A comparison of Coleoptera abundance and diversity between primary and secondary forests

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Abstract: The effects of deforestation and grazing on faunal biodiversity might disappear quickly with forest regeneration or persist well after the development of secondary forest. We compared ground beetle diversity and abundance in a relatively mature secondary forest with a nearby primary forest stand in Monteverde, Costa Rica. Total Coleopteran abundance was similar between forest types, but there was greater species richness in the primary forest (10 vs. 3 species). There was a higher volume of woody debris in the primary forest than in the secondary forest, indicating more structural heterogeneity in the former. We propose that higher species richness in the primary forest is linked to this higher habitat heterogeneity, but the spatial scale at which coarse woody debris is evaluated seems important because there was no correlation between species richness at specific pitfall traps and woody debris within the surrounding 28 m². Results imply that depression of biodiversity after forest disturbances can persist after the development of a mature secondary forest.

Key Words: Carabidae, forest disturbance, ground beetles

Introduction

Though it is widely accepted that large-scale disturbances such as clear-cutting and cattle grazing influence forest structure and biota, it is unclear how persistent these effects are. It is possible that biodiversity recovers quickly and the negative effects of the disturbance rapidly diminish following the development of secondary forest stands. Alternatively, it is possible that these large-scale forest disturbances have lasting effects that persist even after the development of relatively mature secondary forest stands. Lasting effects could be maintained by such things as differences in tree species composition, in nutrient flux rates through the ecosystem and in the abundance of course woody debris relative to primary forest stands.

We evaluated the time scale of biotic recovery from disturbance by comparing a primary forest and a mature secondary forest. Prior to the study the secondary forest stand had been developing for 20 years since logging and was sufficiently well developed to be indistinguishable from the nearby primary forest to the casual observer. Also, the treatment areas were close enough and similar enough to discount dispersal limitations and differences in abiotic factors such as temperature, moisture and radiation. We used ground beetles (Coleoptera: Carabidae) as an indicator of faunal diversity due to the group's diversity and its close association with the soil litter layer. We compared coarse woody debris and leaf litter depth between the primary and secondary forest areas to determine whether persistent differences remained and whether these differences were correlated with carabid diversity.

Methods

This study was conducted on 19 - 21 January 2002, at La Estación Biológia in Monteverde, Costa Rica. Surveys were conducted in primary and secondary forests. Primary forest samples were taken on the Jilguero trail, ~300 m northeast of Monteverde Biological Station (MBS) (elevation 1500 - 1550 m). Secondary forest samples were taken on the Quitirrí trail, ~1200 m south of MBS (elevation 1490 - 1540 m). The secondary forest area had been used as pasture until twenty years prior to the study (M. Hedalgo, pers comm.).

On the mornings of 19 and 20 January, 15 pit fall traps were set along trails at 10 m intervals, ~5 m off trail. All traps consisted of identical 500 mL cups filled with ~100 mL soapy water and recessed until cup rims were flush with leaf litter. Specimens were collected 24 hours after traps were set and were sorted into morphotypes.

Leaf litter depth and woody debris volume were measured within 3 m radius circular plots around each trap. Leaf litter depth was measured in each plot by haphazardly sampling the number of leaf layers at 10 points within each plot. We recorded diameter and length of all fallen wood debris with diameter >5 cm to calculate the total volume of dead wood around each trap.

We tested for correlations between (1) leaf litter depth and species richness by trap and (2) between woody debris volume and species richness by trap. We used an ANOVA to compare leaf litter depth and species richness between forest stands. Total woody debris volume and species richness were compared between forest treatments using a Wilcoxon/Kruskal-Wallis non-parametric test.

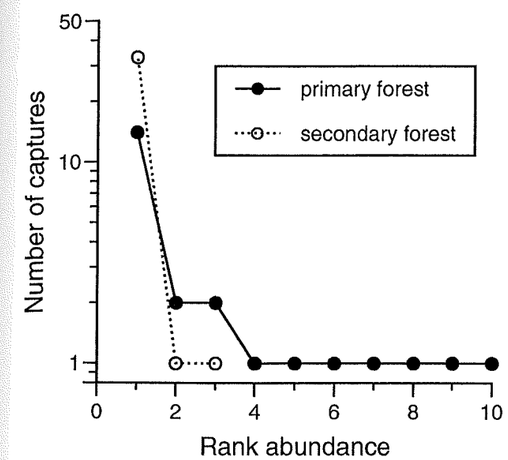

FIG. 1. Rank abundance of Coleopteran morphotypes in primary and secondary forest plots in Monte Verde, Costa Rica.

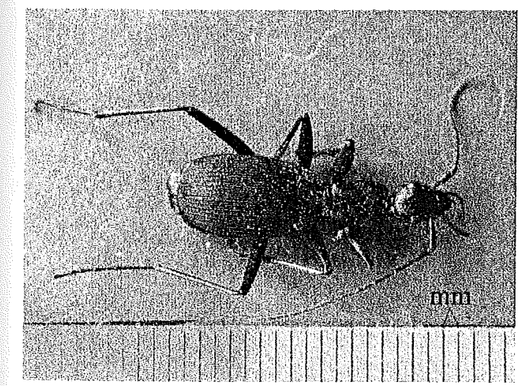

FIG. 2. Most common morphotype (Coleoptera: Carabidae) found in both primary and secondary forest treatments.

Results

We found more beetle species within the primary forest (10 species) than in the secondary forest (3 species), though per-trap richness was not significantly different ($F_{1,28} = 0.45$, $P = 0.51$; Fig. 1). One morphotype of carabid was most abundant in both primary and secondary forest (Fig. 2). Fewer beetles were captured in primary forest than in secondary forest (n = 24 vs. 35), although this difference was not significant among traps ($F_{1,28} = 1.19$, $P = 0.29$). Species richness per-trap was not significantly correlated with either leaf litter ($r = 0.53$, $df = 7$, $P = 0.14$) or woody debris volume ($r = 0.10$, $df = 7$, $P = 0.81$).

Leaf litter depth was very similar between primary forest (mean ± SE; 1.38 ± 0.14 layers) and secondary forest (1.13 ± 0.15 layers; $F_{1,10} = 1.51$, $P = 0.25$). However, woody debris was greater in primary forest (163140 ± 46172 cm³/28 m²) than in secondary forest (36553 ± 33199 cm³/ 28 m²; $F_{1,28} = 5.77$, $P = 0.02$).

Discussion

Our finding that both woody debris volume and total species richness were greater in primary forest than in secondary forest suggests that structural complexity affects species richness of carabids. However, at the finer scale of 28 m² plots around individual traps there were no correlations between species

richness and either woody debris volume or leaf litter depth. It seems likely that higher richness of carabids in primary forests is the result of increased woody resources and higher potential for niche diversification. However, more study will be required to evaluate the spatial scale that is most relevant to carabids, and to separate the effects of coarse woody debris from other factors that covary with it.

Our data indicate that woody debris volume is more important for the diversity of ground beetles than for their abundance. The ability of both forest types to sustain similar beetle abundance might imply that the resource base of the two forests is comparable, and that species richness in the secondary forest is limited by low resource heterogeneity rather than low resource supply. Specific aspects of resource heterogeneity that might be relevant to carabid diversity include physical structure of substrate, predation risk and prey availability. Other measures of habitat complexity such as heterogeneity of soil fungi and soil litter may also contribute to this pattern. Further research is required to analyze the relative importance of these potential factors.

Because Coleoptera are important elements of forest food webs and are also sensitive to habitat alteration, Coleopteran diversity has often been used as an indicator of general habitat quality and ecosystem diversity (Berry et al. 1994, Rykken et al. 1997). In this context, our results imply that logging and grazing can depress habitat heterogeneity and faunal diversity for at least twenty years, which is longer than required for the development of a closed canopy forest. Future research in these forests may offer further insights into the time scale for re-establishment of diversity in forest floor communities, as well as the patterns of species succession following disturbance.

Literature Cited

Berry, M. E., H. M. Fouts, D. J. Gardella, P. L. Kunz, D. M. Larsen and A. E. Liebert. 1994. A comparison of the primary forest understory avifaunal communities of four Costa Rican forests. Pp. 114 - 117 *in* J. L. Bykowski, ed. Dartmouth Studies in Tropical Ecology. Dartmouth College, Hanover, NH.

Levings, S. C. and D. M. Windsor. 1982. Seasonal and annual variation in litter arthropod population. BCI book.

Rykken, J. J., D. E. Capen and S. Mahabir. 1997. Ground beetles as indicators of land type diversity in the Green Mountains of Vermont. *Conservation Biology*. 11: 69 - 78.