Moths at tropical forest margins – how mega-diverse insect assemblages respond to forest disturbance and recovery

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Summary

Tropical forest moth ensembles are often extraordinarily rich in species and complex in structure. There is an increasing number of quantitative studies from all major tropical realms which now allows for a more rigorous assessment of the ways how such ensembles change along habitat transects from the natural forest towards the edge of large conservation areas, or in the course of forest recovery at such margins. Such knowledge is also essential for deciding if moths can be used for monitoring the biotic effects of forest disturbance on mega-diverse insect faunas at all, and which moth groups are the most suitable targets for this purpose. Using very large data sets from low (Mt. Kinabalu National Park, Borneo) and high elevations (Podocarpus National Park, Ecuador), we investigate how species richness and species composition of moths change at small spatial scales along gradients of disturbance at the edge of natural forest reserves. Local species diversity did not always decline, and sometimes even increased, along the gradients. Ensembles of moths from the families Arctiidae or Sphingidae were as rich as in natural forest, or were even more diverse in habitats close to the forest margin. Geometridae and Pyraloidea ensembles, in contrast, tended to be impoverished. Correlations of alpha diversity measures between moth taxa were often poor and thus did not allow for using one group as a 'biodiversity indicator' of others. Estimates of local diversity also depended on the temporal scale of assessment. Species composition was remarkably sensitive to habitat alterations at forest edges even at very small spatial scales, despite the high dispersal potential of many

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moths. Patterns of beta diversity were highly concordant across unrelated moth taxa with very different life history syndromes. Geometridae ensembles responded more sensitively to changes in canopy openness than arctiid moths and yielded more robust results with regard to sampling effects. Therefore geometrids are particularly promising candidates for environmental monitoring in tropical landscapes. Much of the faunal differentiation between forest and margin habitats was due to shifts in abundance relationships, and not to the presence or absence of 'indicator species'. Therefore, abundance-based monitoring appears more appropriate to detect effects of environmental change on mega-diverse moth ensembles. Our results suggest that patterns of beta (rather than alpha) diversity are generally more meaningful to assess the impact of processes at forest edges relevant to nature conservation and landscape planning.

Keywords: alpha diversity, Andes, Arctiidae, beta diversity, Borneo, community composition, disturbance gradient, Ecuador, forest recovery, Geometridae, herbivorous insects, moths, Mount Kinabalu, Pyraloidea, succession

1 Introduction

Tropical forests harbour the largest fraction of terrestrial biodiversity (Sayer et al. 2000, Wright 2005). Decline and deterioration of forests still progress at an alarming rate in most tropical countries (Wright 2005). Hence the reduction of tropical forests is one of the most pressing challenges to the preservation of global biodiversity. Apart from the loss of primary forest areas due to clear-cutting and conversion into agroforests, farmland or settlements, another suite of major threats is related to fragmentation issues (Laurance 1998, Laurance et al. 2002, Armenteras et al. 2003, Wright 2005). Most remaining tropical forests are islands embedded in a non-forested, anthropogenically transformed landscape matrix. Accordingly, principles of island biogeography and metapopulation dynamics (e.g. size and quality of forest remnants, or distances between fragments) determine the long-term fate of populations, species, and communities of organisms that thrive in these fragments. One special topic related to the island nature of today's tropical forests are edge effects (Murcia 1995, Laurance 1998): forest edges are ecological boundaries characterized by very steep gradients from the forest interior to the surrounding open vegetation. Such gradients are well documented for abiotic factors (light, temperature, humidity, wind speed, rainfall; e.g. Camargo and Kapos 1995, Davies-Colley et al. 2000, Newmark 2001) and have manifold effects on the vegetation (Fox et al. 1997, Williams-Linera et al. 1998, Mesquita et al. 1999). Consequences for organisms at higher trophic levels are also evident. In phytophagous animals, such consequences may be mediated indirectly through the dependence on particular plant species whose presence or abundance changes as a consequence of altered abiotic conditions. Alternatively, abiotic conditions may