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ABSTRACT

Most insect diversity decreases with increased altitude. However, little is known about how coleopteran (beetle) diversity changes with respect to altitude in tropical habitats (Hanski and Cambefort 1991). Coleopterans were collected on the property of Estación Biológica Monteverde at three site locations at different elevations using pit-fall traps baited with mango, human scat, or soapy water. The number of individuals and number of species collected were analyzed and divided by morphology into species by comparison with the collection of the Estación Biológica. A relationship existed between the abundance of Coleoptera and the elevation at which they are found. There were no significant differences in species richness at each elevation. Eleven species of coleopterans were predominantly found at one particular elevation more often than the others.

RESUMEN

La mayor parte de la diversidad de insectos disminuye con el aumento en altitud. Sin embargo, poco se sabe sobre cómo la diversidad de coleópteros (escarabajos) cambia con respecto a la altitud en hábitats tropicales (Hanski y Cambefort 1991). Se colectaron coleópteros en la estacíon biológica Monteverde en tres lugares a diferentes elevaciones usando trampas con mango, excremento humano, o agua jabonosa. El número de individuos y de especies colectados fueron analizados y divididos, de acuerdo a su morfología, en especies con el fin de compararlas con la colecíon de la estacíon biológica. Se encontró una relación entre la abundancia de coleópteros y la elevación en las cuales se encontraron. No hubo diferencias significativas en la riqueza de las especies en cada elevación. Once especies del coleópteros se encontraron en una elevación particular más a menudo que el resto de las especies.

INTRODUCTION

Coleopteran diversity is extremely important and can be used as an indicator for diversity in other plant and animal taxa (Halffter and Arellano 2002). Coleopterans can be found in nearly every environment and there are more than 400,000 species, which represent 25% of all described organisms on Earth (Nadkarni and Wheelwright 2000). Costa Rica is home to 110 coleopteran families of the 178 described worldwide; only 28 of the families found in Costa Rica are considered to be common. These 110 families contain 25,800 known species of an estimated 35,000 species in the country (Solís 2002), which is an indication of how little is known of the true number and diversity of coleopterans that inhabit the Monteverde area. Coleopterans are also important in terms of their ecological activities as pollinators, herbivores, and as a keystone food source for many higher predators (Solís 2002). Coleopterans found in varying abundance or species richness within an area would likely indicate variation in overall community diversity as well (Paarmann et al 2002).

Life zones are known to change greatly in sharp elevational changes, which could effect ecosystem compositions over short distances (Holdridge 1967). The Monteverde Cloud Forests has a very steep gradient and ecosystems in the area are known to change greatly over small distances. In general, insect diversity is known to decline as elevation increases, a change that is often linked to decreases in moisture and temperature. This is exemplary of the fact that altitude is the single most important factor determining insect distribution (Nadkarni and Wheelwright 2000). Many other possible explanations for changes in diversity, abundance, and species richness exist, such as predation, composition of plant species, or available food sources (Janzen 1983).

Searching for the trends that affect coleopteran populations now is very important because of the increased extinction rates. It has been hypothesized by Pounds et al (1999), that as global warming trends increase, many species are being found at higher altitudes than before. The Monteverde Cloud Forest is an ideal location to examine the effects of elevational change on population dynamics because of its great coleopteran diversity.

This study examined what variations in coleopteran diversity, abundance, and species richness existed among three elevations (1355 m, 1465 m, and 1570 m) in the Monteverde Cloud Forest. Species composition at each altitude was also examined to determine whether or not different species exhibit different distributional patterns. It was hypothesized that there would be a decrease in coleopteran diversity, abundance and/or species richness. It was also hypothesized that some coleopteran species would be found more frequently at certain elevations, based on previously reported trends (Nadkarni and Wheelwright 2000).

METHODS

STUDY AREA

This study was conducted on the property of Estación Biológica Monteverde in Monteverde, Puntarenas, Costa Rica between the dates of July 21 and July 30, 2005. The three collection sites were located slightly off of the trails at elevations of 1355 m (at the end of the Catarata Trail), 1465 m (located 350 m along Sendero Principal), and 1570 m (located 785 m along Sendero Principal) (Fig. 1). These sites lie in a high altitude cloud forest which annually receives around 3 m of rainfall and also receives moisture from wind-borne mists and cloud cover (Haber et al 2000). Each site was chosen based on similar flora cover and terrain slope in order to compare similar habitats.

METHODOLOGY

Coleoptera were collected from traps two times, each after a five-day period. Collection was done using pit-fall traps similar to those described by White (1983). The traps consisted of a 900 g plastic pail with the bottom cut out and replaced with a wire mesh (Fig. 2). Two sizes of wire mesh (both squares, with a diagonal length of 3.5 cm and 1.5 cm) were used in order to capture a wide range of coleopteran species. One trap of the smaller mesh and two traps of the larger mesh were used for both scat and mango baits at each site. These traps allowed the beetles to crawl through the mesh to the bait, but did

not allow them to fly out of the trap because their wings made them too wide to pass through the openings in the mesh. The three sampling areas contained nine traps each, arranged in a circular pattern to randomize the collection at each site (Fig 3). The target species belonged to the Scarabaeidae family and are also known as dung beetles. Fruit beetles and species of leaf litter beetle were also considered. The traps were baited with either mango, human scat, or soapy water. Mango was chosen as bait to attract frugivorous beetles due to its availability and the fact that it is commonly found throughout Costa Rica. Human scat was chosen to attract dung beetles, based on known effectiveness from a study by Hays (2005). Soapy water was used to catch any beetle that may just happen to fall into the trap by chance. The three types of bait were selected to insure a varied sample of the local coleopteran fauna. The mango traps contained six similarly sized cubes of ripe mango each. The dung traps contained a trowel tip of scat in the bottom. The open traps consisted of a plain 900 g plastic pail filled with 4 cm water containing dish soap (Fig. 4). All the traps were buried so the top was level with the ground surface.

The individuals were collected into zip-lock bags separated by bait type and site location, resulting in a total of nine bags per collection. The coleopterans were separated into morphospecies based on shape, size, horn morphology and presence, leg shapes and antennae morphology. After separation, the morphospecies were identified using the beetle collection owned by the Estacíon Biológica as well as using identification plates (Solís 2002).

RESULTS

A total of 719 individuals were collected representing 28 different species of Coleoptera. A total of 200 individuals from 21 species were found at the lowest elevation, 248 individuals from 20 species were found at the middle elevation and 271 individuals from 18 species were found at the highest elevation (Appendix 1). Coleopteran abundance was shown to be much greater at higher altitudes than at lower altitudes ($\chi^2 = 10.95$, c.v. = 5.99, df = 2). There were no significant differences in species richness among the three elevations. Both species richness and abundance showed very high correlations in comparison with the different altitudes using linear regressions (Fig. 5) (abundance $R^2 = 0.965$, species richness $R^2 = 0.969$).

Site overlap in the individual species was found to be fairly similar at all sites and no particular differences were found from one site to another (Sorenson coefficient for the lowest site compared to the middle site was 0.7805; for the middle site compared to the high site it was 0.7368; and for the low site compared to the high site it was 0.7692). These results suggested that the low and middle sites are the most similar in species overlap and that the middle and high sites were the most different in species composition.

Shannon-Weiner diversity indices indicated that the diversity was the highest at the middle site (H' = 1.026) followed by the low site (H' = 1.002), whereas the high site (H' = 0.967) had the lowest diversity (Zar 1984). The diversities found were not significantly different enough from each other to conclude that elevation had any correlation with species diversity.

Chi-squared analyses for differences in species presence at each site were calculated for each species found (Table 1). *Deltochilum mexicanum* and the species in

the family *Cucujidae* (morph A) had significant site differences, suggesting that *D. mexicanum* can be found much more often at higher elevations and that the species in the family *Cucujidae* (A) can be found much more often at lower elevations (for *D. mexicanum*, $\chi^2 = 54.2$, df=2, and for the species in the family *Cucujidae* (A), $\chi^2 = 84.5$, df=2). Eleven species were found to have significant differences in population at different elevations.

DISCUSSION

The data showed trends that suggest that the most diversity among beetles was found at the middle elevations. Trends were also found that show that abundance in the number of individuals increased with altitude, but that the number of species decreased as the elevation increased (Fig. 5). This suggests that the original hypothesis was incorrect. A reasonable explanation for this may be that those beetle species found at higher elevations are more adapted to that location and have fewer competing species such as flies and other coprophagous insects. Therefore, the site could potentially have an increased carrying capacity for those species still present (Hanski and Cambefort 1991). A majority of the beetles in this experiment were of the family Scarabaeidae. The biggest influence on the populations and diversity of Scarabaeidae likely corresponded with the type and amount of dung available; which are directly correlated to the number of mammals present at each altitude. The abundance of mammals sets the level of resource availability to dung beetles (Hanski and Cambefort 1991). However, dung beetles have also been found to feed on other types of animal dung such as iguana and boa scat (Hanski and Cambefort 1991). This trend could suggest that there are more mammals or at least more dung or dung of higher quality at higher altitudes. The greater abundance at higher altitudes probably deals with specificity of those species present. Some dung beetles are known to prefer fresh dung that has not been contaminated by flies laying their eggs in it. The decrease of flies as altitude increases likely leads to not necessarily more dung, but higher quality dung. *D. mexicanum* is a species known to prefer fresh dung. Its high population at greater altitudes can likely be attributed to the increase in their specialized food source (Hanski and Cambefort 1991).

The H' value at the middle elevation may be a result of the overlap of the species found at higher elevations and the species found only at lower elevations. Trends like that of species *D. mexicanum*, that were shown to be significant (Table 1), indicate that some of the species are found more abundantly at higher altitudes whereas some species, such as the one in the family *Cucujidae* (A), were found mostly at lower altitudes. The Shannon-Weiner diversity index did not measure solely the number of individuals and the number of species, but also how evenly they were distributed. The value at which the two trend lines (increase in abundance with altitude and decrease in species with altitude) intersect each other would be where the diversity index produced (H') is the highest. Overlap is the highest between the lowest and middle elevation which supports this trend. However, because the Shannon-Weiner diversity indices for these sites were not significantly different in every case, the data did not have enough coleopteran diversity differences at each site to draw such robust conclusions. In this case, the differences found could be attributed solely to site location. Subtle trends in this study cannot be attributed to altitudinal differences alone. Interestingly, similar results have been found

in previous studies. A study conducted in the French Alps at altitudes ranging from 1,750 m to 2,960 m in 1985-1987 and using similar baited pit-fall traps, found that species richness decreased as altitude increased. In the same study, abundance of those species still present at higher elevations greatly increased. A similar study on a tropical mountain in Borneo found a similar phenomenon (Hanski and Cambefort 1991). Both of these results were attributed to decreased competition for resources with other insects as elevation increased. These studies stated that decreased values in the equitability index (the comparison between the log of abundance and the species richness) showed a high degree of dominance by a few species at higher elevations. These studies further suggest that the results of the present study were not just a local phenomenon and that coleopteran populations seem to have similar trends in abundance and species richness in montane environments worldwide and not just in tropical wet habitats like that of Monteverde.

Future studies should explore the possibility of vertical migrations toward higher elevations similar to those that have been found in *Norops* lizards and in many birds. Multiple sampling sites at more elevations than the ones considered in this study would add strength to future research. This would contribute in the avoidance of random events that may have occurred at one site, and did not truly reflect abundance and species richness for that elevation.

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