Diversity of Geometrid moths (Geometridae: Lepidoptera) in Kashmir valley, India

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ARTICLE INFO	ABSTRACT
	A total of 2378 geometrid moth specimens were collected from four districts of Kashmir valley during 2018-2019, which comprised of 39 species belonging to 29 genera, 17 tribes and 4 subfamilies. Five species (*Abraxas cashmiria* sp. nov., Antipercnia *pseudoalbinigrata* sp. nov., *Aspitates pseudogilvaria* sp. nov., Chorodna *Baramulia* sp. nov. and *Xenoplia kashmirensis* sp. nov.) are reported for the first time from this area. Diversity indices was highest in Baramulla (H′ = 1.452760) lowest in Srinagar (H′=1.273559). *Alcis repandata* (Linnaeus) was found to be most dominant species (11.02%), while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%).

Introduction

Lepidoptera is the largest insect order with approx. 1,57,424 described species worldwide (Van Nieukerken *et al.,* 2011; Sajjad *et al.,* 2019), out of which 100,000 are moths (Khan and Perveen, 2015) and remaining are butterflies. Family Geometridae (Inchworms or loppers), with approximately 23,002 described species (Nieukerken *et al.,* 2011) is the second most diverse family of Lepidoptera, occurring worldwide except in the Polar Regions. Geometridae is a moth family, its species are nocturnal and tend to be more specific to certain habitats particularly at high altitudes (Axmacher and Fiedler, 2008). Geometrid moths (Lepidoptera: Geometridae) are mostly the forest pests of woody plants, agricultural crops, fruit-berry crops and feed mainly on the leaves of wide range of plants particularly trees and shrubs. Geometrids are abundant and diverse component of most forest ecosystems, this along with their weak flight ability and low propensity to migrate (DeWaard *et al*., 2011) make them excellent indicators of environmental quality (Kitching *et al.,* 2001). The caterpillars are commonly known as loopers or inchworms because of their looping gait resulting from a reduced number of abdominal prolegs. Geometridae are generally secretive and cryptic insects, sometimes moths are green as the leaves on which they rest or have brown, grey and other colours forming mottled bark-like patterns of flecks and wavy lines. Their resting postures enhance camouflage, with the moths spreading their wings flat against the underside of leaves and the caterpillars are often twig-like (Pitkin *et al*., 2007). Many species are bright coloured, but most are drab. Frequently wavy lines transverse the wings but strong and distinct pattern occur often. The geometrids are characterised by the presence of a basal fork between vein A_2 and A_3 in the forewing and vein A_1 is always absent. Almost 2041 species of geometrid moths are reported from India (Kirti *et al.,* 2019) however, their extensive study has not been carried out from different regions of India as it is diverse country in terms of climate, Topography etc.

Material and Methods
Collection of specimens
For the collection of Geometrid moths from different locations of Kashmir valley various intensive and extensive tours were conducted from April 2018-Nov 2019. Adult geometrid moths were trapped with the help of light traps installed at different places during night time. For collection of specimens portable bucket type light traps fitted with 125 W mercury vapour lamp were used. Moths possess scaly wings which are very delicate and get damaged very easily, so as to avoid the wing damage due to overcrowding in the bucket type light trap, the mercury vapour lamp was hung in front of a white cloth sheet secured to a wall or directly over a plain white wall and moths sitting on the cloth or wall were quickly trapped with the help of wide mouth killing bottle containing benzene for quick killing of moths. Places were electricity was not available rechargeable lamps were used as light source for collection.

Selection of site:
The whole area of Kashmir valley is divided into three regions North Kashmir, south Kashmir and Central Kashmir. The collection was done from four districts of Kashmir namely Anantnag, Baramulla, Budgam and Srinagar, where Anantnag is in south , Baramulla in North, Budgam and Srinagar are in central part of kashmir . From each district two locations were selected, one in Forest ecosystem and other in Agri-Horti ecosystem i.e Verinag (1900 mt) and Achabal (1668 mt) from Anantnag; Drangbal (1650 mt) and Wadoora (1588 mt) from Baramulla; Shalimar (1609 mt) and Bemina (1583 mt) from Srinagar; Dodhpathri (2635 mt) and Ompora (1637 mt) from Budgam (Figure 1).
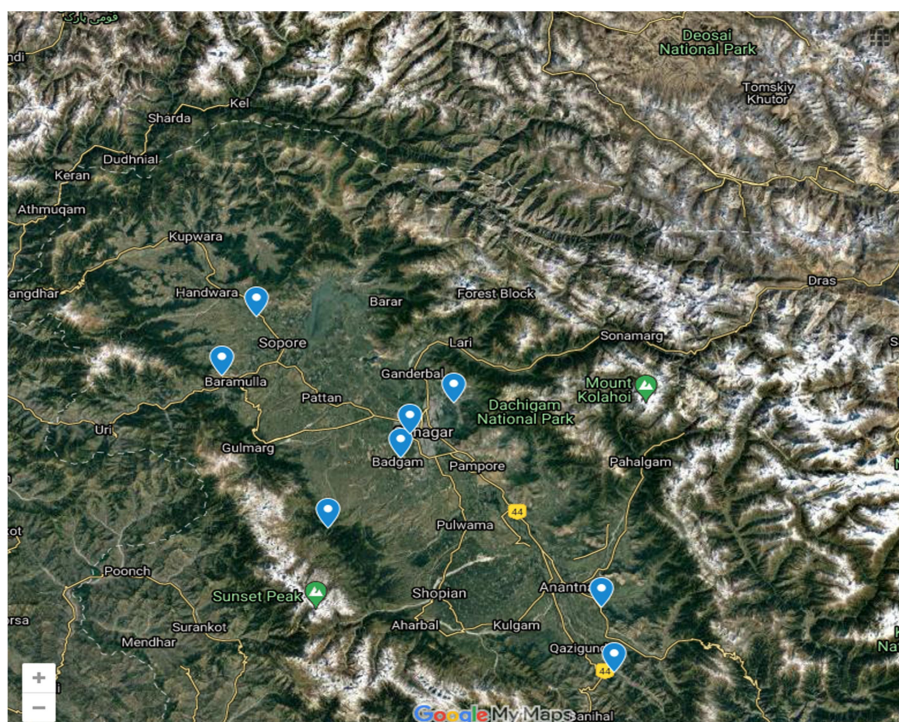

Figure 1: Google image of study areas

Processing and preservation
Collected moths after being killed with benzene or ethyl acetate vapours in killing bottles were transferred into butter paper envelops (to avoid scrapping off of wing scales which is an important morphological character of moths). In laboratory first specimens were placed over water soaked cotton in airtight petridish for

relaxation of muscles so that they can be stretched easily. Then Specimens were properly stretched on wooden stretching board after pinning through the mid of mesothorax. Stretched specimens were then oven dried for 72 hours at 60°C and preserved in fumigated insect collection boxes. Each specimen was labelled properly with name, locality, date of collection, name of collector etc.

Sorting of collected samples

Collected adult moths were sorted on the basis of morphological characters like wing pattern, presence of tymphanum on its ist abdominal segment, wing venation, antennae, thoraxic markings, no. of tibial spur etc.

Identification

Sorted specimens were identified by comparing with available relevant literature e.g The Moths of Borneo, Geometrid Moths of the World etc. To confirm the identification of moths, help was also seeked from Dr. Jasbir Singh Kirti, PAU Patiala India who is presently working on family Geometridae in India. For identification moth genetalia were dissected and directly photographed by using stereo zoom microscope attached with digital camera (Olympus SZX16), however Adult moths were photographed with Nikon DSLR camera. Identification was confirmed by sending these photographs to above mentioned expert.

Specimens were later deposited to museum of bio-systematic laboratory, Division of Entomology, SKUAST-K, Shalimar campus, Srinagar.

Statistical analysis

Diversity data of Geometrid moths was analysed for below mentioned indexes:-

I. **Index of species diversity (Shannan and Wiener, 1963).**

Index of species diversity (H′) = Σ pi log$_{10}$ pi

Where
pi=   Important probability of each species (Ni/N)
Ni=No. of individuals of one specie.
N=Total no. of individuals of all species

II. **Evenness index (Pielou, 1966).**

Evenness index (J) = H$^{'}$ / Log$_{10}$ S

Where
H′=Shannon Wieners index
S=Number of species

III.Index of dominance (Southwood, 1978)

Index of dominance (D) = 1 - J

Where
J=Evenness index

IV.Relative Abundance (R)

R= n/N

n = number of individuals in one species
N = number of individuals in all the species.

Results and Discussion

Total of 2378 geometrid moth specimens were captured from different selected locations of Kashmir valley. This total collection comprised of 39 species belonging to 29 genera, 17 tribes and 4 subfamilies which differed in both abundance and distribution (Table 1). Present results indicated that tribe Boarmiini was found most diverse at species level with 14 species followed by Ourapterygini with 6 species, Gonodontini with 3 species and Pseudoterpini with 2 species while as most of the tribes i.e Thinopterygini, Abraxini, Epionini, Aspitatini, Gnophini, Cidariini, Chesiadini, Larentiini, Gonodontini, Baptini, Hemitheini, Stamnodini and Scopulini were found to be least diverse with one specie each (Table1).

Present investigation revealed that maximum number of species (35) were recorded from Baramulla followed by Anantnag (33) while as minimum (22) were recorded from Srinagar (Table 2). Further *Alcis repandata* (Linnaeus) was the most dominant species in terms of relative abundance (11.02%) followed by *Ascotis imparata* (Walker) (7.53%), while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%) (Figure 1).
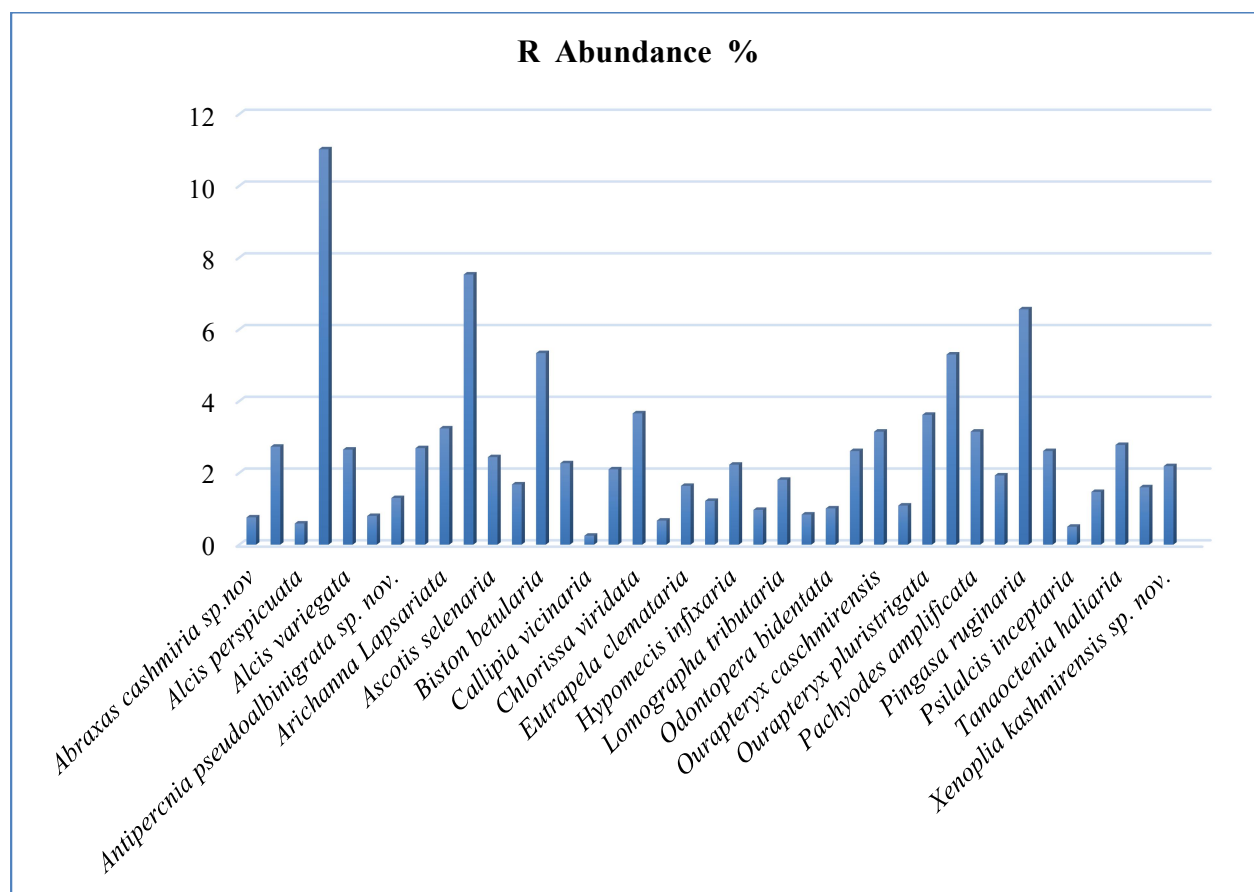
Diversity indices at various localities is framed in Table 2 which indicated that species diversity was found highest in Baramulla (H′ = 1.452760) followed by Anantnag (H′=1.413907) and lowest in Srinagar (H′=1.273559). Results of present study also revealed that evenness

Table 1: Classification of reported species.

S.no.	Family	Sub family	Tribe	Genus		Species	
1.				I.	*Alcis* Curtis	1.	*Alcis variegate* Moore
2.						2.	*Alcis repandata* Linnaeus
3.						3.	*Alcis jubata* Thunberg
4.						4.	*Alcis perspicuata* Moore
5.				II.	*Hypomecis* Hubner	5.	*Hypomecis infixaria (*Walker)
6.				III.	*Arichanna* Moore	6.	*Arichanna lapsariata* (Walker)
7.			Boarmiini	IV.	*Antipercnia* Inoue	7.	*Antipercnia cordiforma* (Inoue)
8.						8.	*Antipercnia pseudoalbinigrata* sp. nov.
9.				V.	*Ascotis* Hubner	9.	*Ascotis selenaria* (Dennis and Schiffermuller)
10.						10.	*Ascotis imparata* (Walker)
11.				VI.	*Lassaba* Moore	11.	*Lassaba contaminata* Moore
12.				VII.	*Chorodna* Walker	12.	*Chorodna baramulia* sp. nov.
13.						13.	Medasina albidaria (Walker)
14.				VIII.	*Psilalcis* Warren	14.	*Psilalcis inceptaria* (Walker)
15.			Epionini	IX.	*Opisthograptis* Hubner	15.	*Opisthograptis moelleri* Warren
16.		Ennominae	Aspitatini	X.	*Aspitates* Treitschke	16.	*Aspitates pseudogilvaria* sp. nov.
17.			Abraxini	XI.	*Abraxas* Leach	17.	*Abraxas cashmiria* sp. nov.
18.			Gnophini	XII.	*Psyra* Walker	18.	*Psyra bluethgeni (*Pungeler)
19.				XIII.	*Ourapteryx* Leach	19.	*Ourapteryx pluristrigata* Warren
20.	Geometridae					20.	*Ourapteryx multistrigaria* Walker
21.			Ourapterygini			21.	*Ourapteryx caschmirensis* Bastelberger
22.						22.	*Ourapteryx sambucaria* Linnaeus
23.				XIV.	*Eutrapela* Hubner	23.	*Eutrapela clemataria* (Smith)
24.				XV.	*Cepphis* Hubner	24.	*Cepphis advenaria* Hubner
25.			Bistonini	XVI.	*Biston* Leach	25.	*Biston betularia* (Linnaeus)
26.						26.	*Biston suppressaria* Guenee
27.			Thinopterygini	XVII.	*Thinopteryx* Butler	27.	*Thinopteryx crocoptera* (Kollar)
28.			Baptini	XVIII.	*Lomographa* Hubner	28.	*Lomographa tributaria* (Walker)
29.				XIX.	*Odontopera* Stephens	29.	*Odontopera bidentata* Clerck
30.			Gonodontini	XX.	*Tanaoctenia* Warren	30.	*Tanaoctenia haliaria* (Walker
31.				XXI.	*Xenoplia* Warren	31.	*Xenoplia kashmirensis* sp. nov.
32.			Cidariini	XXII.	*Heterothera* Inoue	32.	*Heterothera quadrifulta* (Prout)
33.		Larentiinae	Stamnodini	XXIII.	*Callipia* Guenee	33.	*Callipia vicinaria* Dognin
34.			Larentiini	XXIV.	*Photoscotosia* Warren	34.	*Photoscotosia miniosata* (Walker)
35.			Chesiadini	XXV.	*Aplocera* Stephens	35.	*Aplocera plagiata* (Linnaeus)
36.			Pseudoterpini	XXVI.	*Pingasa* Moore	36.	Pingasa ruginaria (Guenee)
37.		Geometrinae		XXVII.	*Pachyodes* Guenee	37.	*Pachyodes amplificata* (Walker)
38.			Hemitheini	XVIII.	*Chlorissa* Stephens	38.	*Chlorissa viridata* (Linnaeus)
39.		Sterrhinae	Scopulini	XXIX.	*Problepsis* Lederer	39.	*Problepsis albidor* (Warren)

Table 2: Diversity indices of geometrid moths in Kashmir valley during 2017-18.

S. No.	District	Total No. of Species	Indices			
			Diversity Index (H)	Evenness Index (J)	Index of Dominance (D)	Species Richness Index (M)
1	Anantnag	33	1.413907	0.931112	0.068887	11.028936
2	Srinagar	23	1.273559	0.948702	0.051297	8.424395
3	Budgam	22	1.284200	0.943066	0.056933	8.660293
4	Baramulla	35	1.452760	0.940865	0.059134	11.466336

Figure 1: Relative abundance of studied geometrid moth species in Kashmir valley

index, index of dominance and richness were 0.940865, 0.059134 and 11.466336 in Baramulla, 0.931112, 0.068887 and 11.028936 in Anantnag, 0.948702, 0.051297 and 8.424395 in Srinagar and 0.943066, 0.056933 and 8.660293 in Budgam district, respectively (Table 1). Family Geometridae is known for its major and minor pest species, caterpillars of this group occupy diverse habitats as external foliage feeders on trees, defoliators on forest trees, agricultural crops and fruit plants (Kirti *et al*., 2008). Not only these species act as plant pest but some were found to affect both domestic and wild animals. During the present course of study, extensive collection cum survey tours were conducted in four different districts *viz*, Anantnag (South Kashmir), Srinagar and Budgam (Central Kashmir) and

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Figure 2: Photo images of Geometrid moths collected from Kashmir valley

1. *Alcis variegate* Moore	2. *Alcis repandata* Linnaeus	3. *Alcis jubata* Thunberg	4. *Alcis perspicuata* (Moore)	5. *Hypomecis infixaria* (Walker)
6. *Arichanna Lapsariata* (Walker)	7. *Antipercnia cordiforma* (Inoue)	8. *Antipercnia pseudoalbinigrata* sp. nov.	9. *Ascotis selenaria* (Denis & Schiffermuller)	10. *Ascotis imparata* (Walker)
11. *Lassaba contaminata* Moore	12. *Chorodna baramulia* sp. nov.	13. *Medasina albidaria* (Walker)	14. *Psilalcis inceptaria* (Walker)	15. *Opisthograptis moelleri* Warren

16. *Aspitates pseudogilvaria* sp. nov.	17. *Abraxas cashmiria* sp. nov	18. *Psyra bluethgeni* (Pungeler)	19. *Ourapteryx pluristrigata* Warren	20. *Ourapteryx multistrigaria* Walker
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31. *Xenoplia kashmirensis* sp. nov.	32. *Heterothera Quadrifulta* (Prout)	33. *Callipia vicinaria* Dognin	34. *Photoscotosia miniosata* (Walker)	35. *Aplocera plagiata* (Linnaeus)
36. *Pingasa ruginaria* (Guenee)	37. *Pachyodes amplificata* (Walker)	38. *Chlorissa viridata* (Linnaeus)	39. *Problepsis albidor* (Warren)	

Baramulla (North Kashmir) of Kashmir valley and the total no of 39 species of adult moths belonging to 29 genera, 17 tribes and four subfamilies i.e. Ennominae, Larentiinae, Geometrinae and Sterrhinae of family Geometridae. All the species were identified with the help of electronic and non-electronic available Literature. Five species (*Abraxas cashmiria* sp. nov., *Antipercnia pseudoalbinigrata* sp. nov., *Aspitates pseudogilvaria* sp. nov., *Chorodna Baramulia* sp. nov. and *Xenoplia kashmirensis* sp. nov.) have been reported as new species. Present findings agree with those of Kumar *et al.* (2018) who conducted the study on biodiversity of geometrid moths in Himachal Pradesh, India to find the status of geometrid moths, during the study he concluded that collected geometrid moths belonged to 27 genera and three subfamilies Ennominae, Geometrinae and Sterrhinae, the subfamily Ennominae was represented with maximum species followed by the subfamily Geometrinae and the subfamily Sterrhinae. Also Walia (2005) published a list of 184 species of family Geometridae from Chandigarh and Himachal Pradesh and out of these, 86 species are under subfamily Ennominae, 46 species under subfamily Sterrhinae, 38 species under subfamily Geometrinae, 13 species belonging to 11 genera of subfamily Larentiinae and a single species under subfamily Desmobathrinae. In present study *Alcis repandata* (Linnaeus) was found most dominant specie in terms of relative abundance (11.02%) followed by *Ascotis imparata* (Walker) (7.53%) while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%). Present records further indicated highest species diversity in Baramulla (H′ = 1.452760) followed by Anantnag (H′=1.413907) and lowest in Srinagar (H′=1.273559).

Conclusion

This paper highlighted the diversity of Geometrid moths from the studied areas of Kashmir valley, total of 39 species are reported which belongs to 4 subfamilies. *Alcis repundata* (Linnaeus) was found most dominant (11.02%) and *Callipia vicinaria* (Dognin) was least dominant (0.25%). Diversity indices was highest in Baramulla (H' = 1.452760) and lowest in Srinagar (H' = 1.273559).

Acknowledgement

Conflict of interest

The authors declare that they have no conflict of interest.

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