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Hymenoptera diversity and abundance in fragmented and continuous forest in San Luis, Costa Rica

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ABSTRACT

Fragmentation of forest habitats can have a negative impact on the diversity of many species. When fragmentation impacts pollination, it can result in major changes to the composition of forest plant communities as well as a reduction in fruit production for nearby agriculture. I studied Hymenoptera diversity in a four hectare fragment and a continuous forest using Euglossine traps as well as a mixture of honey and water to attract Hymenoptera species. Hymenoptera diversity did not differ significantly between the two habitats but abundance of Hymenoptera, Euglossine, and Apidae were all significantly greater in the continuous forest site. This indicates that continuous forest supports a larger, more stable population of Hymenoptera species, thereby supplying steadier pollination services to the forest and nearby farms.

RESUMEN

La fragmentación de los bosques puede tener un impacto negativo en la diversidad de muchas especies. Cuando la fragmentación impacta procesos como la polinización, puede causar cambios grandes de la composición de especies de plantas en las comunidades del bosque. Además podría ocasionar una reducción en la producción de frutos en los cultivos aledaños. Estudié la diversidad de Himenóptera en un fragmento de bosque y un bosque continuo usando trampas de Euglossinos, además de una mezcla de miel y agua. La diversidad de Himenóptera no fue diferente en los dos hábitats. Sin embargo, la abundancia de Himenóptera, Euglossinos, y la familia Apidae fue más alta en el sitio del bosque continuo. Esto indica que el bosque continuo mantiene poblaciones más grandes y más estables de especies de Himenóptera. Por lo que el abastecimiento de polinizadores a los cultivos es más estable en sitios próximos al bosque continuo.

INTRODUCTION

Forests throughout the tropics are experiencing fragmentation as patches are cleared for agriculture and development (Aizen and Feinsinger 1994a). A growing body of evidence is showing that this practice significantly affects forest communities (Aizen and Feinsinger 1994a, Aizen and Feinsinger 1994b, Powell and Powell 1987, Sekercioglu et al 2001). Fragmented habitats differ from continuous forests in several crucial ways. Fragments are discontinuous with reduced area and a greater edge to interior ratio. Wind

and insolation are stronger in fragments, putting organisms at a greater risk for desiccation (Aizen and Feinsinger 1994a). Consequently, susceptible species will suffer in fragments, potentially reducing diversity and abundance in these harsher habitats. Studies of different species have shown that many species suffer when their forest habitat is fragmented (Powell and Powell 1987, Aizen and Feinsinger 1994a). For example, a study by Sekercioglu et al. (2001) found significantly fewer insectivorous birds in the understory of fragments compared to continuous forests. They reported that the best determinant of success by a bird species in fragments was the ability to disperse through deforested habitats (Sekercioglu et al. 2001). By changing the conditions of the habitat, fragments can add new selective pressures for species, favoring those that can adapt to the new conditions.

Changes in species composition have a stronger impact on the forest when they disrupt pollination and seed dispersal mutualisms (Aizen and Feinsinger 1994a). When pollinator populations change, this can impact both native plant species and nearby crops (Aizen and Feinsinger 1994b) because diversity of pollinators may impact pollination and consequently seed and fruit set (Ricketts 2003). A study by Ricketts et al. (2004) showed that coffee plants near large forest patches (greater than 46 ha) produced more fruit than those located far from forest. Pollination studies showed that the increase in production was due to the pollination services received from the nearby forest (Ricketts et al. 2004). However, it is still unclear if small fragments will yield the same benefit.

This study addresses the effects of fragmentation on the abundance and diversity of Hymenoptera. Hymenopterans have a large impact on the forest community because they provide pollination services through bees (Apidae) and biological control of agricultural pests through wasps (Kean and Barlow 2001). My purpose was to determine how fragmentation impacts Hymenoptera populations. My hypothesis was that Hymenoptera diversity and abundance would differ between the four-hectare fragment and the continuous forest. I predicted that diversity and abundance would be greater in the continuous forest. The results of my study will provide insight into what land use strategies are necessary to preserve forest Hymenoptera species for conservation and agricultural benefits.

MATERIALS AND METHODS

My two study sites were located in San Luis, a farming community in Puntarenas, Costa Rica. The farms in San Luis are bordered by either continuous forest or forest fragments. The continuous forest site was located near the edge of a forest that is contiguous with the Monteverde Cloud Forest Preserve. The fragment site, located less than one km away from the continuous forest, was a four-hectare patch situated behind a series of small coffee farms collectively known as Finca la Bella. In each site, I placed my traps 100 m in from the edge of the forest. To catch Euglossine bees, I hung two commercial, yellow euglossine bee traps in each site. The traps were hung from branches at eye level (1.5 m) and were located roughly two meters apart. I placed blotter paper covered with eugenol scent inside each trap. I visited each site in the morning for 11 days between October 26 and November 15. Each day I took three samples of the number of bees present inside or outside the trap. I recorded the bees present when I arrived, ten minutes later, and again

after another ten minutes. I preserved a sample of each species in a vial of alcohol and later identified the species to the genus level.

To study overall Hymenoptera diversity and abundance, I visited each site six times in the morning from November 8 to November 15. In each site, I selected two palm branches at eye level (1.5 m) roughly three meters apart. I sprayed the underside and topside of the leaves with a mixture of one part honey to four parts water. Ten minutes later, I observed each branch for one minute and recorded the number of each Hymenoptera species present. I repeated this two more times for a total of three observations per site each day.

I used the Shannon-Weiner diversity index to calculate the Shannon-Weiner diversity indices for the continuous forest and the fragment. I then used a t-test to determine if the indices were significantly different. I used three separate chi-squared tests to compare the abundances of Hymenoptera, bees, and Euglossine bees in the continuous and fragment sites.

RESULTS

I observed nine species in the continuous forest site and found all but two of the same species in the fragment site (Fig 1). *Apis mellifera* and the clear wing morphospecies were not found in the fragment site (Fig 1). No species were found only in the fragment and all except two species were observed more often in the continuous site (Fig 1). *Eulaema sp.* was observed only once in each habitat (Fig 1). The yellow morphospecies of Ichneumonidae was the only species that was more abundant in the fragment site with ten sightings in the fragment and seven in the continuous site (Fig 1).

Hymenoptera diversity was not significantly different between continuous forest ($H' = 0.659$) and fragmented forest habitats ($H' = 0.631$) (t test, $t = 0.343$, $df = 94.31$, $p > .05$, Fig 1). Hymenoptera abundance was significantly greater in continuous forest compared to the fragment ($\chi^2 = 100.77$, $df = 1$, $p < .05$, Fig 2) as was total bee abundance ($\chi^2 = 19.932$, $df = 1$, $p < .05$, Fig 3). Euglossine bee abundance was significantly greater in the continuous forest site ($\chi^2 = 7.136$ $df = 1$, $p < .05$, Fig 4).

DISCUSSION

I expected the diversity and abundance of Hymenoptera to be greater in continuous forest than in fragmented forest but I found no significant difference. I may have found no significant difference in diversity because my sites were located within 100 meters of the edge of the forest. I chose to sample from the edge to accurately sample the Hymenoptera populations available for pollinating nearby crops. However, the edge habitat of a forest contains some of the same conditions, such as increased wind and insolation that are found in fragments (Aizen and Feinsinger 1994a). This could have altered the community on the edge of the continuous forest.

However, it is also possible that not enough time has passed since fragmentation to show all its effects on the forest. The San Luis area was first cleared for agriculture 50-60 years ago. Often, forest communities take longer than this to fully adapt to a new pressure; it is possible that diversity may decrease in this fragment in the future. This possibility is supported by the higher abundance of Hymenoptera, Apidae, and

Euglossine that I found in the continuous site. These results indicate that fragmentation may lead to smaller populations of Hymenoptera species. Due to genetic drift, a reduced population size is likely to lead to reduced genetic variability, which in turn leads to less stable populations with a greater likelihood of extinction (Aizen and Feinsinger 1994a). Some of the observed Hymenoptera species may later experience local extinctions in this fragment due to their decreased abundance. This would reduce the local diversity of Hymenopterans in the fragment. In the future, the continuous forest may contain greater Hymenoptera diversity, especially if further fragmentation of the four-hectare patch occurs.

It remains to be seen whether fragmentation will ultimately lead to a decrease in Hymenoptera diversity. However, we do know that as conditions change with fragmentation, species that do well in disturbed areas, such as members of the Ichneumonidae family and *Apis mellifera (*Gauld 1995 and Hanson et al.1995), will have an advantage over species that suffer in fragments, such as Euglossians (Powell and Powell 1987). This is not only true for Hymenoptera species; as an order with many plant-animal interactions, a change in either Hymenoptera abundance, diversity, or composition is likely to mean changes for plant communities as well (Aizen and Feinsinger 1994b). Plants that are dependent on declining pollinator species will suffer declines themselves. Euglossine bees are significant pollinators for over 30 tropical plant families including Orchidaceae, Solanaceae, Bignoniaceae, and Luguminaceae. If euglossine bee populations decline in fragmented forest, as it seems they have done in San Luis, these plant families are likely to follow (Powell and Powell 1987).

It is likely that this change in pollinator composition will ultimately result in a less diverse community of plants. Aizen and Feisinger's study on forest fragmentation revealed that 13 out of the 16 plant species studied showed declines in pollination levels from continuous forest to fragments. Seed production also decreased for many of these species in the fragmented forest patches as a result of reduced pollination. This suggests that a smaller group of species will contribute more seeds to the seed set. These few species will eventually come to dominate the plant community in fragments (Aizen and Feinsinger 1994a).

In a farming community like San Luis, preservation of forest diversity is not just for conservation's sake alone. The pollination services provided by forest bee species are highly valuable to nearby agricultural production (Ricketts et al 2004). More diverse pollinator populations stabilize pollination services and help buffer against declines in any one species (Ricketts 2004). Taylor Ricketts has shown that coffee farms near large patches of forest (46 and 111 ha) produce more and higher quality coffee than farms near a narrow riparian strip (2.5 km long by 30-70 m wide)(Rickets 2004). In addition, many species of wasps can also provide ecosystem services as biological control agents for agricultural pests (Kean and Barlow 2001).

The results of my study demonstrate that small forest fragments, even within one km of continuous forest, cannot support the same size of Hymenoptera populations that continuous forest can. This indicates that communities like San Luis cannot continue to fragment their surrounding forests to produce more land for agriculture. As a result, farmers may lose money in the end due to decreased crop yield following decreased pollinator abundance. Further directions for research include repeating this study with a

larger sample size in sites further into the forest to more accurately sample Hymenoptera populations in the forest interior.

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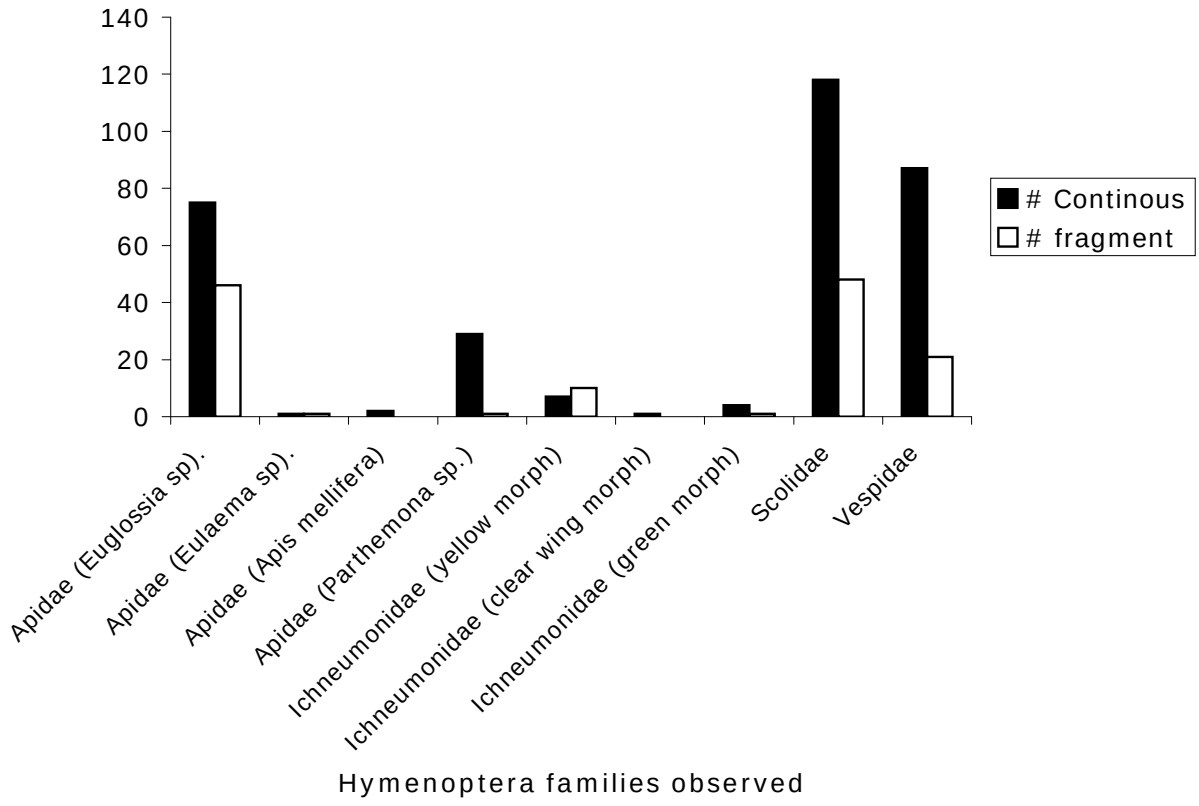

Fig 1. Hymenoptera species observed in continuous and fragment sites. Hymenoptera diversity was not significantly different between sites ($t = 0.343$, $df = 94.31$, $p > .05$).

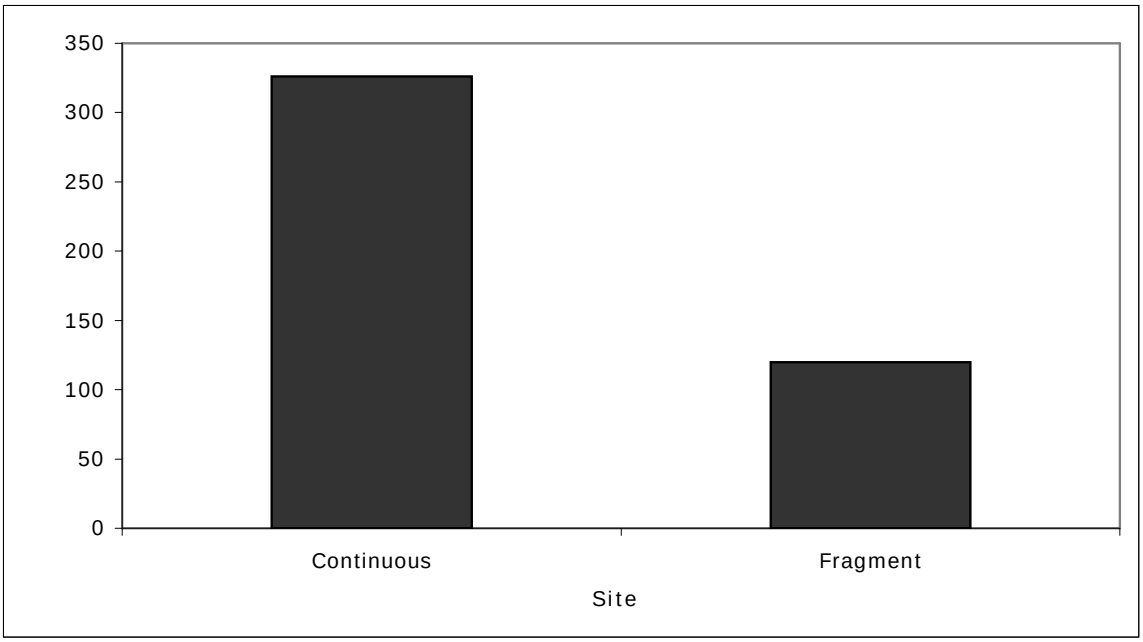

Fig 2. Total number Hymenoptera observed in continuous and fragment sites. Hymenoptera abundance was significantly greater in the continuous forest site (χ^2= 100.77, df =1, p<.05).

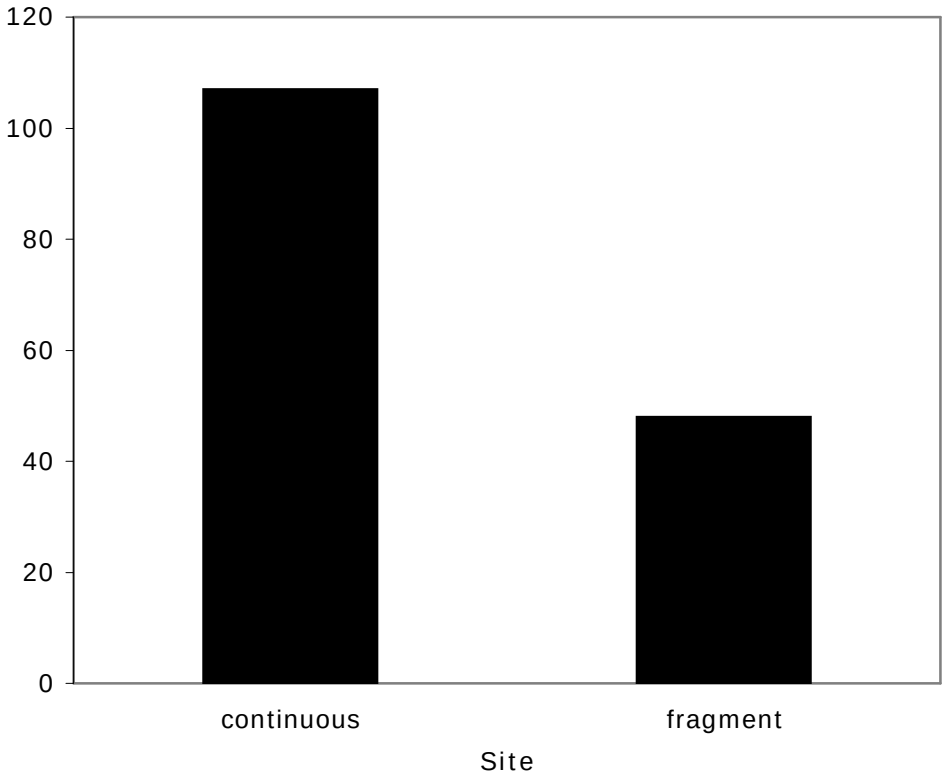

Fig 3. Total number of Apidae individuals observed in continuous and fragment sites. Apidae abundance was significantly greater in the continuous forest site ($\chi^2 = 19.932$, df = 1, $p<.05$).

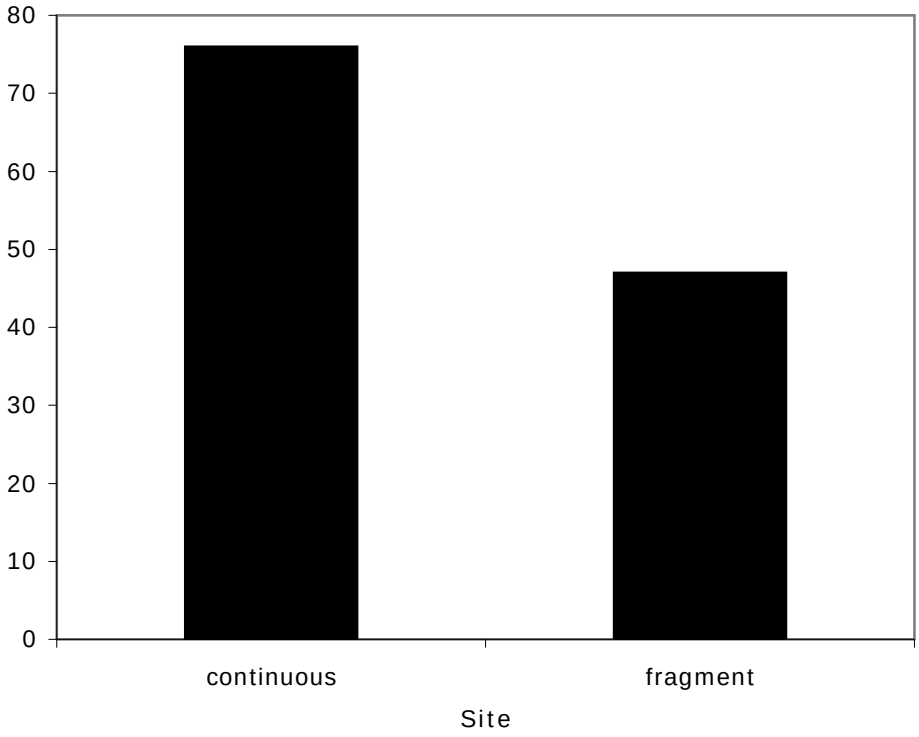

Fig 4. Total number of Euglossinae individuals observed in continuous and fragment sites. Euglossinae abundance was significantly greater in the continuous site ($\chi^2 = 7.136$, df = 1, $p<.05$).