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Altitudinal gradients and species richness: A study on diversity of orthoptera in Nilgiris Shola Forests and Grasslands

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Abstract

Uplands provide refuge for insects subject to lowland habitat loss, but information on their response to climate change is lacking particularly orthopterans. There is a significant reduction in the diversity of grasshoppers however a shift of highly mobile and polyphagous insects towards higher altitudes is prevalent, in the era of climate change. Our study on the diversity of grasshoppers in the Nilgiris shola forest supported that the shift of grasshopper from mid-altitude to high altitude. The high values of Shannon's diversity index (H') were recorded in Nedugula (1.43) followed by Longwood (1.34) and Avalanche shola forests (1.29). The species distributed only in lowland forests are now recorded in the high altitudinal stunted wet evergreen shola forests. It is evident from our study that the upland forests provide refuges to highly mobile insects like grasshoppers when lowland sites have an impact on climatic fluctuations.

Keywords: Altitude, Conservation, Diversity, Orthoptera

Introduction

The altitudinal change was an important parameter to determine the distribution of species. Species diversity and distribution in a particular temperature as well as the microclimate of the habitat including physical and chemical properties of substrate that governed by the altitude, showing a significant correlation between altitude and species distribution (Cesar *et al.*, 2010; Alam *et al.*, 2011). The Nilgiris a part of the Western Ghats in Tamil Nadu has the richest in flora and fauna (Senthamarai Selvan *et al.*, 2016). Since orthopteran insects are good indicators of climate and landscape changes (Corinna & Michael, 2011) and no authentic record of Orthoptera in these sholas was available.

The montane wet temperate forests are the stunted ever green forests locally known as 'sholas'. They are found above 1500 m in the glens, hollows and valleys of the mountains. Nilgiris sholas are situated in the higher mountain tracts of the southern Western Ghats, at an altitude above 1800 m, interspersed with rolling grasslands. Nilgiris sholas are unique in terms of their vegetation and species diversity (Senthilkumar *et al.*, 2014). In the sholas the trees square measure with crooked branches thickly laden with nonvascular plant and alternative epiphytes (Senthamarai Selvan *et al.*, 2015). The natural vegetation in the sholas and the grasslands in Nilgiris was depleting very fast due to introduction of commercially valuable fast-growing trees like Wattle, Eucalyptus, Cypress and Pine to provide pulp for the paper industries by English during the 19th Century. Fortunately, by the late eighties, there was a shift in Government policies. Further plantations of wattle and Eucalyptus were stopped. Experiments are now on to reconvert these plantations into sholas. Studies have shown that the majority of the endemic plants of the Nilgiris tract are highly threatened and many are already extinct because of loss of habitat due to anthropogenic pressure.

Orthoptera is one of the largest orders of the class Insecta, which includes the well-known grasshoppers,

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locusts, crickets, and katydids (Rahana Moideen Koya *et al*., 2017). They form a dominant group of herbivorous insects (Sinclair, 1975) throughout the world, and their high diversity, functional importance and sensitivity to disturbance make them potentially useful bio indicators for land management and climate change (Weiss *et al*., 2013). They are known to occur in a wide variety of habitats, ranging from the littoral zone of the sea shore to grasslands, forests and mountaintops, well above the tree line. Some models explain that the number of species in the 100 m altitudinal bands increases steeply with altitude until 1,500 m above sea level, and between 1,500 m and 2,500 m, little change in the number of species was observed, while above this altitude, a decrease in species richness was evident (Mathew & Mohandas, 2001). However, certain models indicated that insect distributions shift towards higher latitudes, and altitudes (Regniere *et al*., 2009). The current study was focused on orthopteran diversity in the Nilgiris shola forest.

Materials and Methods

Study Sites

The study sites were randomly selected from Nilgiris north and south forest division, Udhagamanadalm. Three locations were selected in each forest division viz., Kothagiri Longwood shola, Uppati shola, Nedugula shola from Nilgiris north division, Avalanche cauliflower shola, Ninth-mile shola and Parson's valley shola from Nilgiri south division respectively. The main criteria for the selected study area are having a high altitude level and having mosaic nature. The Geological attributes were marked for using GPS (e-Tres 30x (Garmin), study sites falling between 11˚12'68.20" N and 11˚44'18.00" N latitude with the elevation ranges from 1937 m AMSL to 2295 m AMSL.

Sampling Method

The entire vegetation was covered by the intensive search out method, which is easy to identify an orthopteran specimen and collected by hand picking as well as sweep net method after locating them. This is one of the widely used sampling methods for sampling Orthoptera (Sanjayan, 1994). Observation on Orthoptera was conducted between 0700 hrs to 1300 hrs during the study period December, 2016 to November, 2018.

Preservation and Identification of Specimens

Collected specimens were narcotized with menthol crystals, brought to the laboratory, processed and pinned properly for further identification. All the specimens were examined carefully and labelled identified specimens were preserved in insect boxes. A cotton wad immersed in preservative (Phenol, Naphthalene, and Para dichlorobenzene in equal ratio) was kept in the corner of the box to restrict ant and fungal attack. The specimens collected were identified by using known literature (Rentz (1979), Tandon and Shishodia (1972), Ingrisch (1990, 2002), Ingrisch and Shishodia (1997, 1998, 2000), Shishodia (2000a, b), Shishodia and Tandon (1990), Naskrecki (1994, 1996a, b, 2000), Naskrecki and Otte (1999) and Senthilkumar *et al*. (2001, 2002). The voucher specimens were present in the depository of the Zoological Survey of India, Southern Regional Centre, Chennai.

Data Analysis

As a measure of a-diversity (diversity within a habitat), the most popular and widely used Shannon's diversity index (H¢) was calculated since it is well accepted that all species at a site, within and across systematic groups contribute equally to its biodiversity (Ganeshaiah *et al*., 1997). In addition, Simpson's diversity index (l) and coverage estimators were also calculated as per Colwell and Estimate (2004) using the software EstimateS 7 as well as prioritization of species for selection of a site for conservation of Orthoptera was calculated by Senthilkumar *et al*. (2002).

Results

The studies on orthopteran fauna of the Nilgiri Shola forests gave us promising results to conserve Orthoptera. Fifteen species of Orthoptera were recorded from Nilgiris Shola forests and grasslands (Table 1). Six species belonging to the family Acrididae and Tettigoniidae were collected followed by two species in the family Gryllidae and only one species was recorded in the family Prygomorphidae.

The species *Phlaeoba infumata* Brunner von Wattenwyl, 1893 was recorded in four sites viz., Avalanche and Ninethmile of Nilgiris south forest division, Longwood and Nedungula of Nilgiris north forest division as out of six sites. The taxonomic hierarchy

Table 1. Species richness and priority analysis through root weight of Orthopteran fauna in Nilgiri sholas

Sl. No.	Name of the Species	Name of the Subfamily	Weight	Avalanche	Longwood	Nedugula	Ninth mile	Parson's valley	Uppati
1.	*Orthacris (Orthacris) maindroni* Bolívar, 1905	Orthacrinae	9	-	+	-	+	+	-
2.	*Oxya fuscovittata* (Marschall, 1836)	Oxyinae	9	-	+	-	-	-	-
3.	*Gryllodes sigillatus* (Walker, 1869)	Gryllinae	8	-	+	+	+	-	-
4.	*Phlaeoba infumata* Brunner von Wattenwyl, 1893	Acridinae	7	+	+	+	+	-	-
5.	*Orthelimaea securigera* (Brunner von Wattenwyl, 1878)	Phaneropterinae	7	-	-	-	-	-	+
6.	*Phaneroptera (Phaneroptera) gracilis* Burmeister, 1838	Phaneropterinae	7	-	-	-	-	-	+
7.	*Heteracris pulchra* (Bolívar, 1902)	Eyprepocnemidinae	9	-	-	+	-	-	-
8.	*Gastrimargus africanus* (Saussure, 1888)	Oedipodinae	9	+	-	+	-	-	-
9.	*Mirollia cerciata* Hebar, 1922	Phaneropterinae	7	+	-	-	-	-	-
10.	*Mecopoda elongata* (Linnaeus, 1758)	Mecopodinae	9	+	-	-	-	-	-
11.	*Euconocephalus incertus* (Walker, 1869)	Conocephalinae	9	-	-	-	+	-	-
12.	*Hexacentrus major* Redtenbacher, 1891	Hexacentrinae	9	-	-	-	-	+	-
13.	*Acrida exaltata* (Walker, 1859)	Acrididae	7	-	-	-	-	-	+
14.	*Acrida gigantean* (Herbst, 1786)	Acrididae	7	+	-	-	-	+	-
15.	*Gryllus (Gryllus) bimaculatus* De Geer, 1773	Gryllidae	8	-	-	+	-	-	-
		Total Diversity	121	39	33	41	33	25	21
		P1	27	34	27	21	17		
		P2	21	21	21	15	17		
		P3 **P4**		14	7	7	17		
		P5			7	7	17		
		32				7	17		

*P1- Percentage of the complement; P2- Diversity increment after selecting the Avalanche; P3- Diversity increment after selecting the Avalanche and Longwood; P4- Diversity increment after selecting the Avalanche, Longwood and Nedugula; P5- Diversity increment after selecting the Avalanche, Longwood, Nedugula and Ninth mile.

of orthopterans in the selected study sites was arrived at by root weight method (Table 1). It gives a set of additive weights (Column W) reflecting the position of each species in the taxonomic hierarchy (Vane-Wright *et al*., 1991). Total diversity for the 15 complementary species in each study site is given in row (Table 1). Among that maximum of 5 spp. of Orthoptera recorded in Avalanche and Nedungula, it is indicating the radial complement of 10 spp. were not observed in these two shola forests. Therefore, the recorded diversity is separated as 33 percent in these study sites. When compared to Avalanche, the 20 percent of increment in Nedungula, Longwood, Ninth mile, Uppati and only 13 percent in Parson's valley sholas respectively (Table 1).

To arrange the subfamily wise weights: each species = 1 unit weight; each genus = 2 unit weights. The collected orthopterans were falling under 10 different subfamilies viz., Acridinae, Phaeneroptinae, Gryllinae, Orthacrinae, Oxyinae, Oedipodinae, Eyperpocnemidinae, Mecopodinae, Conocephalinae and Hexacentrinae. The unit of measurement is set as 4, 5 & 6 for afore mentioned subfamilies in Orthoptera. The subfamilies, like Acridinae and Phaeneroptinae gain 4 units and the last seven subfamiles gain 6 units of weightage each, because of only one species in each subfamily.

The species richness in shola forests both in Nilgiris North and South divisions doesn't have any similarity (Table 2), however, the species composition differed. The species such as *Mirollia cerciata* Hebard, 1922, *Hexacentrus major* Redtenbacher, 1891, *Heteracris pulchra* (Bolivar, 1902), *Orthelimaea securigera* (Brunner von Wattenwyl, 1878) and *Phaneroptera gracilis* Burmeister, 1838 were found only in the Cauliflower shola, Parson's valley shola, Nedugula shola and Uppati sholas respectively (Table 1). The species namely *Orthacris* (*Orthacris*) *maindroni* Bolívar, 1905, *Gryllodes sigillatus* (Walker, 1869), were recorded in more than three locations. The occurrence of the rare species like *Mirollia cerciata* Hebard, 1922, *Acrida exaltata* (Walker, 1859), *Acrida gigantea* (Herbst, 1786) and *Gryllus* (*Gryllus*) *bimaculatus* De Geer, 1773 in Nedugula, Uppati, Parson's valley and Avalanche Cauliflower shola respectively indicated that the sites are unique with characteristic vegetation types.

Shannon's diversity index was calculated as a measure of diversity within the habitat. The diversity indices H', and λ appear useful as they incorporate both species richness and evenness into a single value. The Shannon's diversity index (H') gave high values for Nedugula (1.43) followed by Longwood (1.34) and Avalanche shola forests (1.29) (Table 3).

Simpson's diversity index, 'λ', also gave high value for the aforementioned sites. It indicates that the shola forests and grasslands in these locations are occupied by species with more individuals. The availability of host plants in the habitat is vital for insect colonization. The type of vegetation in a habitat influences not only species present, but also the number of individuals. Though the study sites fall under two different forest divisions, the assemblage of the orthopteran community varies and the similarity index was worked out to understand the closely related sites between Nilgiris North and South divisions.

The dendrogram (Figure 1) was a dram to understand the similarity between sites of two different divisions concerning Orthoptera diversity. Nedugula shola forest in Nilgiris North division is grouped under Ninth mile and Avalanche sholas in Nilgiris South division. However, Parsons' valley shola in Nilgiris South is grouped under Longwood and Uppati sholas in Nilgiris North Division.

Discussion

The natural ecosystems, still untouched by man, are characterized by a great diversity of animal and plant species. These heterogeneous conditions form the basis of a stable and well-balanced environment in which the population oscillates within certain limits (Senthilkumar *et al*., 2006). This study on Orthoptera has again supported the fact that a heterogeneous habitat likes sholas forest and grasslands provide refuge to Orthoptera species. This observation is supported by the study of acridids diversity in Tamil Nadu (Senthilkumar *et al*., 2009). The species recorded namely, *Orthacris (Orthacris)*

Table 2. Diversity, Species richness and geographical attribute in Nilgiris sholas, Tamil Nadu

Sl. No.	Location	Division	Latitude °N	Longitude °E	Altitude M (MSL)	No. of species	Shannon's index (H')
1.	Longwood shola	Nilgiris North	11.26	76.52	1970.6	4	1.34
2.	Uppati shola	Nilgiris North	11.3	76.54	1937.1	3	0.91
3.	Nedugula shola	Nilgiris North	11.36	76.53	1941.2	5	1.43
4.	Avalanche shola	Nilgiris South	11.12	76.35	2036	5	1.29
5.	Ninth mile shola	Nilgiris South	11.44	76.62	1946	4	1.24
6.	Parson's valley shola	Nilgiris South	11.38	76.58	2295	3	0.99

Table 3. Diversity indices of orthoptera in Nilgiri sholas

Sl. No.	Diversity index	Avalanche	Longwood	Nedugula	Ninethmile	Parson's valley	Uppati
1.	Species richness	5	4	5	4	3	3
2.	Singletons	2	0	0	1	0	0
3.	Unique	2	0	0	1	0	1
4.	ACE	7.01	4	5	4.34	3	3
5.	ICE	7.16	4	5	4.42	3	3.88
6.	Chao 1	5.75	4	5	4.5	3	3
7.	Chao 2	5.75	4	5	4.5	3	3.12
8.	Jack 1	6.75	4	5	4.87	3	3.87
9.	Jack 2	7.6	4	4.55	5.62	1.71	3.98
10.	Bootstrap	5.79	4	5.12	4.37	3.2	3.44
11.	MM mean	5.99	4.52	5.75	5.3	4.3	5.59
12.	Colewel	4.73	3.91	4.99	3.87	2.98	2.98
13.	Alpha diversity index	2.29	1.07	1.5	1.59	1.35	1.35
14.	Shannon index	1.29	1.34	1.43	1.24	0.99	0.91
15.	Simpson's index	3.47	3.99	3.91	3.82	2.89	2.81

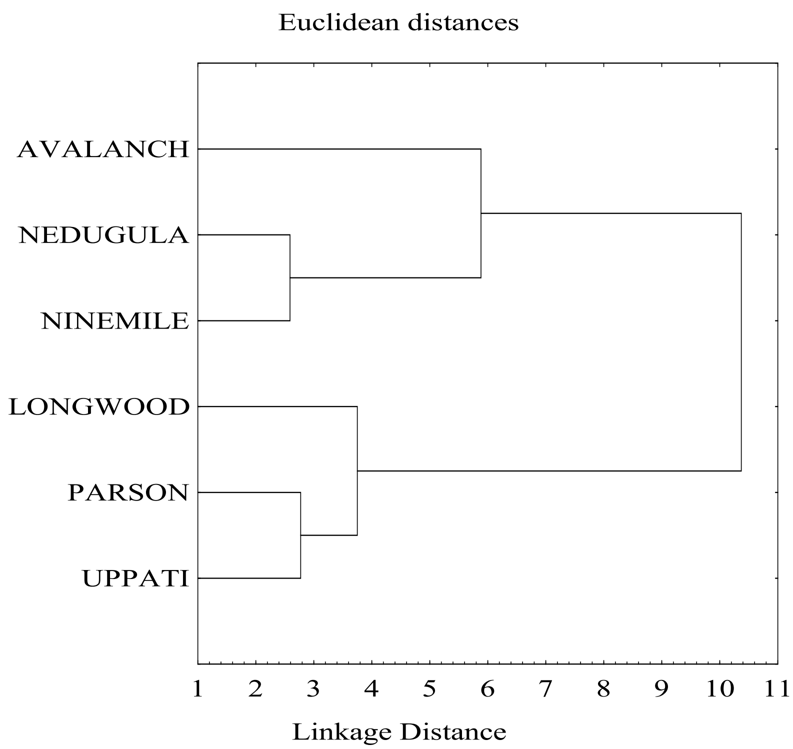

Figure 1. Dendrogram showing the similarity of sites in relation to Orthoptera species assemblages.

maindroni Bolivar, 1905, *Heteracris pulchra* (Bolivar, 1902), *Gelastorhinus africanus* Uvarov, 1941, *Phlaeoba infumata* Brunner von Wattenwyl, 1893, *Mecopoda elongata* (Linnaeus, 1758), *Mirollia cerciata* Hebard, 1922 and *Hexacentrus major* Redtenbacher, 1891 were earlier found in the low to mid elevations, lowland forests in particular (Sanjayan *et al*., 2002; Senthilkumar *et al*., 2009). None of these species was reported earlier in high altitudes over and above (Senthilkumar *et al*., 2002). It is evident from the study of Chen *et al*., (2009) that tropical insect species have undertaken a shift towards higher altitudes, confirming the global reach of climate change impacts on biodiversity. Grasshopper diversity was predicted to decrease significantly in higher altitude however; species richness is predicted to more towards higher altitudes (Maes *et al*., 2010). At middle latitudes, distribution shifts towards higher latitudes and altitudes seem to be prevalent, especially in highly mobile and polyphagous species (Chen *et al*., 2009). Detailed models of the responses to the climate of each insect are needed to predict distribution changes with any accuracy. However, it seems difficult to make general predictions about the responses of major forest insect species to climate change in their current ranges. There is an increasing risk of "invasion" an increasingly hospitable ecosystem by the more mobile species. However, certain models indicate that insect distributions should not be expected to expand, but rather to shift towards higher latitudes and altitudes (Regniere *et al*., 2009). The present study supports the said that the orthopteran species are move towards high altitude owing to change in climatic conditions, warner in particular at low to mid altitudes, have harbourers like shola forests gives asylum to specimens who wanders surround.

Conclusion

Climate change and habitat destruction are linked to global declines in vertebrate biodiversity, including mammals, amphibians, birds, and fishes. However, global species richness, and the combined effects of climate change and land use on invertebrates remain poorly understood. The vast majority of research on insect responses to altered climatic factors has focused on butterflies and beetles in temperate ecosystems, with a strong bias on the diversity of Orthoptera. Moreover, studies regarding tropical forest insects with respects to altered climate and habitat condition are still very incipient. The present study is an attempt at the felt need. The study on distribution and diversity of Orthoptera in Nilgiris high altitude shola forests and grasslands showed that the species found only distributed in lowland forests are now recorded in high altitude evergreen forests. At higher elevations, we observed clear upward shifts in the elevational ranges of species, with the influence of global warming. It supported the prediction that the shifts of species towards higher altitudes seem to be prevalent, especially in a highly mobile insects the grasshoppers. It is evident from our study on the diversity of grasshoppers in Nilgiris shola forests that tropical insect species have undertaken refuge at high altitudes, confirming the global reach of climate change impacts on biodiversity.

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