Indian Forester, 141 (9) : 985-992, 2015
http://www.indianforester.co.in

ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

MOTH ASSEMBLAGES (LEPIDOPTERA: HETEROCERA) AS A POTENTIAL CONSERVATION TOOL FOR BIODIVERSITY MONITORING – STUDY IN WESTERN HIMALAYAN PROTECTED AREAS

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ABSTRACT

Insects have long been ignored in the conservation approaches despite their fundamental roles in terrestrial ecosystems. Considering the lack in taxonomic expertise in the diverse insect groups, they are slowly making their way into the biodiversity monitoring studies. Moths belonging to the third largest insect order Lepidoptera are a hugely diverse and functionally important group, which can be a potential bio-indicator group in this present situation of environment degradation. Recent studies have brought this less studied group in focus for addressing conservation issues and a lot remains to be explored about this fascinating group of insects. In this paper we have shown some preliminary results of two studies done on moth assemblage in Western Himalayan Protected Areas. The studies aim to give an insight about the community structure and distribution patterns within the assemblages which can be a way forward for future bio-monitoring studies.

Key words: Moths, Biodiversity indicators, Western Himalaya, Protected areas.

Introduction

Insects, the less explored yet ecologically significant group of animal world are steadily creeping their way into the present biodiversity conservation scenario. They are of paramount significance in the face of global biodiversity loss and its implications (Fox *et al.,* 2011). There is a poleward shift of insect species as a consequence of global climate change (Spector, 2008) and rapid conversion of forest area into agriculture land has resulted severe loss of insect species in the tropics (Nichols *et al.,* 2007). In the present situation where there is a huge discrepancy between the losses in insect species and the attention given towards it (Spector, 2008), insect conservation has a greater scope than ever before. Lack of taxonomic expertise and sheer diversity are the main impediments to insect conservation studies. For such a hyperdiverse taxa like insects, evaluating species diversity is extremely time-consuming (Lawton *et al.,* 1998) and labour intensive. Insects offer so many avenues to look into effect of disturbance that outweighs the technical challenges involved (Kitching *et al*., 2000) and the huge number of species gives statistical power to results that are derived. This ubiquity of the taxa helps to generate a pattern among the species distribution and occurrence (Kitching *et al.,* 2000). Keeping this in view, many studies are being developed on certain groups of insects which are easily sampled, taxonomically well demarcated and can act as surrogate for the entire community (Holloway, 1985; Kitching *et al.,* 2000). Lepidoptera, comprising of moths and butterflies is one such group. Lepidoptera has gained prominence as indicator taxon as it displays strong association with the vegetation, their depletion and subsequent regeneration. Moth communities are being studied extensively and receiving conservation interest at the same time, attaining high value as an indicator group (New, 2004) as they have shown strong indicator properties in studies of (Kitching *et al.,* 2000) and (Summerville *et al.,* 2004b). Studies on moth community across land-use changes have shown their sensitivity to the environmental alterations (Ricketts *et al.,* 2001; Scalercio *et al.,* 2007).

Why conserve Moths?

Moths are vital to terrestrial ecosystems as major herbivores, pollinators and in nutrient cycling but their natural populations are negatively affected by degradation of their habitat due to anthropogenic activities (Lomov *et al.,* 2006). The largest families of moth (such as Noctuidae: 35,000 species; Geometridae: 21,000 species) each include more species than the whole of the butterflies taken together. Another "working division" of the Lepidoptera, of considerable relevance to public perception as well as in conservation, is that of so-called "macrolepidoptera" and "microlepidoptera". The former includes the butterflies and larger moths and is by far the better documented

Moths belonging to the third largest insect order Lepidoptera are a hugely diverse and functionally important group, which can be a potential bio-indicator group in this present situation of environment degradation.

group, largely because it includes the taxa which have traditionally attracted most attention from collectors and hobbyists. Butterflies have become the "flagship species" in insect conservation due to the attention given in the past to their preservation and conservation (New, 1997). Moths, particularly their caterpillars, are major agricultural pests in many parts of the world e.g.-Corn Borers, Bollworms, the caterpillar of the gypsy moth, which is an invasive species, causes severe damage to forests in the northeast United States. Several moths in the family Tineidae are commonly regarded as pests because their larvae eat fabric such as clothes and blankets made from natural proteinaceous fibers. Some moths are farmed. The most notable of these is the silkworm, the larva of the domesticated moth *Bombyx mori*. It is farmed for the silk with which it builds its cocoon. As of 2002, the silk industry produces over 130 million kilograms of raw silk, worth about 250 million U.S. dollars, each year. There are several species of Saturniidae that are also farmed for their silk, such as the *Ailanthus* moth (*Samia cynthia)*, the Chinese Oak Silkmoth (*Antheraea pernyi*), the Assam Silkmoth (*Antheraea assamensis*), and the Japanese Silk Moth (*Antheraea yamamai*).

As Indicator Species

Bio-indicator study is a part of conservation biology and it basically deals with maintaining the ecological relationships among the species applying the scientific knowledge (Caughley and Gunn, 1996). It is only in the last three decades that the invertebrates have been considered in such studies. Moths have been established as an indicator species of effects of fragmentation, land-use pattern, deforestation and regeneration (Kitching *et al.,* 2000; Ricketts *et al.,* 2001). Moths have demonstrated effectively their role as an indicator of the remnant of woodlands within the agricultural land-use in northern England, UK (Usher and Keiller, 1998). Response among sub-families to environmental disturbance is varying with some being more abundant in disturbed areas (Kitching *et al*., 2000). Being herbivorous they reflect the quality of vegetation in a particular location. To develop targeted monitoring programme, an understanding of patterns in taxonomically well-defined groups is a pre-requisite. It will yield much more information than species-centric approach. The impacts of environmental disturbance can be understood and dealt with in much more holistic fashion (Kitching, 1994 and Didham, 1997). Moths are sufficiently speciose and diverse to detect ecosystem level impacts (Holloway, 1985). McGeogh (1998) in an attempt to address some of the issues concerning the studies of terrestrial bio-indicators like lack of goal directedness, hypothesis testing, had suggested three categories of indicators according to their application, which are :- i) Environmental indicators, ii) ecological indicators & iii) biodiversity indicators. Moths have the eligibility for all the three categories and have displayed their power as potent indicators (Fig.1). In India studies reflecting the ecological relationships of moths are lacking so far. New endeavours which will explore the diversity patterns and the factors governing them and the threats to the population are now gaining momentum.

There exists a lacuna in studies pertaining to conservation of moths as the status and distribution of most of the species are poorly documented. Taxonomic complexities does not allow this group to be included in studies that requires species level identification and that is where they play the "bridging role" in practical conservation considerations. Species centric conservation always has target species which are ecological specialists and tend to be under threat due to the changing environment (New, 1997). Finding ecological relationships of moth community assemblages are relatively easier to study due to their sheer diversity and the amount of data available on the extent of change in time and space corresponding to a large range of habitat variables (New, 1997). But in Indian scenario, the task is still improbable as region-specific species distribution records are not readily available and someone looking into these aspects would be easily bewildered with the amount of unidentified species from a regional inventory. This is why in India, moths and butterflies have still not been used as a indicator taxa in rapid habitat quality assessment, whereas in Europe and North America Lepidoptera is established as a potent bioindicator through many studies on effects of human activities (Ricketts *et al.,* 2001; Summerville and Crist, 2002; Lewis, 2001; Dumbrell and Hill, 2005; Wallis DeVries and Raemakers, 2001; Poyry *et al.,* 2005; Swengel, 1996; Fleishman, 2000; Fleishman *et al.,* 2005a).

The Indian Scenario

Faunistic records of Lepidoptera from Indian subcontinent were initially compiled by Linnaeus (1758), Cramer (1775); Fabricius (1775); Kollar (1844); Butler (1886); Donovan (1800). The lists and catalogue were published by Walker (1854); Moore (1888); Kirby (1892); and Cotes and Swinhoe (1886). Hampson (1891-1914) published lists and catalogues along with descriptions of the Indian and exotic moths present in the collection of the British Museum (Natural History) London. Moore published a list of moth fauna of Bengal and Andaman and Nicobar Islands and studied many genera and

species of nocturnal Lepidoptera collected by W. S. Atkinson, W. C. Hockings, J. H. Hockings and also by himself form Kolkata and North-West Himalayas. Swinhoe published the Lepidoptera of Bombay & in Madhya Pradesh. Snellen (1890) published on a catalogue of the Pyralidae of Sikkim collected by Henry J. Elwes and the late Otto Moller. Hampson (1891) published the information on Lepidopterous Fauna of Nilgiris. Hampson (1892, 1894, 1895, 1896) published four volumes of the "*Fauna of British India*". He (1903, 1908, 1919) further published supplementary paper and studied of new moths collected by Mons. Bell and Scott (1937) published "*Fauna of British India*" to family Sphingidae. Sevastopulo (1956) published notes on Heterocera of Kolkata. The moths of south-east Asia are studied by Barlow (1982). Arora (1997, 2000) published some moth species from the Nanda Devi Biosphere Reserve and some Indian pyralid species of Economic Importance respectively. Arora and Chaudhury (1982) published on the lepidopterous fauna of Arunachal Pradesh in adjoining areas of Assam in North-East India. Arora and Gupta (1979) published monograph of family Saturniidae of India. Chandra (1993, 1996) has studied moths from Bay Islands and Great Nicobar Biosphere Reserve. Gupta *et al.* (1984) published brief reviews on family Lymantriidae of India. Moth fauna of West Bengal has been studied by Mandal and Ghosh (1997); Mandal and Maulik (1997); Ghosh and Choudhury (1997) and Bhattacharya (1997). Mandal and Bhattacharya (1980) studied the subfamily Pyraustinae from Andaman Nicobar Island while Arora (1983) published moth fauna of Andaman & Nicobar. Bhattacharya provided historical account Indian Pyralidae. Mandal and Ghosh (1991) described some species of moths from Tripura. Moth fauna of Orissa have been studied by Mandal & Maulik (1991). "Taxonomy of Moths in India" has been published by Srivastava (2002). Mehta (1933) studied comparative morphology of the male genitalia in Lepidoptera. Moth fauna of Meghalaya was studied by Mandal and Ghosh (1998). Ghosh (2003) recorded 525 Geometrid species from Sikkim. Dover, Fletcher and Bainbridge, and Smetacek (1993) have described several species of moths from India. Sanyal *et al.* (2011 and 2013) have studied the diversity and indicator species of moth assemblages across different vegetation zones along with the diversity and distribution pattern of moth assemblages along altitudinal gradient in the Gangotri Landscape, Western Himalayas.

Figure 2 shows a comparison of number of publications on moth conservation in India and the rest of the world during the last 11 years. Moth collections across the country houses about 40% of the estimated 10,000 species found in India (Smetacek, 2013) which adds on to this issue. Post Independence had seen many foreign workers describing many species of moths from India, which is around 700 species, while Indian studies were able to describe fewer than 50 species. This can be attributed to the lack of reference material collections found in India. There are four major collections of Lepidoptera in India which represents about 40% of Indian Moth species. Natural History Museum, London houses the best collection of Indian Lepidoptera followed by Hope Collection at the University Museum, Oxford. The National Forest Insect Collection, at Forest Research Institute, Dehradun contains about 3800 species of Lepidoptera with high percentage of butterfly representation, the National Agricultural Insect Collection (IARI New Delhi) has 3302 species predominantly moths. The Bombay Natural History Society Collection houses around 1500 species of

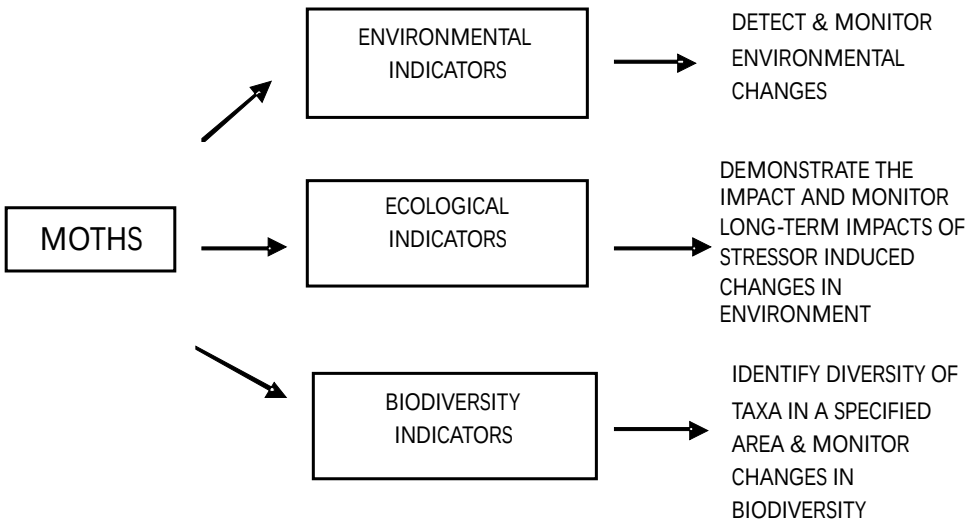

Fig.1: Functions of moth in each category of bioindication (adapted from McGeogh, 1998)

Lepidoptera (Smetacek, 2013).

The IUCN Red List of Threatened Species lists very few moth species (722, in 2013.2). It reflects the little constructive revision of the species. In lesser known parts of the world, some species are enlisted as "critically endangered", while they are just "data deficient" (Clarke and Spier, 2003). There is a huge underestimation for the need of conservation if the list is considered, as most of the species have not been evaluated individually. Assemblage and community studies have a wider spectrum of benefits from conservation point of view rather than species-targeted management.

Moths of Gangotri National Park, Govind Wildlife Sanctuary and National Park

A study was conducted in Gangotri Landscape Area (i.e three high altitutde protected areas, Gangotri National Park and Govind Wildlife Sanctuary and Govind National Park) in the district Uttarkashi which represents the biogeographical zone 2B of Western Himalaya. This study was first of its kind in Gangotri Landscape and is one of the few studies on moth communities in India. Moth assemblages varied largely among zones and showed a pattern in relation to altitude, temperature and related microclimatic variables. Inventory completeness was highest for mixed riparian and scrub forest (91.9%) followed by pine forest (84%) , broadleaf forest (70.1%) and conifer and alpine forest (44.2%). 16 families and 1992 specimens of moths were collected from the 20 sampling sites and were primarily sorted into 784 morphospecies. The family Geometridae was the most dominant family in all the vegetation zones sampled, followed by the families Noctuidae, Arctiidae and Pyralidae (Fig. 3). It was observed that despite small differences in geographic distance the landscape was able to support high Lepidopteran diversity and unique patterns of site similarities were observed between forests (Sanyal *et al.*, 2011, 2013).

Nanda Devi Biosphere Reserve

A Similar study is initiated in Nanda Devi Biosphere Reserve in the Garhwal Himalayas. Nanda Devi Biosphere Reserve (30^0 08'-31^0 02'N, 79^0 12'- 80^0 19'E) includes the Nanda Devi and Valley of Flowers National Park (core area: 712.12 km^2, buffer zone: 5148.57 km^2). The area exhibits the typical features of the Western Himalayas characterized by temperate forests, sub-alpine forests, and alpine meadows and is an important repository of biodiversity. The heterogeneity of this landscape provides a refuge for such endemism and supports over 1,000 species of flora and about 520 species of fauna. Studies on invertebrates like Spiders, Butterflies, Beetles and ongoing study of moths aims to evaluate indicator

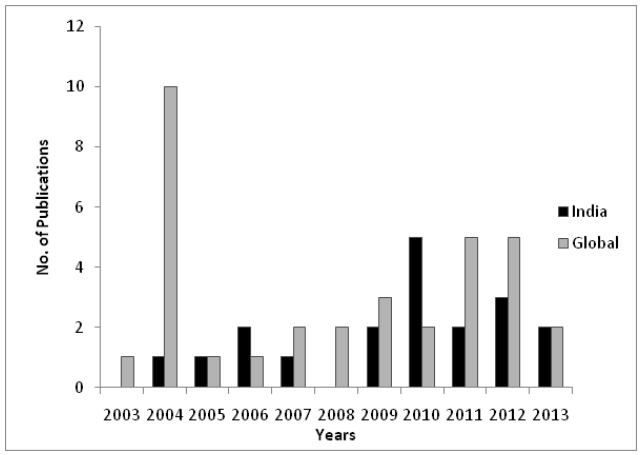

Fig.2: Comparison of number of publications on diversity/ conservation of moths globally and in India in the past 11yrs (Based on the number of publications listed in each case in the first 10 pages of Google Scholar search).

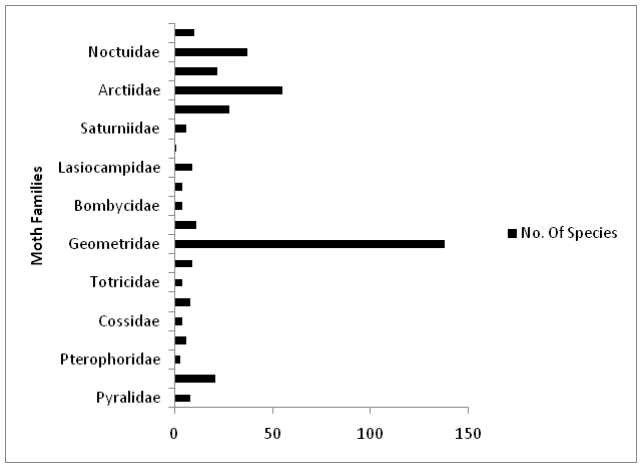

Fig.3: Number of species in all the families identified in the Gangotri Landscape Area.

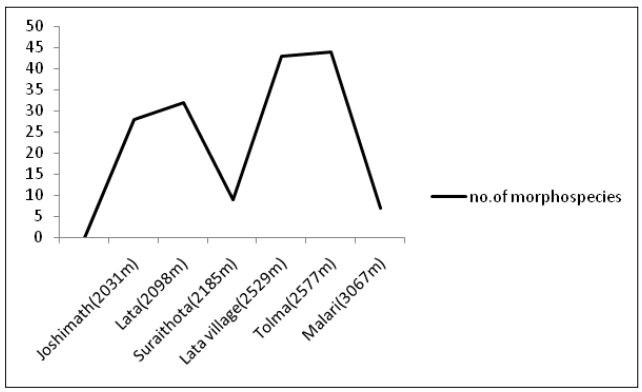

Fig. 4: Number of morphospecies across the elevation in the six distinct sites sampled.

species reflecting certain habitat conditions providing a knowledge base for long-term ecological monitoring in this area. The research initiative plans to sensitize the local communities and stakeholders for identifying the indicators and thus conduct the monitoring in a holistic manner which is vital for assessing future changes and

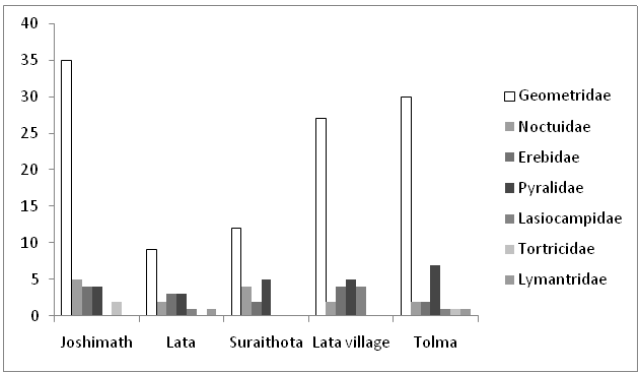

Fig. 5: Proportion of families of moths found across the sites

shift of climatic condition of the region.

Reconnaissance Survey

A preliminary survey was conducted in different locations and habitat types (Joshimath, Lata, Tolma, Suraithota and Malari) of Nanda Devi Biosphere Reserve between April-June 2013. Moths were sampled from dusk-to-dawn including vegetation sampling in (20 × 20) m^2 plots ensuring homogenous vegetation cover. A total of 163 individuals were recorded across the sites. A total of five most diverse families (Noctuidae, Geometridae, Arctiidae, Crambidae, Lymantridae) were identified as morphospecies (Fig.4). Family Geometridae was the prominent family across all the sites (Fig. 5). The influence of climatic, topographic and anthropogenic effect on moth assemblages was also investigated.

What we need to do?

Species-targeted conservation demands complete understanding of the threats against which the species need to be protected. The sound knowledge of the ecology and biology of the species clarifies the causes of decline or survival of the species pertaining to certain environmental conditions. In some cases generalists face decline more than the specialist, which raises the concern of wider environmental changes.

For sustainable development in biodiversity conservation the importance of a complete inventory cannot be denied. Insect inventory still needs revision as they are fragmentary and incomplete in most cases, and much is lacking with regards to the faunistic inventory of a particular state or landscape, which makes monitoring and conservation of insects an impractical thing for the forest management. Studying easy-to-monitor assemblages has far more conservation implications as they can act as surrogates for the entire insect community and indicators of changes in habitat quality. Moth diversity should be correlated as surrogate for the entire insect community, so that the protected area managers have a clear picture of the total diversity and develop their management strategies accordingly.

As an outcome of such an initiative, the species diversity might be categorised into different groups by characterization of habitat as indicator species, as habitat generalists that occur in all habitat types; forest generalist, most abundant in the forest habitats and forest specialist species. Landscape management schemes can attempt to maintain and encourage by management practice to design the conservation of protected area.

Collection of moths as reference material from studies in different areas of the country should be established and maintained. Many projects have been proposed to improve Indian taxonomic abilities but they have very minor implications in this field in general. Policy-makers are bureaucrats who lack the genuine concern of conservation and should be made aware with the guidance of experts in the field and right policies must be formulated in the interest of persistence of moths (Smetacek, 2013). The major practical need for the issue of conservation is to generate enthusiasm and popularize the species and to channelize the very limited funding to the most deserving cases. A well-thought approach for long term monitoring should be implemented rather than being driven by emotions and the conflict of ever increasing human population and exploited resources should be mitigated for developing moths as a sustainable conservation tool.

जैवविविधता अनुवीक्षण के लिए एक सक्षम संरक्षण साधन के रूप में शलभ संचयन (लेपिडोप्टीरा : हीटीरोसीरा) पश्चिमी हिमालयन संरक्षित क्षेत्रों में अध्ययन

प्रिथा डे, वी.पी. उनियाल और अबेश के. सान्याल

सारांश

स्थलीय परितंत्रों में कीटों की आधारभूत भूमिका होने के बावजूद संरक्षण एप्रोचों में लम्बे समय से इनकी अनदेखी की गई है। विविध कीट समूहों में वर्गिकी विशेषज्ञता में अभाव पर विचार करते हुए ये धीरे-धीरे जैवविविधता अनुवीक्षण अध्ययनों में अपना रास्ता बना रहे है। तीसरे सबसे बड़े कीट गण *लेपिडोप्टीरा* से संबंधित शलभ एक विशाल रूप में विविध और कार्यात्मक रूप से महत्वपूर्ण समूह है, जो पर्यावरण निम्नीकरण की इस वर्तमान स्थिति में एक सक्षम जैव-निर्देशक समूह हो सकते हैं। हाल के अध्ययनों से संरक्षण विषयों के समाधान के लिए यह कम अध्ययन किया गया समूह केन्द्र में आया है तथा कीटों के इस मोहक समूह के बारे में अभी बहुत कुछ जानना बाकी है। इस शोधपत्र में पश्चिमी हिमालयन संरक्षित क्षेत्रों में शलभ संग्रहण पर किए गए दो अध्ययनों के कुछ प्रारम्भिक परिणामों को दर्शाया गया है। इस अध्ययन का उद्देश्य संग्रहणों के भीतर समुदाय संरचना

और वितरण पैटर्नों के बारे में एक अन्तदृष्टि देना है, जो भावी जैव–अनुवीक्षण अध्ययनों के लिए पथ प्रदर्शक बन सकते हैं।

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