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MOTHS AS ECOLOGICAL INDICATORS: A REVIEW

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ABSTRACT: The unpredictable and dangerous nature of climate change has grown substantially from last century, it leads to various hazardous problems such as global warming, storms, heavy rains, change of land use pattern, drier climate and forceful migration of millions of organisms. Insects have played key roles in terrestrial ecosystems, yet they have been ignored in conservation approaches. Insects are slowly making their way into the biodiversity studies. The sudden and uncertain changes call for the use of indicator organisms. These indicator organisms show us the changes occurring in our surroundings. Moths are affected by the minute changes in climate and also show changes in reproduction, mortality, dispersion and development. Many experimental findings were conducted by scientific community globally and found that moths are suitable indicators for open areas as well as forest patches. Moths being functionally important and huge, diverse group, can be used as potential bio-indicator group in the present scenario of environmental degradation. Moths as ecological indicators is established globally covering a wide range of current environmental issues like habitat fragmentation, climatic changes and deforestation etc.

KEY WORDS: Indicator, Lepidoptera, moths, environment degradation, diverse, climatic changes

Biodiversity and monitoring assessment are considered vital tools for conservation management (Noss, 1990). Thus monitoring assessment is very censorious for assessing the range of a taxon and prediction of population trends (McGeoch et al., 2010). Functional groups or particular taxa are widely used as bioindicators to reflect environmental changes. These taxa act early by indicating the levels of taxonomic diversity at a site (McGeoch, 1998). Bioindicators are also used for conservation prioritization, response to management and monitoring of ecosystem. Ecological monitoring by insects is essential for several reasons (Spellerberg, 2005). Firstly, various ecosystem and community are unexplored till yet, data collected during monitoring can be added to biodiversity sudies. Secondly, long term data is also needed to understand how anthropogenic activities affect the environment and insect diversity. Moreover, information gathered during monitoring can act as a warning for conservationists to prevent adverse effects on humans and other living organisms. Though invertebrates are neglected in monitoring as well as conservation strategies, yet they are a functionally significant component of biodiversity. Now, they are becoming part of an important part of ecology and conservation strategies (McGeoch et al., 2011). Invertebrates as biological indicators show trends in community composition and species richness more accurately than vertebrates, because of being abundant and more diverse (Bisevac & Majer, 1999; Kremen et al., 1993), and cost-effective to use. The small size of invertebrates makes them more

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sensitive to environmental conditions. It can be good ecological and environmental bioindicators. Their movable property makes them move in response to changing environmental conditions. Their, short generation time gives numerical responses and variability in ecological characteristics gives a wide range of specific environmental response taxa (Samways et al., 2010). Approximately two-thirds of the known organisms are insects and are viewed to be good indicators because of abundant nature, and adaption to different types of environmental conditions (Samways, 1994). Ectothermic organisms such as moths are generally influenced by environmental conditions and lead to modifications in dispersal, development, reproduction and mortality of insect species. These changes cause alteration in voltinism, developmental rate and act upon directly on a population of insects (Bale et al., 2002).

Lepidoptera is one of the most diverse group, representing 157,424 described species globally (van Nieukerken et al., 2011). Lepidopterans are most sensitive indicators determining environmental quality changes (Erhardt, 1985; Kiser, 1987; Thomas, 2005; Wirooks, 2005). In Europe, diurnal Lepidoptera (moths & butterflies) moths are used as indicators for accessing the state of semi-natural grasslands (Rákosy & Schmitt, 2011). Moths are widely accepted as the most sensitive indicators determining the quality of environment and changes occurring in it (Thomas, 2005; Wirooks, 2005). They are also considered vital for ecosystem services because of various roles such as agricultural pests (Sharma & Bisen, 2013), food for various organisms, night pollinators (Macgregor et al., 2015). In addition, they are identified easily, ecologically very sensitive and behavioural monitoring of moths can be paired easily with diversity studies. As demonstrated by Enkhtur et al. (2017), moths are a suitable indicator of grazing pressure in Mongolia. This finding is also supported by other countries such as Scotland (Littlewood, 2008); Finland (Pöyry et al., 2005) and Canada (Bachand et al., 2014). In Germany, higher diversity of micro-moths was found in ungrazed plots in comparison with grazed plots (Rickert et al., 2012). In Canada moths and plants provide complimentary bio-indication of ecosystem condition under various herbivore densities in a study of ecosystem recovery after reduction of large herbivores (deer) (Bachand et al., 2014). Composition and diversity of steppe habitats were influenced by large herbivores (Manier & Hobbs, 2006), having a direct impact on moths. In addition, moths have been widely used as indicators of plant diversity and habitat type in forest ecosystem (Intachat et al., 2005; Lomov et al., 2006).

Ecological indicators must be having one or all of the following characteristics:

- Must provide early warning in response to environmental disturbances (Woodley,1996).
- Must indicate directly the cause of change (Herricks & Schaeffer, 1985).
- Must provide continuous assessment and intensity of stress (Gibbs et al., 1999).
- Must be cost-effective and effectively involved in monitoring (Davis, 1989; Di Castri et al., 1992).

Ecological bioindicators can be divided into various categories depending on their response to environmental changes such as detectors (these are naturally occurring indicators which are sensitive to minor environmental changes, and their number decreases as environmental stress increases), exploiters (their number increases as environmental stress increases), e.g. Chironomidae (Resh & Rosenberg, 1993) and accumulators (these absorb heavy metals and can be used to access the level of toxin levels in an environment) e.g. Carabidae (Jenkins, 1971).

The literature for this review paper was downloaded from various databases such as Google Scholar, Research Gate and PubMed using keywords such as moths, Lepidoptera, environment and indicator organisms and by searching in the bibliographies of papers we found. Most of the articles belong to reputed publications such as Springer, Elsevier, Taylor & Francis and BioOne etc. Braga & Diniz (2018) used a modified light trap for the sampling of saturniid moths in Brazil from August 2012 to July 2013. The light source used in a light trap was a UV fluorescent lamp (15 W) operated by a battery of 48 A. Though light used was weak but yielded good capture size that lives in specific vegetation size. Species richness of Family Saturniidae was found highly representative as compared to previous studies, majority of the species were found during the rainy season. Choi (2011) also used a light trap in Southern South Korea from 2001-2004. The light source in a trap was UV light (22 watts) connected by 12- V battery. A total number of 63 species of moths were identified as indicator organisms. Among them, *Corgatha nitens* and *Idaea impexa* were found both in secondary and conifer dominated forests, Garaeus mirandus was found to as mature forest species. *Maliattha signifera, Chiasmia hebesata, C. nitens* were found found in both secondary forests and sea shore locations. *Corgatha nitens* and *Idaea impexa* were found in secondary forest at seashore locations. An & Choi (2013) used a light trap consisting of 22 watt UV light as light source connected to 12 V battery in South Korea from May to October 2005 to 2009. During the study, 173 light traps were used, from each sampling site, samples were collected 27 to 30 times. Species richness of Noctuidae was highest followed by Geometridae and Notodontidae. It was found that the increase in the number of combinations of candidate taxa increased the average correlation value.

Rákosy & Schmitt (2011) used eight automated light traps having 6 W black light as a light source powered by 12 W battery. Each light trap was supplied with a small amount of ether to narcotize moths. Later on, moths were released after statistical analysis. In addition, transect walks were also performed as time plots on butterflies and diurnal moths (family Zygaenidae and Sessidae). Though this method is not as standardized as normal transect walks, but gives good results. During the study, each site was visited twice for 30 minutes. Moreover, during the study, pheromone traps were used by them for Sessidae moths only. After this, moths were released back to their habitats. During the study total number of 534 species of moths were collected, and the mean number of moths per light trap decreased significantly, an important was observed in macro-moth non-target species with highly significant loss of individuals at conservation sites. Dennis et al. (2019) used RIS for monitoring of moths. RIS monitors moth populations (nocturnal) through light traps. RIS captures consistent samples which makes them reliable without harming moths. This study was carried out in Scotland through 517 RIS traps from 1968- 2014. It was found that more moth species decreased significantly in abundance than increased. Coulthard et al. (2019) also used RIS for collection of moths across the UK between 1974 to 2014. During the study, data was recorded from 43 light traps at 430 sites. Overall, no co-relation was found between genetic distance estimates and abundance changes estimates. In addition, 52 % species were found decreasing over the data period, 26 % were increasing, and 21% were stable. Kitching et al. (2000) showed that some species of moths decreased in the relative abundance with an increase in environmental stress and vice versa and concluded that moths act as an indicator of presence or absence of host plant species. Netherer & Schopf (2010) found that increase in temperature created negative impact on maintenance and termination of diapause in Europe and concluded that moths act as indicators of habitat. Rákosy & Schmitt (2011) found that number of moths increase after the restoration of site. Dieker et al. (2011) concluded that temperature caused uphill movement as well as the extinction of moths, and concluded that moths are suitable ecological indicators of forest and open areas.

DISCUSSION

Biodiversity and its conservation were broadly recognized by masses since the Rio conference of 1992. In most areas of the world, main conservation efforts were on the preservation of savannahs, tropical rain forests and boreal forests (Lawton et al., 1998). Insects have played key roles in terrestrial ecosystems, yet they have been ignored in conservation approaches. Insects are slowly making their way into the biodiversity studies. Productivity and species diversity of biological communities have proved to be important indicators of environmental health (Rapport et al., 1998; Gerlach et al., 2013), that can be used to access the stability of pasture. Lepidoptera has been used to show habitat changes (Hayes et al., 2009), management (associated with logging in tropical forests), (Summerville et al., 2009; Kadlec et al., 2009) and pollution (Hilbeck et al., 2008).

Most of the moth species are considered as good indicators of habitat quality because they were found to be responding to vegetation types, successional process and human disturbances. Moths qualify the criteria of being good for ecological studies because they can be easily attracted towards light traps, which results in an efficient and comparable estimates of species richness and abundance (Choi, 2008). Moreover, moths are also found responding to successional processes (Hilt & Fiedler, 2006) and anthropogenic disturbances (Choi, 2008). The effectiveness of moths as ecological indicators is established globally through experimental datasets (Kitching et al., 2000; Summerville et al., 2004; Lomov et al., 2006) especially covering a wide range of current environmental issues like habitat fragmentation, climatic changes, deforestation and alteration of land use. As explained by Niemelä et al. (1993), species having shorter generation times, will respond quickly to any disturbances than those having longer generation times and are therefore better indicator species. Moths are abundant, diverse, functional importance, high reproductive potential, short generation time, sensitivity to perturbation, ease of sampling, insects are widely used as indicator species to monitor environmental changes and to accesses the success of environmental changes (Andersen et al., 2004).

Most common applications behind the use of Indicator organisms are: monitoring of environmental health; monitoring of environmental integrity; evaluation of habitat restoration; assess effects of pollution. The functioning and services of an ecosystem are affected by various factors such as upsurge in population and climatic change. Indicator organisms are those living organisms that are monitored easily and whose status predicts the condition of the habitat where they live (Bartell, 2006; Burger, 2006). The purpose for choosing a particular as an ecological indicator depends on various factors such as desirable traits, feasibility to analyze and cost together results into the choice of indicators. These ecological indicators quantify the magnitude of stress, degree of exposure or degree of ecological response to the exposure. The use of ecological indicator depends on the assumption that presence or absence, and fluctuations in these indicators reflect changes taking place at various levels in the ecological hierarchy, from genes to species and ultimately to entire regions (Noon et al., 1999). The efficacy of using biodiversity indicator for different types of taxa has been debated widely. Findings of several researchers showed a positive correlation of species richness across taxa among butterflies, vascular plants, tiger beetles, and recommend the use of a specific group as an indicator (Pearson & Carroll, 1998; Pharo et al., 1999). In contrast, findings of other researchers showed weak indicator relationships across different types of taxa (Ricketts et al., 1999; Vessby et al., 2002). Axmacher et al. (2004) showed geometrid moth assemblage is closely related to the environmental factor and vegetation at a particular altitude. Brehm & Fiedler (2005) recorded high diversity of geometrid moths found at disturbed sites. These geometrid moths offer appropriate habitats for a number of species and also provide early successional stage plants (which later on serve as larval food resources).

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