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DIVERSITY OF MOTH (LEPIDOPTERA: HETEROCERA) IN DIFFERENT FOREST AREAS OF NORTH-WEST HIMALAYA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author SDP identified moth species, conceptualized and wrote the manuscript. Authors GS and VMS authors helped in writing and checked the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A study on moth diversity was carried out in the different forest areas of North-West Himalaya. Moths were collected from different forest areas such as deodar, chir pine, mixed, sal and teak of Himachal Pradesh and Uttarakhand by using light traps. A total of 61 moth species belonging to 53 genera, 21 sub-families and 11 families were recorded from different forest types of North-West Himalaya. The recorded moth families Erebidae (23 genera, 28 species in 6 subfamilies) and Geometridae (10 genera, 10 species in 3 subfamilies) were very frequent with a less frequent documentation from Crambidae (7 genera, 7 species in 2 subfamilies), Noctuidae (6 genera, 6 species in 4 subfamilies), Eupterotidae (1 genera, 3 species in 1 subfamily), Notodontidae (1 genera, 2 species in 1 subfamily), Drepanidae (1 genera, 1 species in 1 subfamily), Euteliidae (1 genera, 1 species in 1 subfamily), Hyblaeidae (1 genera, 1 species), Limacodidae (1 genera, 1 species in 1 subfamily) and Nolidae (1 genera, 1 species in 1 subfamily).
The most diverse family of moth species recorded in the study belonging to this family, Erebidae, 45.90% followed by Geometridae 16.39%, Crambidae 11.47%, Noctuidae 9.83%, Eupterotidae 4.91%, Notodontidae 3.27% and other families constituting 1.63%. The moth population were found highest in mixed forest as compared to species-specific forest tree species. The moth diversity was highest in the month of July-September and declined from October onwards. Along with this study, future studies on similar lines will help documenting the moth diversity of different forest types of India.

Keywords: Lepidoptera; heterocera; moths fauna; forest areas; North-West Himalaya.

1. INTRODUCTION

Forests in India are highly diverse and encompass several forest types such as evergreen tropical rain forests, dry alpine scrub types, semi evergreen rain forests, deciduous monsoon forests, subtropical pine forests, and temperate montane forests [1]. Forest is one of the most important terrestrial ecosystems [2]

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and it has been regarded as one of the most species rich habitats, especially for arthropods [3]. There are several abiotic and biotic factors responsible for damage to forest health ecosystems [4,5]. Arthropods plays significant role in forest ecosystem as dispersers, pollinators, decomposers, plants feeders, preys and predators. They are important for the forest health ecosystem. But, some arthropods like insects pest caused serious damage to forest health ecosystem [4]. North-West Himalayan (NWH) region in India is spread over three mountainous states, Himachal Pradesh, Jammu & Kashmir and Uttarakhand and its covers an area of 3,31, 392 km^2 (10% of the total geographical area of India). The climate of Indian Himalaya is governed by the extra– tropical weather systems of Asia. Significant portion of this area lies in high altitudes above 3000 m, which is covered by snow-clad peaks, glaciers, and alpines. On lower slopes forest cover and large part of human habitation occurs. Some major forest tree species in the North-West Himalaya are *Albizia procera, Anogeissus latifolia, Abies* sp., *Alnus* sp., *Alstonia scholaris, Bomboo* sp., *Bauhinia purpurea, Betula alnoides, Butea monosperma*, *Butea frondosa*, *Bomabax malabaricum*, *Capparis spinosa*, *Cedrus deodara*, *Dalbergia* sp., *Eucalyptus* sp., *Ficus* sp., *Haldina cordifolia, Lantana* sp., *Mangifera indica*, *Picea* sp., *Pinus* sp., *Pongamia pinnata*, *Quercus* sp., *Shorea robusta*, *Syzygium cumini, Tectona grandis*, *Terminalia* sp., *Toona ciliata*, *Zizyphus* sp. Many forest tree species herbs and shrubs are found in the forest areas [6].

Moths are known to be one of the most appropriate taxonomic groups for environmental evaluation and have great economic importance [7]. Moths are conspicuous terrestrial invertebrates, that represent the majority of the insect order Lepidoptera with over 165,000 described [7]. Being a prominent element of terrestrial ecosystems, they play significant role in the ecosystem as pollinators of flowers, herbivores of crops and wild plants and prey for numerous species of spiders, reptiles, rodents, birds, and bats [8, 9,10]. Many moth species are nocturnal plant-feeding insects and are almost entirely associated with forest tree species from nursery stage to young plantations, natural forest and others crops [11-16], that largely depend on animal-assisted pollination [17,18] as well as being pests of forestry, agricultural, vegetables and horticultural crops [19-23]. These polyphyletic groups of insects represent more than 90% of all lepidopterans of the earth and a large number of moth species are still waiting to be discovered and named, mostly from the tropical regions of the world [24]. The present knowledge on the insect fauna of Indian forests is largely based on earlier studies by pioneer researchers [25,26]. Later, several studies have explored the moth diversity from different states, Union territory and biogeographic zones of India [27,28]. The moth group consisting of over 1, 27,000 species found in the world [29]. In India over 10000 to 12000 species of moth have been estimated [30,31]. The Himalayan moth diversity is currently estimated to be 4,107 species under 1,726 genera spreading over 153 subfamilies and 53 families. Among the major families, Erebidae holds the maximum number of species followed by Geometridae and Noctuidae [32]. However, different areas of North-West Himalaya have undoubtedly received more attention than anywhere else because of its extremely rich biodiversity of Moths [33-41]. But, not much information available on moth faunal diversity of different forest types of North-West Himalaya. Therefore, keeping this in view, this survey was conducted in different forest areas of North-West Himalaya in 2019 to collect and identify the moth diversity of the forest area. With such data publicly availed, the authors aimed to shed light on the moth diversity of the different forest types of the North-West Himalaya. Moth studies on the moth diversity from different forest areas of North-West Himalaya are family- or subfamily-specific. The current study attempts to understand the moth diversity from various families found in the study area.

2. MATERIALS AND METHODS

The 26 days survey was conducted in order to collection of different insect fauna including moths from different forest areas of two states of North-West Himalaya (Photo Plate 1). Samples were collected from Himachal Pradesh between 06th and 21st July 2019 (14 days) and Uttarakhand between from 9th and 22nd October 2019 (12 days). The details of survey localities are given in (Table1).

2.1 Collection Methods

Sampling of moths was done at night between 7.30 and 11.00 P.M. by using light traps (Photo Plate 2). Moths which were attracted to the traps were collected by using a sweeping net with (25 cm diameter). The moths collected were killed by Ethyl acetate vapour [42,43,44].and properly kept in the butter paper (envelope) and taken to the Entomology laboratory of Zoological Survey of India, Dehradun, where they were pinned and stored in insect storage boxes.

2.2 Identification of Specimens

The collected moths were identified up to genus and species level based on the keys [25], other published

literatures [45-49] and field guides [50, 15] and website [51]. Moths were recorded using visual observation and photographs. The number of subfamilies, genera, species and total number of individuals collected during the study period were recorded. The collected moths were photographed using Digital camera (Nikon D 3500 DSLR). All the specimens collected from study area have been registered and deposited at Zoological Survey of India, Northern Regional Centre, Dehradun, Uttarakhand.

Photo Plate 1. Different types of forest in the study area of North-West Himalaya

Photo Plate 2. Light Traps sheet used for collection of moths at study areas

Table 1. Details of surveyed localities of North-West Himalayan states

S. No.	Forest areas	District/ States	Forest types	GPS coordinates	Altitudem
1	Dharmashala Forest area	Kangra Himachal Pradesh	Deodar and Chir pine forest	N 32° 14. 993' E 076° 17. 984'	2000
2	Dalhousie Forest area	Chamba/ Himachal Pradesh	Deodar and Chir pine forest	N 32°33.772′ E 076°03.550′	1970
3	Rajpura Forest area	Chamba/ Himachal Pradesh	Mixed Forest	N 32°59.630′ E 076°10.60′	489
4	Govind Wildlife Sanctuary	Uttarakashi, Uttarakhand	Mixed forest	N $31^0$04’13.05’ E $078^0$06’16.01’	1438 1295
5	Taluka forest area,	Uttarakashi, Uttarakhand	Mixed Forest	N $31^0$04’43.89’ E $078^0$14’45.04’	2100
6	Annua Forest area	Rudraprayag, Uttarakhand	Mixed Forest	N $30^0$16'38.99' E $078^0$58’13.78’	711
7	Corbett National Park	Nainital, Uttarakhand	Sal and Teak forest	N $29^0$25’16.66’ E 079^0 00’.04.62’	322

3. RESULTS AND DISCUSSION

During the study period, 61 species, 53 genera and 11 families moths were recorded from different forest types such as Deodar, Chir Pines, Mixed and Sal and Teak of North-West Himalaya (Table 2, Photo Plate 3). These include Crambidae, Erebidae, Drepanidae, Eupterotidae, Euteliidae, Geometridae, Hyblaeidae Limacodidae, Noctuidae, Nolidae and Notodontidae. Moths from families Erebidae (28) and Geometridae (10) occurred more frequently than species from following families, Crambidae (7), Noctuidae (6), Eupterotidae (3), Notodontidae (2), Drepanidae (1), Euteliidae (1), Hyblaeidae (1), Limacodidae (1) and Nolidae (1). The high abundance species from these families can be attributed to the presence of a large number of forest ecosystems with a variety of host plants. The moths population were found highest in mixed forest as compared to species-specific forest types (Table 3, Image 1). The moth diversity in the month of July-September was observed to be the highest and declined in October onwards.

The most diverse family of moths recorded in this study was family Erebidae, with (45.90%) of moths species recorded in the study belonging to this family, followed by Geometridae (16.39%), Crambidae (11.47%), Noctuidae (9.83%), Eupterotidae (4.91%) Notodontidae (3.27%) and other families constituting (1.63%) of the rest (Table 3, Fig.1). Several species of moth larvae of different families are recognised the notorious pests of forestry, agricultural crops including vegetable crops in India [12, 13, 52].

Several reports are available the moth species caused serious damage to forest trees species, agricultural and vegetables crops in India [19, 20, 21, 53, 54]. The Noctuid moth species, *Spodoptera litura* is famous and commonly called tobacco cutworm or cotton leafworm. It is serious polyphagous insect pests of numbers of forestry, agricultural and vegetables crops in India. Its larval host plant is more than 87 and infested most economic importance plants. The species parasitize the plants through the larvae vigorous eating patterns, oftentimes leaving the leaves completely destroyed. The moth's effects are quite disastrous, destroying economically important agricultural crops and decreasing yield in some plants completely. Their potential impact on the many different cultivated crops, and subsequently the losses the local agricultural economy. The Erebid moth species, *Achaea janata* is also important insect pests forestry, agricultural and vegetables crops in India. It is commonly called castor semi-looper or croton caterpillar. The larvae damage foliage, resulting in defoliation and reduction of photosynthesis process. They also attack stems and bore into them, and finally the whole plant wilts and dies.

The larvae of two moth species, *Hyblaea puera* (Hyblaeidae) and *Eutectona machaeralis* (Crambidae) are recognised as major pests of an economical important forest tree species in India. They are regularly and recurringly plagued by these larvae, popularly known as teak defoliator and leaf skeletonizer [12,55,56,57].In addition to defoliation, during epidemics these insects also feed on the inflorescence and are responsible for poor seed formation and seed setting in teak. Teak defoliation caused by these insect pests is a well recognized problem in India. These pests adversely affect the tree growth and vigour and are responsible for both qualitative and quantitative losses in timber production, besides causing certain abnormalities [56,57]. Continuous feeding of these insects on young teak crop cause a loss of about 65% of the normal increment in growth and sometimes even the death of the defoliated trees [58,59,60].

The Erebid moth, *Spilarctia obliqua* is well recognised as major forestry pests and plants species pests in North-West Himalaya. The Noctuid, *Agrotis ipsilon* is found throughout India and are major pests of forestry as well as agricultural and horticultural crops in India. The Geometridae moth species, *Hyposidra talaca* is also recognised major pest of number of forest tree species in the country. The Notodonotids, *Selepa celtis* moth larvae are voracious feeders of several species of forestry importance, consuming all the tissues of infested leaves except the midribs and main veins; they sometimes cause complete defoliation. The Crambid moth *Spoladea recurvalis* larva is a major pest of the several forestry, agricultural, vegetable and horticultural crops in India [61].

Among insects, the moths belonging to the Order Lepidoptera- Heterocera are economically very important since they are the primary herbivores in the forest and agro ecosystems due to the large-scale crop damage caused predominantly in their larval stages [62]. They are diverse in their habits and are adapted to a variety of conditions. Being highly sensitive to changes in the environment, they are easily affected by even relatively minor perturbations in the habitat; they have been considered as indicators of environmental quality [63, 64].

Moths are strongly influenced by the local weather and are highly sensitive to environmental changes [65]. Hence, studies on the diversity of moth fauna of particular region especially forest ecosystem of North-West Himalaya is vital to assess the biodiversity loss of the area. The forest ecosystems are under enormous pressure all over the world and due to human activities the fauna and flora in natural habitats like forests are facing severe threat. The diversity, abundance and distribution of moth fauna may reflect the status of the ecosystem in which they live. As moth species are the largest in the order Lepidoptera, the several families can be used as a model for assessing the impact of biotic and abiotic factors on the diversity of organisms [66, 67].

Photo Plate 3. Moths diversity of North-West Himalaya

1. Bradina diagonalis, 2. Diaphania indica, 3. Cnaphalocrocis medinalis, 4.Parotis marginata, 5. Spoladea recurvalis, 6. Cyclidia substigmaria, 7.Cyana coccinia, 8. Creatonotos transiens, 9. Chrysorbdia bivitta, 10.Macrobrochis prasena, 11. Brunia antica, 12.Asota plaginota, 13. Cladarctia quadriramosa, 14. Achea janata, 15.Creatonotos gangis, 16.Lymantrai marginata, 17. Nyctemera adversata, 18. Macrobrochis gigas, 19. Mocis frugalis, 20. Cydalima laticostalis, 21. Bastilla crameri, 22. Eupterote gardneri, 23. Problepsis vulgaris, 24. Chrysocraspeda olearia, 25. Antipercnia belluaria, 26. Hyposidra talaca, 27. Nacna malachitis, 28. Thysanoplusia orichalcea, 29. Phalera grotei, 30. Chiasmia eleonora, 31. Traminda mundissima

Table 2. Checklist of Moth diversity recorded during the study period

S. No.	Family	Subfamilies	Species	Distribution in different forest area of North-West Himalaya
1	Crambidae Latreiille, 1810	Spilomelinae Guenee, 1854	*Bradina diagonalis* Guenee, 1854	Rajpura Forest area, Chamba, Himachal Pradesh
2			*Cnaphalocrocis medinalis* Guenée, 1854	Corbett National Park, Nainital, Uttarakhand
3			*Diaphania indica* Saunders,1851	Corbett National Park, Nainital, Uttarakhand
4			*Parotis marginata* Hampson, 1893	Corbett National Park, Nainital, Uttarakhand
5			*Cydalima laticostalis* Guenee, 1854	Corbett National Park, Nainital, Uttarakhand
6		Pyraustinae Meyrick, 1890	*Spoladea recurvalis* Fabricius, 1775	Dalhousie Forest area, Chamba, Himachal Pradesh
7			*Eutectona machaeralis* Walker, 1859	Corbett National Park, Nainital, Uttarakhand
8	Drepanidae Meyrick, 1895	Cyclidiinae Warren, 1922	*Cyclidia substigmaria superstigmaria* Prout, 1918	Dalhousie Forest area, Chamba, Himachal Pradesh
9	Erebidae Leach, 1815	Arctiinae Leach, 1815	*Agylla pallens* Hampson, 1894	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
10			*Amata passalis* Fabricius, 1781	Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
11			*Brunia antica* Walker, 1854	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
12			*Chrysorbdia bivitta* Walker, 1856	Dalhousie Forest area, Chamba, Himachal Pradesh
13			*Cladarctia quadriramosa* Kollar, 1844	Dalhousie Forest area, Chamba, Himachal Pradesh
14			*Creatonotos gangis* Linnaeus, 1763	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
15			*Creatonotos transiens* Walker, 1855	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
16			*Cyana coccinia* Walker, 1854	Corbett National Park, Nainital, Uttarakhand
17			*Macrobrochis gigas* Walker, 1854	Corbett National Park, Nainital, Uttarakhand
18			*Macrobrochis prasena* Moore, 1894	Dalhousie Forest area, Chamba, Himachal Pradesh,
19			*Nyctemera adversata* Schaller, 1788	Dalhousie Forest area, Chamba, Himachal Pradesh,
20			*Olepa ricini* Fabricius, 1775	Dalhousie Forest area, Chamba, Himachal Pradesh
21			*Spilosoma obliqua* Walker, 1855	Chamba Forest areas, Chamba, Himachal Pradesh
22			*Syntomoides imaon* Cramer, 1779	Taluka Forest area, Uttarakashi, Corbett National Park, Nainital, Uttarakhand
23			*Spilarctia obliqua* Moore, 1872	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
24		Aganainae Lafontaine & Fibiger, 2006	*Asota plaginota* Butler, 1875	Corbett National Park, Nainital, Uttarakhand
25		Calpinae Boisduval, 1840	*Oraesia emarginata* Fabricius, 1794	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
26			*Calyptra minuticornis* Guenee, 1852	Corbett National Park, Nainital, Uttarakhand
27		Erebinae Leach, 1815	*Achaea janata* Linnaeus, 1758	Dalhousie Forest area, Chamba, Himachal Pradesh Corbett National Park, Nainital, Uttarakhand
28			*Achaea serva* Fabricius, 1775	Corbett National Park, Nainital, Uttarakhand
29			*Ercheia cyllaria* Cramer, 1779	Corbett National Park, Nainital, Uttarakhand
30			*Pericyma cruegeri* Butler, 1886	Corbett National Park, Nainital, Uttarakhand

S. No.	Family	Subfamilies	Species	Distribution in different forest area of North-West Himalaya
31			*Mocis frugalis* Fabricius, 1775	Corbett National Park, Nainital, Uttarakhand
32			*Mocis undata* Fabricius, 1775	Corbett National Park, Nainital, Uttarakhand
33			*Bastilla crameri* Moore, 1855	Corbett National Park, Nainital, Uttarakhand
34		Eulepidotinae Grote, 1895	*Anticarsia irrorata* Fabricius, 1781	Corbett National Park, Nainital, Uttarakhand
35		Lymantriinae Hampson, 1893	*Lymantria marginata*, Walker, 1855	Corbett National Park, Nainital, Uttarakhand
36			*Lymantria mathura* Moore, 1856	Corbett National Park, Nainital, Uttarakhand
37	Eupterotidae	Eupterotinae Forbes, 1955	*Eupterote mollifera* Moore, 1894	Chamba Forest areas, Chamba, Himachal Pradesh
38	Swinhoe, 1892		*Eupterote undata* Blanchard, 1844	Chamba Forest areas, Chamba, Himachal Pradesh
39			*Eupterote gardneri* Bryk, 1850	Chamba Forest areas, Chamba, Himachal Pradesh
40	Euteliidae Grote, 1882	Euteliinae Grote, 1882	*Eutelia adulatrix* Hubner, 1813	Chamba Forest areas, Chamba, Himachal Pradesh
41	Geometridae Leach, 1815	Ennominae Duponchel, 1845	*Antipercnia belluaria* Guenee, 1858	Dalhousie Forest area, Chamba, Himachal Pradesh
42			*Chiasmia eleonora* Cramer, 1780	Corbett National Park, Nainital, Uttarakhand
43			*Biston suppressaria* Guenée, 1858	Chamba Forest areas, Chamba, Himachal Pradesh
44			*Hyposidra talaca* Walker, 1860	Corbett National Park, Nainital, Uttarakhand
45		Geometrinae Leach, 1815	*Agathia lycaenaria* Koller, 1848	Corbett National Park, Nainital, Uttarakhand
46			*Comostola laesaria* Walker, 1861	Dalhousie Forest area, Chamba, Himachal Pradesh
47		Sterrhinae Meyrick, 1892	*Problepsis vulgaris* Butler, 1889	Dalhousie Forest area, Chamba, Himachal Pradesh
48			*Chrysocraspeda olearia* Guenee, 1857	Corbett National Park, Nainital, Uttarakhand
49			*Scopula mecysma* Swinhoe, 1894	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
50			*Traminda mundissima* Walker, 1861	Dalhousie Forest area, Chamba, Himachal Pradesh, Corbett National Park, Nainital, Uttarakhand
51	Hyblaeidae Hampson, 1903	-	*Hyblaea puera* Cramer, 1777	Corbett National Park, Nainital, Uttarakhand
52	Limacodidae Duponchel, 1845	Limacodinae Duponchel, 1845	*Parasa lepida* Cramer,1799	Dalhousie Forest area, Chamba, Himachal Pradesh
53	Noctuidae	Acronictinae Smith & Dyar, 1898	*Nacna malachitis* Oberthur, 1880	Dalhousie Forest area, Chamba, Himachal Pradesh,
54	Latreille, 1809	Aediinae Beck, 1960	*Aedia leucomelas* Linnaeus, 1758	Corbett National Park, Nainital, Uttarakhand
55		Noctuinae Latreille, 1809	*Agrotis ipsilon* Hufnagel, 1766	Dalhousie Forest area, Chamba, Himachal Pradesh, Taluka Forest area, Uttarakashi, Corbett National Park, Nainital, Uttarakhand
56			*Spodoptera litura* Fabricius, 1775	Dalhousie Forest area, Chamba, Himachal Pradesh, Near Corbett National Park, Ramnagar, Uttarakhand
57		Plusiinae Boisduval, 1829	*Thysanoplusia orichalcea* Fabricius, 1775	Corbett National Park, Nainital, Uttarakhand
58			*Chrysodeixis eriosoma* Doubleday, 1843	Corbett National Park, Nainital, Uttarakhand
59	Nolidae Bruand 1847	Eligminae	*Selepa celtis* Moore, 1860	Corbett National Park, Nainital, Uttarakhand
60	Notodontidae Stephens, 1829	Phalerinae Butler, 1886	*Phalera goniophora* Hampson, 1910	Dharamshala Forest area, Chamba, Himachal Pradesh,
61			*Phalera grotei* Moore, 1859	Dalhousie Forest area, Chamba, Himachal Pradesh

Table 3. Number of families, genera and species recorded during the study

S. No	Families	Number of Genera recorded	Number of Species recorded	% of different species
1	Crambidae	7	7	11.47%
2	Drepanidae	1	1	1.63%
3	Erebidae	23	28	45.90%
4	Eupterotidae	1	3	4.91%
5	Eutelidae	1	1	1.63%
6	Geometridae	10	10	16.39%
7	Hyblaeidae	1	1	1.63%
8	Limacodidae	1	1	1.63%
9	Noctuidae	6	6	9.83%
10	Nolidae	1	1	1.63%
11	Notodontidae	1	2	3.27%
	Total	53	61	

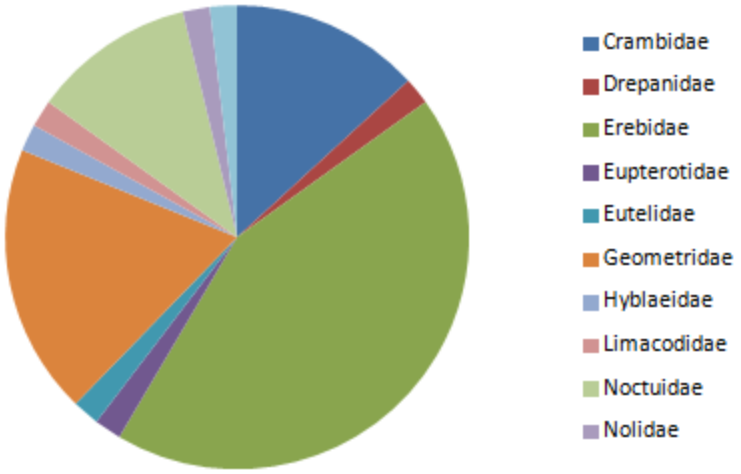

Fig 1. Showing the status of different families in the study areas

4. CONCLUSION

This current study highlights the diversity, abundance the distribution of moths in the different forest areas, thereby contributing the greater understanding of the role of moths in forest ecosystem. It is also reported the host plants that were observed to often use by moth in the study area. Further studies on bioecological and impact on plants species will help in documenting the moth diversity of different forest types in the North-West Himalayan region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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