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FOREST COVER TYPES AS DETERMINANTS OF MOTH DIVERSITY IN INDIAN HIMALAYAN REGION

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ABSTRACT: The relationship between forest cover types and moth species richness is poorly understood in Indian Himalayan region. In the present study simple and multiple linear regression model was analysed to understand the effect of area of three forest cover types (very dense forest, moderately dense forest and open forest) on species richness of moth families in Indian Himalayan region. It was found that out of 23 moth families reported from the Indian Himalayan region only one moth family (Bombycidae) had significant simple linear relationship with different forest cover types. Multiple linear regression modelling shows three forest cover types can explain more than 50% variation in total moth species richness and species richness in 10 moth families (Arctiidae, Bombycidae, Crambidae, Erabidae, Geometridae, Lasiocampidae, Pyralidae, Saturniidae, Sphingidae and Uraniidae). Our study suggests that forest cover types have great role in shaping moth species richness in Indian Himalayan region.

KEY WORDS: Indian Himalaya, forest cover, moth, species richness

Current approaches in terrestrial biodiversity conservation focus predominantly on plants and vertebrates Axmacher et al. (2011). In many respects, conservation is local (Mittermeier et al., 2011) because people generally care more about the biodiversity in the place in which they live (Mittermeier et al., 2011). Biogeographical variation in species richness and endemic richness is critical to our understanding and conservation of biological diversity (Vetaas & Grytnes, 2002). In an effort to prioritize conservation efforts, scientists have developed the concept of biodiversity hotspots (Fisher & Christopher, 2007). These biodiversity hotspots (containing high levels of species richness and/or endemism) are the targets to set geographic priorities for conservation (Ricketts et al., 2002). The Indian Himalayan Region (IHR) which is situated in the "Himalaya Biodiversity Hotspot" harbours a wide spectrum of biodiversity which is reflected in diverse groups of flora, fauna and microorganisms (Ray et al., 2007). Lepidoptera are the most diverse order of insects associated primarily with angiosperm plants and, with some 160,000 named species, are one of the largest insect orders (New, 2004). Many moth lineages contain very few species, and some have highly localised distributions, so that endemism is often very high – both within lineages and amongst species of more widely distributed higher taxa (New, 2004). Conservation biologists have used indicator species as surrogates to assess the magnitude of anthropogenic disturbance, to monitor population trends in other species, and to locate areas of high regional biodiversity (Summerville et al., 2004). Because of high diversity and intermediate position in trophic cascades, the herbivorous insects become ideal objects with which to study the

effects of environmental gradients in habitat conditions on the diversity of faunal communities (Axmacher et al., 2009).

It is a near universal truth that species richness increases with the increment of forest cover in a given area. But so far no studies have been done to understand effect of forest cover in shaping species richness of moth families in the Indian Himalayan Region.

MATERIALS AND METHODS

Geopolitically, the Indian Himalaya comprises the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh and northern part of West Bengal. The rest of the Himalaya falls within the political boundaries of Pakistan, Nepal, Bhutan, China and Northern Myanmar. For our study we selected five administrative areas (the state of Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh and the district of Darjeeling of the state of West Bengal) which are located in the Himalayan region of West Bengal. We chose geopolitical units for our study because biodiversity conservation practices are influenced by the geopolitical boundaries.

We obtained the area of different forest covers from India State of Forest Report (2015). For our analysis we used percentage (%) of 3 forest cover types (very dense forest, moderately dense forest and open forest), in respect to total geographic area of five administrative areas (Table 2, Fig. 2).

We collected moth distribution data in five administrative areas from available published literatures (for Himachal Pradesh - Sekhon & Singh, 2015; Sekhon, 2015; Sharma et al., 2013; Thakur & Kumar, 2014, 2015 and Walia, 2005; for Uttarakhand - Sanyal et al., 2013, 2017; Sondhi & Sondhi, 2016; Uniyal et al., 2013, 2016; for Darjeeling - Bhattacharya, 1997; Ghosh & Chaudhury, 1997; Gupta, 1997; Mandal & Ghosh, 1997; Mandal & Maulik, 1997; Shah & Mitra, 2015; for Sikkim - Bhattacharya, 2003; Ghosh, 2003; Gupta, 2003; Khan & Raina, 2017; Kirti et al., 2016; and Majumdar (Chaudhury), 2003; for Arunachal Pradesh - Arora & Chaudhury, 1982; Chada et al., 2017; Chandra & Sambath, 2013; Kirti et al., 2017 and Rajesh et al., 2016).

Total 1910 species of moths under 23 families were so far reported from five administrative areas (the state of Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh and the district of Darjeeling of the state of West Bengal) of Indian Himalayn region (Table 1, Fig. 3).

For our analysis we used data of 11 moth families (Arctiidae, Bombycidae, Crambidae, Erabidae, Geometridae, Lasiocampidae, Pyralidae, Saturniidae, Sphingidae, Uraniidae and Zygaenidae) and rest 12 moth families (Brahmaeidae, Callidulidae, Cossidae, Drepanidae, Eupterotidae, Limacodidae, Notodontidae, Noctuidae, Oecophoridae, Thyrididae, Tineidae and Torticidae) was ignored as their distribution data were not adequate for regression analysis.

We used moth species richness in five administrative areas as dependent variables and area of different forest cover types as explanatory variables. For this study, we assumed that all the variables (environmental, geological and ecological) are remained identical in four states except moth distribution and area of forest cover types.

First we had performed o factor analysis of variance (ANOVA) using species richness of moth families and administrative regions as source of variation to found that was there any significant difference of species richness present between the moth families and between the administrative regions. Then, we analyzed effects of area of total forest cover on species richness of moth families in

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five administrative areas using simple linear regression model and the effects of area of very dense forest (VDF), moderately dense forest (MDF) and open forest (OF) on species richness of moth families in five administrative areas using multiple linear regression models.

RESULTS

After performing two factor analysis of variance (ANOVA) using species richness of moth families and administrative regions as source of variation (Table 3) we had found that there was significant difference of species richness present between the moth families ($p = 2.9 \times 10^{-15}$) but there was no significant difference of species richness present between the administrative regions ($p = 0.254$).

Out of the 11 families of moths, species richness of only Bombycidae had significant ($p<0.05$) simple linear relationship with area of total forest as well as with very dense forest, moderately dense forest and open forest (Table 4, Fig. 4).

After performing multiple linear regression modelling (Table 5, Fig. 5) with area of 3 forest cover types (very dense forest, moderately dense forest and open forest) as predictor variables and total moth species richness and species richness of 11 moth families we had found that these three types of forest covers explains more than 50% variation of species richness in 10 moth families (Arctiidae, Bombycidae, Crambidae, Erabidae, Geometridae, Lasiocampidae, Pyralidae, Saturniidae, Sphingidae and Uraniidae), more than 91% variation of total moth species richness and species richness in 7 moth families (Arctiidae, Bombycidae, Crambidae, Erabidae, Geometridae, Lasiocampidae and Uraniidae) where for family Zygaenidae these forest cover types explains only 25.5% variation of species richness.

DISCUSSION

Diversity and distribution of moths depend on several factors such as host plant specificity (Lopez-Vaamonde et al., 2003; Light & Knight, 2005; Tasin et al., 2006; Cho et al., 2008; Mattila et al., 2009; Tasin et al., 2009; Silva & Furlong, 2012; Thöming et al., 2013), habitat specificity (Kadlec, 2009), Rainfall (Choi, 2008), relative humidity (Choi, 2008), topographic complexity (Highland et al., 2013), elevation (Beck & Vun Khen, 2007; Brehm et al., 2013), habitat disturbance (Beck & Vun Khen, 2007), Human caused habitat conversion (Beck & Vun Khen, 2007), invasive plant abundance (Schooler et al., 2009), Risk of egg parasitism (Sadek, 2010), duration of sunshine (Choi, 2008) etc.. None of these factors has ability to shape moth species richness solely. Our study suggests that quantity of different types of forest cover area has significant effect on the species richness of moth families in linear combination, with exception of few moth families in Indian Himalayan region. It is recommended to the researchers to collect all the environmental and geological information while documenting moth diversity in a region so that determining factor of moth species richness will be revealed by more fine scale analysis, which in turn, helps forest managers to plan conservation action in a proper way.

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Table 1. Distribution of numbers of species under 23 families of moths in 5 administrative region of India which are located in the Indian Himalayan region.

Moth family	Administrative area					Total
	Himachal Pradesh	Uttarakhand	Darjeeling	Sikkim	Arunachal Pradesh	
Arctiidae	0	6	7	6	10	16
Bombycidae	0	4	1	0	11	15
Brahmaeidae	0	1	0	0	0	1
Callidulidae	0	1	0	0	0	1
Cossidae	0	4	0	0	0	4
Crambidae	0	47	45	69	7	152
Drepanidae	0	20	0	0	0	20
Erabidae	4	82	38	29	60	205
Eupterotidae	0	5	0	0	0	5
Geometridae	191	276	317	524	48	1016

Lasiocampidae	0	11	0	0	2	11
Limacodidae	0	13	0	0	0	13
Notodontidae	0	10	0	0	0	10
Noctuidae	112	154	0	0	0	235
Oecophoridae	0	1	0	0	0	1
Pyralidae	0	11	6	0	1	18
Saturniidae	0	8	18	0	26	39
Sphingidae	0	33	40	22	2	85
Thyrididae	0	1	0	0	0	1
Tineidae	0	1	0	0	0	1
Torticidae	0	5	0	0	0	5
Uraniidae	0	10	0	0	3	13
Zygaenidae	0	8	34	0	2	43
Total	307	712	506	650	172	1910

Table 2. Percentage of forest cover types (in respect to total geographic area under study) in 5 administrative regions of India which are located in the Indian Himalayan region.

	Himachal Pradesh	Uttarakhand	Darjeeling	Sikkim	Arunachal Pradesh
Total forest cover	7.2343	11.932	1.1706	1.6525	33.104
Very dense forest	1.5871	2.3402	0.3564	0.2461	10.241
Moderately dense forest	3.1411	6.6957	0.321	1.0633	15.408
Open forest	2.5061	2.8965	0.4932	0.3431	7.4543

Table 3. Result of two factor analysis of variance (ANOVA) using species richness of moth families and administrative regions as source of variation.

Source of Variation	SS	df	MS	F	p-value	F critical
Moth family	352027.4	22	16001.25	9.647	2.9×10^{-15}	1.664
Administrative regions	9027.443	4	2256.861	1.361	0.254	2.475
Error	145957	88	1658.602			
Total	507011.8	114				

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Table 4. Significant ($p<0.05$) simple linear relationship between Predictor variables [very dense forest (VDF), moderately dense forest (MDF) and open forest (OF)] and Response variable species richness of families of moths.

Response variable	Predictor variable	β	SE	Constant	R^2	$F_{1,3}$	p
Bombycidae	Total forest cover	0.344	0.051	-0.594	0.939	46.214	0.007
Bombycidae	Very dense forest	1.082	0.163	0.004	0.936	43.85	0.007
Bombycidae	Moderately dense forest	0.735	0.104	-0.715	0.943	49.85	0.006
Bombycidae	Open forest	1.519	0.325	-0.9587	0.879	21.84	0.019

Table 5. Effects of area of very dense forest (VDF), moderately dense forest (MDF) and open forest (OF) on species richness in moth families. β refers to the parameter estimate from a multiple regression (positive values are in boldface); SE is the standard error of that estimate. R^2 values in boldface type signify those parameters explaining >91% of the variation in species richness.

		VDF		MDF		OF	
	R^2	β	SE	β	SE	β	SE
Total Species	**0.998**	-96.728	11.237	**159.928**	8.949	-255.441	19.981
Arctiidae	**0.915**	**2.410**	1.328	**1.549**	1.058	-6.134	2.361
Bombycidae	**0.978**	**0.888**	0.871	**0.924**	0.694	-1.686	1.550
Crambidae	**0.998**	**4.649**	1.491	**18.278**	1.188	-51.916	2.652
Erabidae	**0.826**	-9.153	15.549	**24.012**	12.383	-33.376	27.648
Geometridae	**0.912**	**23.20**	64.99	**56.15**	51.76	-203.78	115.56
Lasiocampidae	**0.923**	-4.4573	1.6691	**3.8101**	1.3293	-1.3719	2.968
Pyralidae	0.509	-3.120	4.225	**3.035**	3.365	-2.184	7.512
Saturniidae	0.65	**6.802**	8.456	-0.431	6.734	-6.209	15.036
Sphingidae	0.657	**0.069**	13.173	**8.728**	10.491	-22.348	23.423
Uraniidae	**0.924**	-3.793	1.499	**3.426**	1.194	-1.366	-2.666
Zygaenidae	0.255	**5.698**	15.601	-1.821	12.424	-6.224	27.740

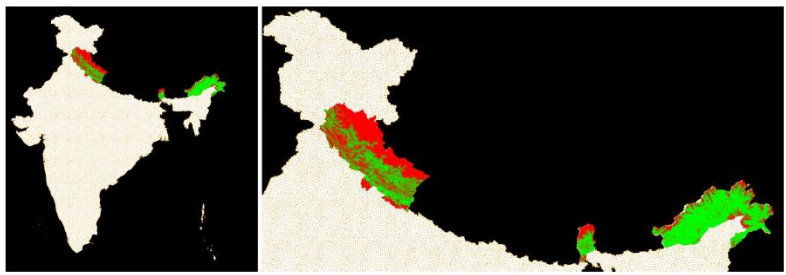

Figure 1. Location of 5 administrative regions of India which are located in the Indian Himalayan region (the forest cover areas are in green colour).

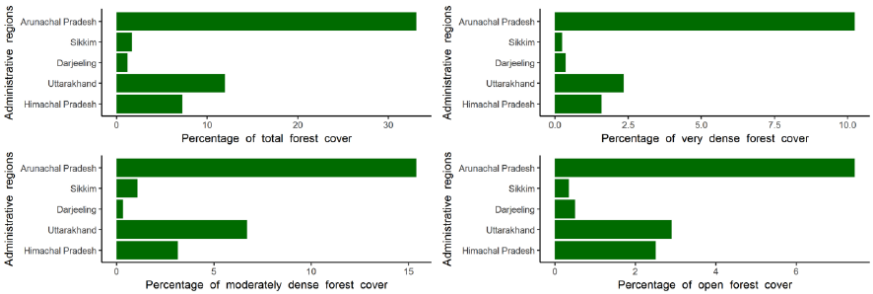

Figure 2. Comparative account of percentage of forest cover types (in respect to total geographic area under study) in 5 administrative regions of India which are located in the Indian Himalayan region.

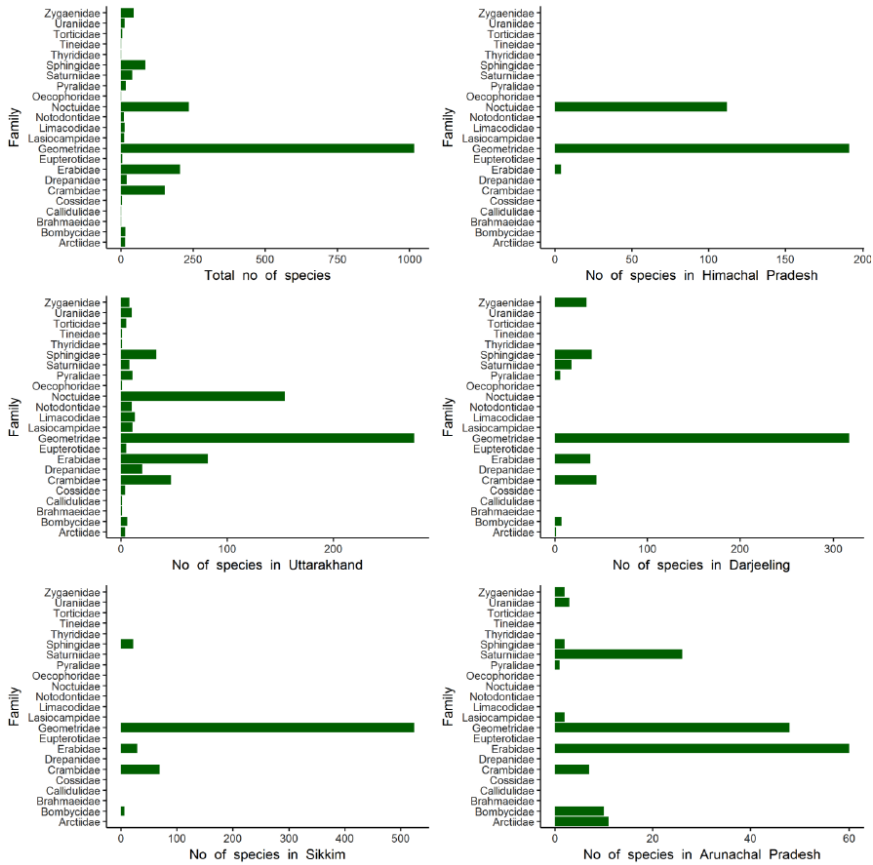

Figure 3. Comparative account of numbers of species of moths under 23 families in 5 administrative regions of India which are located in the Indian Himalayan region.

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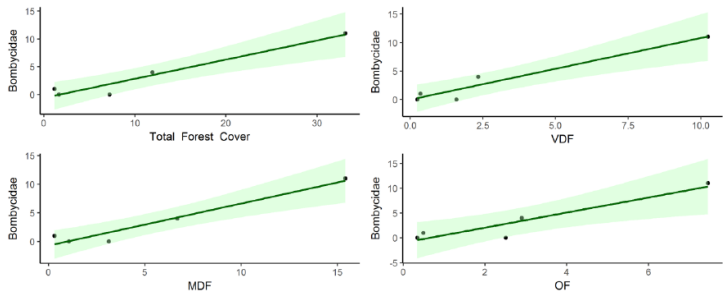

Figure 4. Significant ($p<0.05$) simple linear relationship between predictor variables [very dense forest (VDF), moderately dense forest (MDF) and open forest (OF)] and species richness of Bombycidae family.

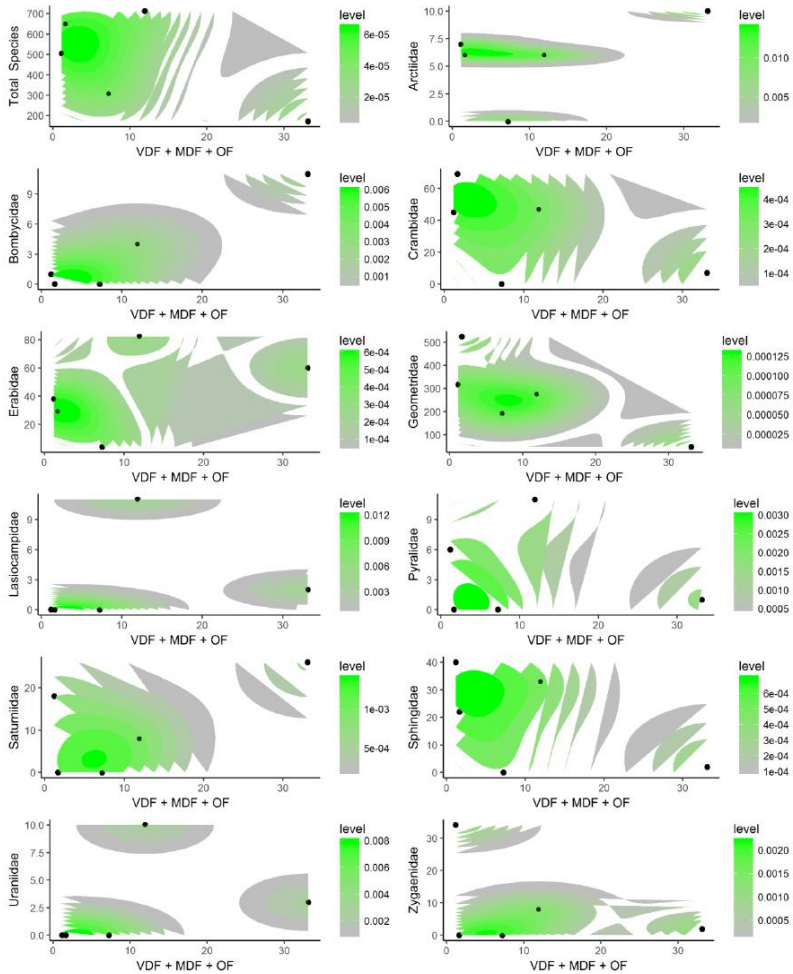

Figure 5. Contour plot of multiple linear relationship between predictor variables [very dense forest (VDF), moderately dense forest (MDF) and open forest (OF)] and species richness of moth families.