Bee and wasp diversity and abundance along an elevational gradient, Monteverde, Costa Rica

Mary Oppold
College of Liberal Arts, Bioscience, University of Iowa

Abstract

Many studies of the class Insecta have shown a decrease in species richness with increasing latitude and increasing elevation. Total insect abundance also decreases with increasing altitude, while body size increases at higher elevations. Bee and wasp species diversity and richness were compared along an elevational gradient between 1,126 m and 1,706 m in tropical montane forests in Costa Rica. It was hypothesized that both species abundance and diversity would decrease with increasing elevation and that body size would increase with elevation. No significant difference in species diversity was found along the elevational gradient, although the similarity in species composition between each transect was relatively low. Significant differences in abundances were found between the three elevations tested. Bee and wasp abundance was significantly greater at the lowest elevation (1,126 m). However, there was no significant difference in abundance between the middle and highest elevations. No significant difference was found between body size at the three elevations.

Introduction

Insects are not distributed evenly when studied at a global level; this trend often applies at a local level as well. Many orders of insects have been found to decrease in species richness with increasing latitude and increasing elevation (Stevens 1992). Families in the order Hymenoptera are known to decrease in species richness as elevation increases (Hanson and Gauld 2000). This may be due to more harsh climatic conditions at higher elevations (Stevens 1992). More adverse conditions favor a larger body size in higher altitudes. Bergmann’s rule states that pollinator body size increases with altitude, which has been supported by Malo and Baonza (2002). Malo and Baonza cited decreasing temperature with higher altitudes as the main driving force for increased body size.

Fossil records show that Hymenoptera have been around for over 200 million years (Ugalde 2002). Hymenoptera is the second largest and one of the most important
orders, in regards to mankind, of the class Insecta (Ugalde 2002). Many Hymenoptera are parasites or predators of insects and help keep pest populations down while others are important plant pollinators (Borror and DeLong 1971). Species distributions of Hymenoptera in Costa Rica are known to be restricted to one or two altitudinal zones of the following: lowland (0-800 m), intermediate (800-2000 m), and montane (> 2000 m) (Hanson and Gauld 2000). The range and distribution of Hymenoptera in Costa Rica is being severely affected by deforestation (Hanson and Gauld 2000). An evaluation of solitary bee taxa in 1993 concluded that populations had decreased 85% over the past 20 years because of wildfires, deforestation, and conversion of forest for agriculture use (Frankie and Newstrom 1993).

The reduction of forest habitat for bees and wasps is of particular concern on mountaintops where endemism is high (Hanson and Gauld 2000). Understanding Hymenoptera distributions and abundance is essential (Breed 1999) for determining the effects of habitat reduction by deforestation and fragmentation. This information may aid in predicting what taxa are most sensitive to deforestation (Hughes et al. 2000).

It is argued that altitude is the most important factor for determining insect distribution (Hanson and Gauld 2000). Little is known about the richness and abundance of bees and wasps in tropical wet forest areas, where cloud cover is constant, rain is prevalent, and there is a sharp elevational gradient, such as in areas found in Monteverde and San Luis, Costa Rica. In this study bee and wasp species diversity and abundance were compared at three sites along an elevational gradient between 1,126 m and 1,706 m. It was hypothesized that both species abundance and diversity would decrease with increasing elevation and that body size would increase.

**Materials and Methods**

Bees and wasps were collected at three different elevations (1,126 m, 1,433 m, and 1,706 m). A transect of 110 m long was placed at each elevation. Transect 3 (1,706 m) was selected to be the highest elevation of collection, with a 300 m elevation change between each successive transect, placing transect two at 1,433 m and transect one at 1,126 m. Transects 2 and 3 were placed in the forest adjacent to the Estación Biológica, Monteverde, in montane wet forest (Fig. 1). The transects were located on paths S. Jilguero and S. Division respectively. Transect one was located in premontane wet forest in upper San Luis on Nenes’ property (Fig. 2). Once at the desired elevation the starting spot was marked with flagging tape and 110 m were measured out, marking the middle and the end of each transect.

Both color and scent were used to attract bees and wasps using the pan trap method (Steven Hendrix, personal communication). The colors yellow, blue, and white were chosen because they are in the visual range of wasp and bee spectrum (Romoser and Stoffolano 1998). The scents geranol, eugenol, and eucalipto were applied to each bowl daily with cotton. Twelve colored bowls were placed along every transect starting at 0 meters and spaced every 10 m. Transects were located on trails in order to promote visibility for bees and wasps. Bowl colors were placed in a repeating order in each transect; each color represented four times per transect. The order was blue, white, and yellow for transect one; white, yellow, and blue for transect two; and yellow, blue, and...
white for transect three. The pattern sequence was determined by picking the three colors at random and then repeating the procedure for each site.

After placing the 12 colored bowls at each site they were partially filled with soapy water, which prevented the bees and wasps from escaping the bowls once they entered. Only partially filling each bowl prevented loss of organisms by rain causing the bowls to overflow. The bowls were left out for 24 hours and then collected between 5:15 and 9:00 a.m. during five consecutive days. Upon collection, all insects in each bowl were placed in a designated bag, labeled with transect location, date, and bowl color. Each bowl was then refilled with soapy water and left for another 24 hours, at which time the collection process was repeated. Collections were performed July 21st through 25th, 2005.

All labeled bags were brought back to the lab, where the insects were strained out, rinsed, and placed in a jar with eighty percent alcohol. Each jar was labeled with transect number, bowl color, and date of collection. All insects from the same bowl color of a particular transect were combined in one jar. With the aid of a dissecting scope, all bees and wasps captured were identified to morphological species. Characteristics used for identification were antennae location, length, color, and pubescence; abdomen color, shape, and pubescence; thorax shape, color, and ovipositor; wing veination; and leg characteristics such as color and spurs. Every new morpho-species found was pinned, tagged, assigned a code of letters for a name, and described in writing for future comparison. All morpho-species were also assigned a number that correlated with a relative size scale ranging from 0.5 to 8, the smallest species receiving 0.5. All wasps and bees that were repeats of a previous morpho-species were tallied but not pinned. The individuals tallied were still kept separated by bowl color, transect number, and date collected.

Once all bees and wasps were identified to morpho-species, the diversity, similarity, and differences in abundance of wasps and bees were determined for each transect. The diversity of each transect was determined using the Shannon-Weiner index. The Jaccard Similarity Index was used to compare each site to the others for overlap in morpho-species. Chi-square analysis was used to test for significant differences in abundance between each transect. A Kruskal-Wallis Test was used to compare size categories with elevation. Analysis of Variance and Fisher’s PLSD were used to test for bowl color preference.

Results

A total of 492 individuals were caught over the five days of collection, 273 from transect one, 102 in transect two, and 117 from transect three (Table 1). Seventy-six morpho-species were found in total, 52 in transect one, 41 in transect two, and 39 in transect three. Diversity was very similar between the three sites with transect two having a slightly higher diversity (H’ = 1.445), while transect one and three were almost identical (H’=1.427 and H’=1.421 respectively) (Table 1). No significant differences in diversity were found between the three elevations (Modified t-test, sites one and two: t = -0.359, p > 0.05. Site one and three: t = 0.209, p > 0.05. Sites two and three: t = 0.442, p > 0.05.) The lower and middle sites were the most similar in species composition (Jaccard coefficients for similarity β = 0.424), intermediate between the middle and upper sites (β
= 0.414), and the lowest between lower and upper (β = 0.373) (Table 2). The abundances were significantly different from each other among the three elevations (X² = 109.353, p < 0.05), with the lower elevation having a significantly greater abundance of bees and wasps than the middle (X² = 77.976, p < 0.05) and upper elevations (X² = 62.4, p < 0.05) (Table 2). No significant differences were found between the size of wasps and bees at the three elevations (Kruskal-Wallis). A significant difference in bee and wasp abundance caught per bowl color was found (One-way ANOVA, F = 6.067, P = .0047), (Fig 3). Yellow bowls caught a significantly higher abundance of bees (N = 17, x = 20.647 ± 22.042) than either blue (N = 15, x = 6.133 ± 1.023) or white (N = 15, x = 6.200 ± 4.280), but there was no significant difference found between white or blue (Fishers PLSD, Yellow and Blue: p = 0.0045. Yellow and white: p = 0.0047).

Discussion

Overall species diversity did not show a significant difference along the elevational gradient. This contradicts a study preformed by Murphy (2003), where it was discovered that Meliponinae and Apidae revealed a decrease in diversity with increasing elevation. Murphy’s study included 750 to 1,800 m of elevation, just over 1,000 m elevation change. This may indicate that the elevation gradient from 1,126 to 1,706 m is not large enough to detect any changes in diversity. Abiotic and biotic factors may not change enough to lower the diversity as elevation increases within this range. Further research using a larger elevation gradient is needed to test for a change in wasp and bee diversity.

Although diversity was very similar between the three elevations, species overlap was relatively low. This reveals that species composition is changing with elevation, which is supported by studies finding that Hymenoptera are often restricted to particular zones of elevation (Hanson and Gauld 2000). The forest for the upper two transects at Monteverde was premontane wet forest while San Luis was premontane moist forest (Haber 2000). A study performed in similar locations (1,200 m in San Luis to 1,600 in Monteverde) on the family Formicidae, revealed low similarity levels between three sites within elevation (Neely 2004). Differences in vegetation structure between these two life zones exist due to different abiotic factors such as annual rainfall, temperature, and humidity. The spatial geographic distribution for bees is determined by factors such as climate, vegetation, competition for resources, and availability of nest sites (Roubik and Hanson 2004). A lack of overlap suggests that bees and wasps are specializing in small elevational ranges, even though some are able to fly distances over two km (Roubik 1983). It is not clear whether abiotic factors such as temperature, cloud cover, and rain or biotic factors such as food resources, nesting habitat, or host abundance are the cause of species composition change with elevation. Hypothetically some wasps and bees could fly the distance from transect one to transect three in one foraging trip. If Hymenoptera were indeed foraging that distance, species composition between transects would be expected to be the same. This indicates that species have potential niches throughout the entire spectrum of elevation used in this study, but supports the idea that species only utilize certain niches, and increase their ability to thrive in that particular habitat. This may be due to resource partitioning because of competition. This study did not test for factors effecting composition other than elevation so further studies are needed to examine the affect of abiotic and biotic factors. The morpho-species compositional
change with elevation may be important in defining specific nesting areas and food sources for different species.

The greater abundance of Hymenoptera in the lower transect than the middle and upper transects further support Brehm (2003), who found that the abundance of insects decreases with increasing altitude. It is possible that this is due to more desirable foraging conditions, such as higher temperature and less cloud cover at lower elevations for bees and wasps (Hanson and Gauld 2000). There was not a significant difference between transect two and transect three. It is possible that these locations had more similar daily weather conditions than either site did with transect one. This seems unlikely because bee and wasp morpho-species composition similarity is lower for transect two and three than it is for transect one and two.

The lack of a significant increase in bee and wasp size with increasing elevation may be due to a pan trapping bias toward smaller bees (Gaddis unpublished data). It is possible that larger bees are able to forage higher in the canopy where wind conditions are stronger, making it more difficult for them to detect the bowls. The pan traps were placed on the ground, and do not attract bees and wasps that are foraging at heights that make them unable to detect the pan traps. In order to get an estimate of bee and wasp size for a particular elevation, it is necessary to sample at varying heights throughout the canopy and understory. This would allow for a more accurate size measure, which may or may not show size variation with elevation.

The preference for yellow bowls by bees and wasps is interesting as previous studies have found that a certain species of wasp, *Nasonia vitripennis*, showed no preference between blue and yellow (Baeder and King 2004). However it has been found that parasitic wasps show a preference for yellow over white in regards to host species (Lobdell et al. 2005). None of these studies determined why there were or weren’t preferences. It is possible that yellow is the most visible color to bees and wasps, but further studies are needed to determine cause of preference.

Although the diversity of bees and wasps did not decrease with increasing elevation, it is important to note that the composition between each site and abundance of bees and wasps caught at each transect were different. Deforestation may have negative implications for bees and wasps because losing one level of elevation may lead to the destruction of many species that are not found and cannot survive in remaining habitats of different elevations. If bee and wasp species’ ranges are reduced or their habitat destroyed by such forces as deforestation, they will be forced to move to a different habitat, in which they may not be able to survive. Future studies of bees and wasps along a larger elevational gradient would be helpful in determining the repercussions of deforestation on bee and wasp populations.

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Literature Cited


Malo, J. E., and J. Baonza. 2002 Are there predictable clines in plant pollinator interactions along altitudinal gradients? The example of Cystisus scoparius (L.) Link in the Sierra de Guadarrama (Central Spain). Diversity and distributions. 8: 365.


Table 1. Bee and wasp diversity and abundance found at three elevations at Monteverde, Costa Rica. Transect 1 (1,126 m), transect 2 (1,433 m), transect 3 (1,706 m). (H’ from Shannon-Weiner; A = total number of individuals found.)

<table>
<thead>
<tr>
<th>Location</th>
<th>H'</th>
<th>A</th>
</tr>
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<tbody>
<tr>
<td>Transect 1</td>
<td>1.427</td>
<td>273</td>
</tr>
<tr>
<td>Transect 2</td>
<td>1.445</td>
<td>102</td>
</tr>
<tr>
<td>Transect 3</td>
<td>1.421</td>
<td>117</td>
</tr>
</tbody>
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Table 2. Similarity in morpho-species and abundance comparisons of wasps and bees between three elevations at Monteverde, Costa Rica. Transect 1 (1,126 m), transect 2 (1,433 m), transect 3 (1,706 m). (β = Jaccard similarity index; X² = Chi-square comparisons of abundance)

<table>
<thead>
<tr>
<th>Location</th>
<th>β</th>
<th>X²</th>
<th>P</th>
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<td>77.976</td>
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</tr>
<tr>
<td>Transect 1 vs 3</td>
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<tr>
<td>Transect 2 vs 3</td>
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<td>1.027</td>
<td>&lt;3.84</td>
</tr>
<tr>
<td>Transect 1 vs 2 vs 3</td>
<td>------</td>
<td>109.353</td>
<td>&gt;5.99</td>
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Figure 3. Relationship between the abundance of bees and wasps and bowl color. Yellow and Blue: P=0.0045. Yellow and white: P=0.0047. Significantly more were caught in yellow bowls (N = 17, x = 20.647 ± 22.042) than blue (N = 15, x = 6.133 ± 1.023) or white (N = 15, x = 6.200 ± 4.280). (ANOVA, F = 6.067, P = .0047) (Fisher’s PLSD, yellow and blue P = 0.004; yellow and white P = 0.005)