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Millipede Diversity and Distribution in the Sirumalai Hills (Eastern Ghats), Tamil Nadu, India

B. Ramanathan[1], R. Gnanamani[2] , T.S. Pathan[3] and G.Indira Rani[4]

[1]*Department of Zoology, Yadava College, Madurai – 625 014, India.*
Email: ram040784@gmail.com
ORCID ID: 0000-0001-5964-4650

[2]*Department of Zoology, Yadava College, Madurai – 625 014, Tamil Nadu, India.*
Email: gnanamani87@gmail.com
ORCID ID: 0000-0001-6662-1510

[3]*Department of Zoology, Kalikadevi Arts, Commerce and Science College, Shirur (Ka), Maharashtra, India. Email: drtanvir7981@gmail.com*
ORCID ID: 0000-0002-7368-586X

[4]*Department of Zoology, E.M.G. Yadava College, Madurai-625014, India*
Email:*ranima94@gmail.com*
ORCHID ID: 0009-0000-7491-6132

**Corresponding author's E-mail: ram040784@gmail.com*

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Abstract

Millipedes are one of the significant terrestrial fauna in the forest ecosystem to decompose the plants' debris. Despite their environmental significance, records on millipede distribution are quite scarce and invalid in Tamil Nadu, India. The first investigation is an attempt to assess the population of millipedes at different elevation levels of Sirumallai Hills from July 2020 to June 2021. The number of millipedes was recorded using pitfall trapping and quadrant sampling. Millipede diversity and distribution in different elevations were evaluated with the help of Shannon's and Simpson's indexes and richness and evenness were estimated by standard methods. A total of 8 species of millipede belonging to the order Polydesmida, Sphaerotheriida and Spirobolida were recorded in lower, middle and higher elevations. Our results showed that Orthomorpha coarctata, Oxidus gracilis, Haphaphe haydeniana, Aulabolus newtoni and Trigoniulus corallinus species were in found all the elevations and most abundant in lower elevations. Arthosphaera magna, Arthosphaera dalyi and Arthosphaera distica species were abundant in middle elevations and scarce in upper and lower elevations. Diplopod species abundance and diversity were lesser in lower and higher elevations when compared to the middle elevation. Despite their richness similarities in all elevations, there were differences in the composition of the millipede species between the elevations.

Keywords: *Millipede, Orthomorpha coarctata, Oxidus gracile, Trigoniulus corallines, Arthosphaera magna, Arthosphaera dalyi and Arthosphaera distica*

1. Introduction

Biodiversity offers a significant role in the worldwide economy and sustainable development by providing direct and indirect benefits to mankind. Rich biodiversity indicates a healthy environment and the development of life-support essential for the welfare of people through various goods and

services. The biological diversity enriches the soil, maintaining the water and climatic cycle and changing waste materials into rich manure. Macroinvertebrates play an important role to provide fertility to soil by stimulating the stability and productivity of forest[19]. Moreover, elevation is purely alternate for a suit of biotic and abiotic factors that influence the level of biodiversity[2]. Hence, identifying ecologically important causal fundamental factors is vital to explain variation in species richness along elevation gradients[29].

Monitoring biodiversity in forest ecosystems is a fundamental step to assessing their functions and providing the required information for effective management[28]. Invertebrate animals are essential, effective components and useful indicators of other fundamental elements of biodiversity, maintaining of ecosystem and renewal, health system and related threats[30]. While, the most ecological importance of invertebrates in forest ecosystems, they have little attention because of identifications difficulty. For creating to plan the conservation of these animals, monitoring biodiversity is a significant procedure to determine the diversity pattern and distribution of species within the forest ecosystem. Macroinvertebrates enrich the quality of forest soil through a breakdown of litter due to feeding and burrowing activity[23]. In this important soil component, millipedes are one of the vital macro arthropods that contribute to maintaining the forest ecosystem.

The class diplopods (Myriapoda) are millipedes belonging to the phylum Arthropoda which is the third largest class after Insecta and Arachnida[40]. An estimated 80,000 species and subspecies of millipedes around the world, of which only 12,000 species have been described formally[6]. Millipedes known as a thousand leggers move very slowly because they have short legs and also millipedes are lethargic and secretive animal[32]. Millipedes are widespread on all continents except Antarctica and are mostly found in deciduous temperate, tropical and subtropical forests (dark and damp places, under the stone logs and bark of a tree, rotting leaves and rotten wood)[16]. Millipedes are significant macro arthropods in forest ecosystems and play a crucial role in enriching the decomposing process of plant debris and stimulating the microbial activity[35]; serve as environmental indicator[25;] improve the soil structure content of organic matter and nutrients components of soil[38].

Biodiversity improves the economic value of the human population directly or indirectly[14]. Modern research focused on how biodiversity influences ecosystem and ecological processes which are created a positive relationship between biodiversity and ecosystems[33,27]. The occurrence and abundance of millipede species depend on their habitat which alters with increasing altitude[8], thereby differentiated by availability of food materials and vegetation structure[4]. The diversity pattern of millipedes was reported in Alagar Hills Reserve Forest in Tamilnadu[1]. A little diversity of the pill millipede was reported in an evergreen forest of Westernghats, India[3, 21]. Choudhari *et al*.,[12] studied the diversity of millipedes in Yelagirihill, Eastern Ghats. Chezhian and Prabakaran[11] observed the diversity pattern of millipede species in Yelagirihill, Eastern Ghats. Recent research noted the millipede diversity pattern and its changes in the Northern and Western Ghats of Rajgurunagar, India[5,32]. Thomas wesener[41] said that, though several authors worked as millipedes in India, Indian authors use or used Diplopoda in their publication works only. Moreover, He suggested that documentation and identification of millipedes are poor in India and young researchers come forward to make proper taxonomy key for Indian millipede species. Hence, this is a little attempt to work to identify and provide information on millipede diversity within the Southern Eastern Ghats of Sirumalai hills in Tamil Nadu, India.

2. Materials And Methods

Study Area

Sirumalai Hills (Eastern Ghats) biosphere evergreen reserve (10º27'N 77º29' E) in Tamil Nadu, located in Dindigul District and extends to Madurai District. The two types of vegetation are layered, in which the lowered vegetation is very poor. The canopy is open dry deciduous or evergreen vegetation. Three different locations were selected at different altitudes at Sirumalai hills (950 (lower elevation), 1150 (middle elevation) and 1350 (higher elevation) masl (meters average sea level)), which were visited every month from July 2020 to May 2021. The lowest site was at 950 m elevation because that is where millipedes seemed to first occur, while 1350m is the highest elevation of the Sirumalai Hills reserve forest. Observation of millipedes was made through 5 quadrats (1 m × 1 m) in each study site and each sampling date and the mean number of millipedes/quadrats was calculated.

Millipedes were collected from the study area by hand picking, and species were identified by using various field guides and available literature.

Data Analysis

Standard methods were used to calculate the richness and evenness of millipede species at different altitudes. The diversity indices were calculated using the Ludwig and Reynolds software package[27]. Two indices are needed to compute Hill's diversity numbers: (a) Simpson's index (λ), which is sensitive to changes in the most abundant species in a community and (b) Shannon's index (H1), which is responsive to changes in the great quantity of rare species in the community. Meteorological data such as temperature, humidity and rainfall of the study area were collected from the study area during the study period simultaneously.

3. Results and Discussion:

Millipede samples were collected in three elevations and identified based on the morphological characteristics features such as color, head, antennae, mandibles, gnathochilarium, column, thoracic shield, tergites, anal shield, legs and genital pores. In total 8 millipede species belonging to three orders were identified from 541 individuals. Polydesmida (3 species) and Sphaerotheriida (3 species) were the most represented in terms of species richness followed by and Spirobolida (two species). Out of 541 individuals, the highest millipede abundance was observed in the middle elevation (294 individuals, representing 54.34% of all millipedes were collected). Next to this, in lower elevation, 186 individuals, 34.38% of all the millipedes were collected. Whereas, at the higher elevation, 61 individuals, 11.27% of all the millipede species were collected.

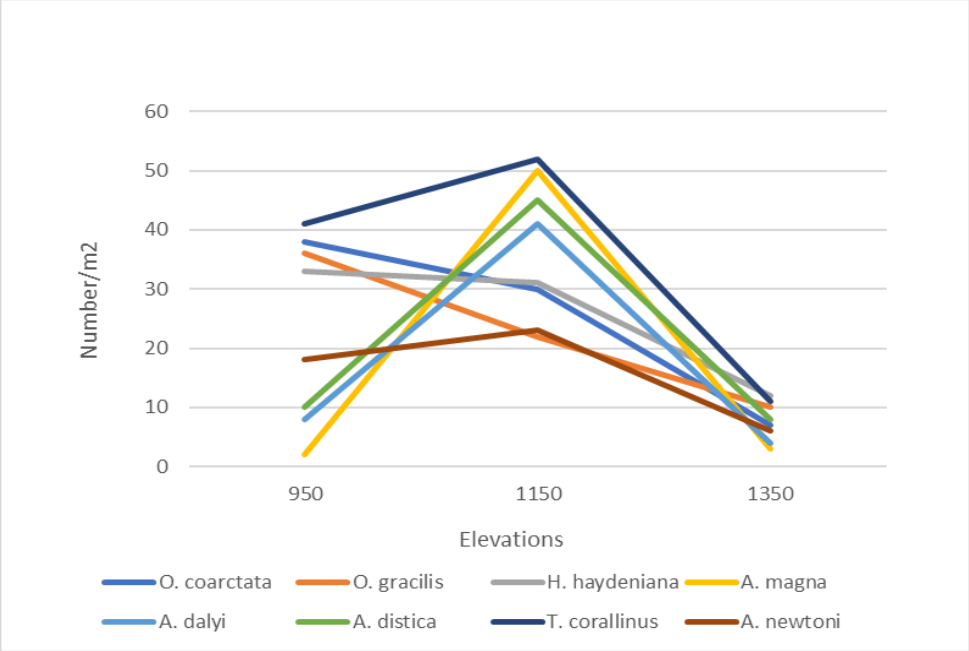
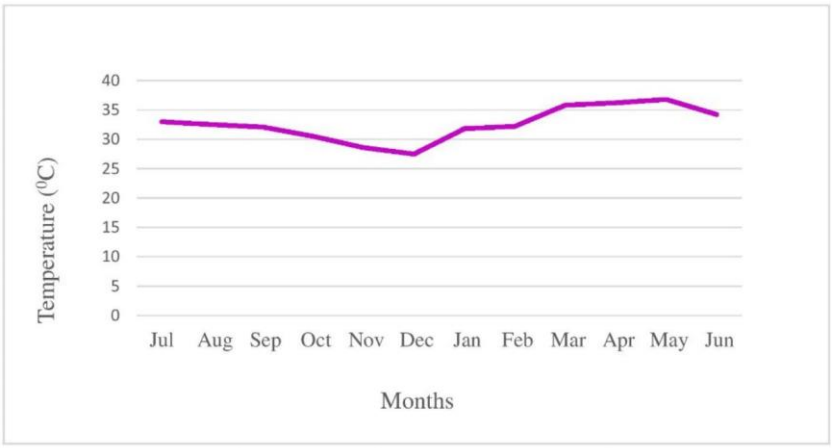


Fig.1 Density of eight different Millipede species in the study area of Sirumalai hills during July 2020- June 2021

The maximum number of millipede, *T. corallines* (41/m^2) and a minimum number of millipede, *A. magna* (02/m^2) were observed in lower elevations. The most number of millipedes in middle elevation *T. corallines* (52/m^2) and the least number of millipedes, *O. gracilis* (22/m^2) were observed. Whereas, the highest number of millipede *H. haydeniana* (12/m^2) and lowest number of *A. magna* (3/m^2) were observed in the higher elevation. The density of the millipedes decreased in the order of elevation 1150 M (294/m^2), 950 M (186/m^2) and 1350 M (61/m^2) from July 2020 to May 2021 (Fig.1). In general, differences of millipede abundance among the elevation types were highly significant ($P<0.05$).

Fig.2.



Temperature in the study area from July 2020 to June 2021.

Fig.3. Humidity in the study area from July 2020 to June 2021.

Richness indices (R_1: 1.23; R_2: 0.46) and Simpson's index (0.11) were found to be lesser in the mid-elevation (1150 m) than in the lower elevation (0.16) and higher elevation (0.13) (Table.1.1). With reference to Shannon's index, it declined from -1.99, -1.91 and -1.80 at 1150, 1350 and 950 m elevations respectively. With respect to Hills diversity number, it was maximum (N_1: 0.13; N_2: 8.33) in middle elevation (1150 m) followed by (N_1: 0.14; N_2: 7.69) in higher elevation (1350 m) and (N_1: 0.16; N_2: 6.25) in lower elevation (950 m). The three indices (E_1, E_2 and E_3) were chosen to assess the evenness of millipede species abundance in the elevations. The lowest species evenness indices were observed in altitudes 950 m (E_1: 0.88; E_2: 0.02; E_3: -0.12) followed by 1150 m (E_1: 0.98; E_2: 0.01; E_3: -0.12) and 1350 m (E_1: 0.94; E_2: 0.01; E_3: -0.12).

Climatic factors that prevailed near the study area are provided in Figure.1, 2 and 3. During the study period, maximum (36.8^{0}C) and minimum (27.3^{0}C) temperatures were recorded in May 2021 and December 2020 respectively. Whereas maximum (73.3%) and minimum (48%) humidity were recorded in November 2020 and April 2021 respectively. The highest rainfall (240.01mm) was observed in October 2020. The meteorological parameters such as temperature and humidity significantly altered the population density and biomass of millipedes. A critical comparison of rainfall with the data on population density and biomass did not provide any significant conclusion.

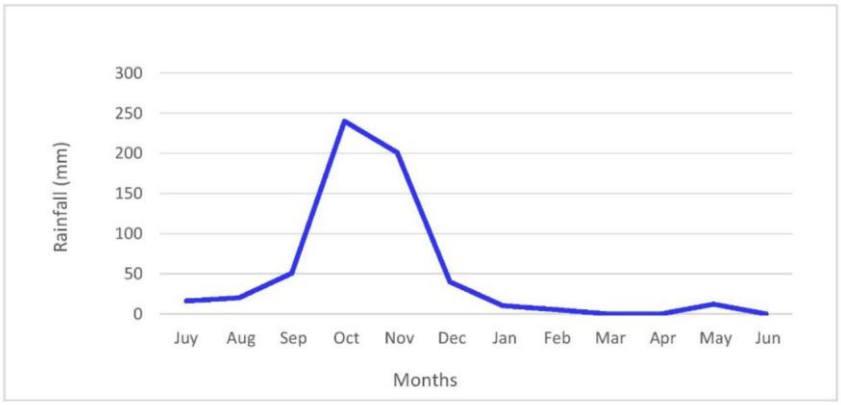


Fig.4. Rainfall in the study area from July 2020 to June 2021.

Table.1. Diversity of different species of millipedes distributed at three elevations of Sirumalai hills reserve forest from July 2020 to May 2021.

Indices		Elevations		
		950 M	1150 M	1650 M
Richness	R_1	1.34	1.23	1.70
	R_2	0.58	0.46	1.02
Diversity Indices	Simpson's index (λ)	0.16	0.11	0.13
	Shannon's Index (H')	-1.80	-1.99	-1.91
Hills Diversity	N_1	0.16	0.13	0.14
	N_2	6.25	8.33	7.69
Evenness	E_1	-0.88	-0.98	-0.94
	E_2	0.02	0.01	0.01

Source: Ledwig and Reyonlds, 1988

Table:2 Temperature in the study area from July 2020- June 2021

Month	**Temperature (^{O}C)**
July-2020	33
August-2020	32.5
September-2020	32.1
October-2020	30.5
November-2020	28.6
December-2020	27.5
January-2021	31.8
February-2021	32.2
March-2021	35.8
April-2021	36.2
May-2021	36.8
June-2021	34.2

Table.3: Rainfall in the study area from July 2020- June 2021

Month	Ranifall (mm)
July-2020	16.3
August-2020	20.2
September-2020	50.7
October-2020	240.1
November-2020	200.8
December-2020	40.2
January-2021	10.6
February-2021	5.7
March-2021	0
April-2021	0
May-2021	12.2
June-2021	0

Table.4: Humidity in the study area from July 2020- June 2021

Month	Humidity (%)
July-2020	53.7
August-2020	56.9
September-2020	60.8
October-2020	70.4
November-2020	78.3
December-2020	72.5
January-2021	53.2
February-2021	50.5
March-2021	49.2
April-2021	48
May-2021	49.3
June-2021	50.6

The present study determined the diversity and distribution of millipede species in three elevations of Sirumalai Hills, Tamil Nadu, India. The occurrence of the millipede community showed high dissimilarity among the sites and strong patterns of turnover along the elevational gradient. Shannon's (H') and Simpson's (λ) diversity indices were calculated. Moreover, both indices are sensitive to changes in the abundance of rare species in a community and the most abundant species in a community. The present study noted that the two diversity indices showed much difference in millipede distribution and diversity. Shannon's index predicts that each member is randomly sampled from a large population and all millipedes are represented in the sample. Simpson's index, which gives the possibility of two individuals drawn at random from a population belonging to the same species, increases with the decrease in diversity. Hence, it is understood that mid-elevation has the highest diversity, and the lowest and highest elevations have the lowest diversity pattern.

The important variation of abiotic and biotic environmental changes along elevational gradients strongly affects the patterns of abundance, distribution, and diversity of most organisms. As emphasized by Brown and Lomolino[7], lower elevational zones usually vary from higher altitude by the following: (1) a greater overall quantity of resources and population number; (2) additional refugia and space for species with large habitat ranges; (3) greater habitat diversity; and (4) a greater possible for serving as a target for potential immigrants. The great quantity of feeding associations can strongly depend on habitat structure[8] which changes with increasing altitude, thereby differentially changing the existing amount of food resources for feeding guilds and the vegetation structures necessary for foraging by different functional groups along the elevation gradient[4].

Millipede species community composition was unique at each location along the elevational gradient. These elevational patterns are reliable with those of arid climates where communities are formed by temperature and precipitation[10,17]. The present investigation reveals the point that a high level of millipede species diversity in mid-elevation, which confirms the mid-elevational richness in species abundance is recorded in the Philippines by Samson *et al*.,[37] and from Madagascar by Fisher[15].The higher Shannon's diversity index exposed by middle elevation indicates that it delivers more chances for survival in the form of ecological niches than those in lower and higher elevations. The lower level of elevation is highly disturbed due to human movements and cattle grazing. Moreover, in lower elevations, the canopy cover is open due to this dry and barren land rendering fewer potential niches. The rocks and stones provide shelter to millipedes from extremes of temperature and humidity during summer. Closed canopy is the first significant factor that reduces the sunlight and the second factor is under-story vegetation in higher elevation reduces the number of potential niches. In higher elevation, the rate of transpiration by plants is high which creates humid climatic condition and nearby water streams makes the surrounding very cool. This may be the reason for moderate evenness and diversity indices shown by the higher elevation. But, the middle elevation with reasonable canopy and litter supports understorey vegetation like herbs and shrubs and offers more potential niches and protection during periodic flooding. All species of millipede occupied equal proportions in the middle elevation, and this confirms the high evenness and diversity indices observed in middle elevations.

Derek *et al*.,[13] suggested that ground-dwelling arthropod assemblages are context-dependent making them extremely vulnerable to environmental change, particularly in lower (arid) and higher (precipitation) elevations. Middle elevation provides the most suitable environment for arthropods when compare to the lower and higher elevation hence maximum availability of arthropod species in mid elevation[9]. Jan Peter *et al*.,[20] recorded that arthropod species richness peaks at mid-elevation, these patterns may be driven by unlikable climatic conditions at higher elevations which are influenced by human disturbances at lower elevations. Different elevational richness patterns are probably due to (a) a general decline of species richness with increasing altitude[39], (b) a plateau of species being the richest at lower altitudes then declining towards the highest elevations[18] and (c) a mid-elevation peak of species richness[22,24]. Moreover, mid-elevation are centers of the richest diversity hence peak litter arthropod abundance was recorded at middle elevations by Sabu *et al*.,[36]. Alagesan and Ramanathan[1] emphasize that millipede species diversity and abundance were higher in the middle elevation compared to that in lower and higher elevations of Alagar hills (Eastern Ghats).

Andrea *et al*.,[2] combined six reasons out of the hypotheses projected for variation in species diversity, namely, time available for speciation and scattering, spatial heterogeneity, floral structure, competition, environmental stability, and productivity. These explanations can be attributed to the variation in diversity indices between elevations observed in the present examination. From the present investigation, it is confirmed that distinct deviations in the diversity of millipede species in different elevations and the highest diversity of millipedes noted at the middle elevation in the Sirumalai hills (Eastern Ghats) suggest that these are centers of the richest diversity and abundance that should be imported as areas for further intense conservation.

4. Conclusion

Millipede (Ground – dwelling macro arthropods) species varied in different elevations in the Sirumalai Hills, Tamil Nadu, India. This variation is likely driven by temperature and precipitation. The present investigation suggests that millipede assemblages are dependent on the climatic environment of the elevation, which is affected in lower elevation due to arid and human disturbances and higher elevation in humid. In the middle elevation, reasonable canopy and litter support understorey vegetation and offer more potential niches to the millipedes and protection during periodic flooding. Moreover, the Middle elevation provides the most suitable environment for millipedes when compared to the lower and higher elevation. Hence, all species of millipede occupied an equal proportion in the middle elevation, and this confirms the high evenness and diversity indices observed in middle elevations. Furthermore, the middle elevation act as a center of the richest diversity and abundance of millipede species, hence we provide special attention to mid-elevation for further intense conservation of endemic millipede species.

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Conflict of interest:
The authors declare no conflict of interest.

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