evenness value was recorded in the species *Perittopus* (0.6234) during the study period.

**Table No.5: "Diversity analysis of hemipteran species in three shoals"**

| Species | Individuals | Shannon_H | Margalef | Evenness_e^H/S |
|---|---|---|---|---|
| *Metrocorissp* | 246 | 1.091 | 0.3633 | 0.9929 |
| *Limnometrasp* | 60 | 0.8897 | 0.4885 | 0.8114 |
| *Limnogonussp* | 28 | 0.5983 | 0.3001 | 0.9095 |
| *Perittopussp* | 52 | 0.2206 | 0.2531 | 0.6234 |
| *Sigara (Tropocorixa) sp* | 110 | 0.8372 | 0.4255 | 0.7699 |
| *Enitharessp* | 254 | 1.076 | 0.3612 | 0.9779 |
| *Anisopssp* | 213 | 1.021 | 0.373 | 0.9251 |
| *Heleocorissp* | 104 | 0.9709 | 0.4306 | 0.8801 |

## DISCUSSION AND CONCLUSION

India gained global attention through its culture, geography and biodiversity etc. India has two biodiversity hotspots such as, the Western Ghats and the Eastern Himalayas. The knowledge of aquatic and semi-aquatic Hemiptera from these areas is limited to the taxonomic preliminaries, recording a few species from different parts of these regions. Thirumalai and parties of Zoological Survey of India (1983 to 2006) conducted some survey regarding studies of aquatic and semi aquatic

bugs in Western Ghats. In connection with that the present study was conducted by surveying the Shola forests in Idukki district of Kerala, parts of Southern Western Ghats. In order to study the biodiversity, almost all of the aquatic insects were collected from three Shola forests, Mathikettan Shola National Park, Pampadum Shola National Park and Anamudi Shola National Park during the period of June 2012 to May 2014. Nymphs and larvae of insect orders such as Ephemeroptera, Plecoptera, Trichoptera and Coleoptera were also collected with true aquatic insect order Hemiptera.

Diversity is the richness and variety of a natural community (Odum, 1971) [24]. Variety of species and relative abundance of species are the two components of diversity. It is essential to measure for effective management and conservation of species in a particular habitat according to the number of individuals and number of species. Generally three categories of species diversity measures are there. It includes species richness indices, the species abundance and propotional abundance of particular species indices (Magurran, 1988) [22]. A very few studies have been conducted on the insects in shola. In 1995, Thomas *et al* (1995) [25] reported on the patterns and changes of litter arthropods at different altitudes in Kodaikanal hills.

The present study documented seven species of Nepomorpha and Gerromorpha in shola forests among the 1454 number of aquatic insects. Mathew *et al* (2001) [26] reported 1051 insects belonged to 344 species from Mannavanshola (Anamudishola national park) and 150 insects from Chembra hills at different duration of studies. He also reported 5.36 species diversity at Mannavan Shola and Chembra was 4.22. Similar studies conducted in other parts of Western Ghats reported that species diversity ranged between 4 and 5 (Mathew *et al*, 1998) [27]. The Shannon diversity of hemipteran families of three shola forests in the present study showed that it ranged between 1.507 (MNP) and 1.023(ANP). Margalef index showed the range of 0.665 (PNP) to 0.563(ANP). This diversity range cannot be compared with the studies of Mathew *et* al hence the present study exclusively for aquatic insects in the Shola. However, all the studies revealed that species diversity was decreased with increasing altitude. Similar observation was observed in the present study that there is a negative correlation between species diversity and altitude. The Margalef's species richness index showed highest value in PNP (0.665) and lowest value in ANP (0.563). But, the study of Mathew *et al* (2001) [28] reported the insect species richness was highest in Mannavan shola (part of Anamudi shola national park) (10.61). Here also, the study was in relation with terrestrial insect fauna. This may be the reason which the richness index showed less in the present study. Due to its endemic nature, aquatic insects have to be protected through conservation of Shola forest.

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## CONFLICT OF INTEREST

Authors declare no conflict of interest

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## APPENDIX

**Details of study sites of Shola forests in Idukki District, Kerala**

| Station | Latitude | Longitude | Altitude (m) |
|---|---|---|---|
| Anamudi Shola S 1 | N10° 09' 58.48″ | E77° 09' 23.47″ | 1600 |
| Anamudi Shola S 2 | N $10^0$ 11' 30.5″ | E$077^0$12' 20.9″ | 2000 |
| Anamudi Shola S 3 | N $10^0$ 14'52.2″ | E$077^0$11'30.4″ | 2400 |
| Pampadum Shola S 1 | N $10^0$ 07' 58.5″ | E$077^o$14'28.4″ | 1900 |
| Pampadum Shola S 2 | N$10^o$10'70.9″ | E$077^0$15' 25.5″ | 2000 |
| Pampadum Shola S 3 | N $10^0$ 07' 70.9″ | E$077^0$17' 28.4″ | 2200 |
| Mathikettan Shola S1 | N $9^0$ 57'51.2″ | E$076^0$14' 34″ | 1000 |
| Mathikettan Shola S 2 | N $9^0$80' 82.4″ | E$076^0$15'35.3″ | 1200 |
| Mathikettan Shola S 3 | N $10^0$ 01' 09.3″ | E$076^0$16' 41.7″ | 1900 |