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Jesse Laine

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Insect communities across forest fragments of different sizes in Monteverde

Jesse Laine
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ABSTRACT

Forest fragmentation creates numerous boundaries and microclimates that affect organisms of all taxa. I studied the composition of insect communities across two forest fragments of different sizes, as well as continuous forest and pasture. Pitfall traps and sweep netting techniques were used to sample 888 insects overall. The fragments had similar numbers of insects and morphospecies, regardless of size. The pasture had the most morphospecies present. In addition, Forest edges consistently showed higher abundance and diversity than forest cores. This indicates that reduction of habitable land does not always reduce the numbers of individuals and species, and in some cases can increase them. Only four of the total 145 morphospecies sampled were found living in every site. This means 2.8% of morphospecies were resilient and generalist enough to exist across the different habitats. This research shows that the differences in habitat created by fragmentation are exceptionally difficult for insects to manage. Future research should do similar samples in different regions and climates.

Comunidades de insectos en fragmentos de bosques de diferentes tamaños en Monteverde

RESUMEN

La fragmentación del bosque crea numerosos límites y microclimas que afectan a organismos de todos los taxones. Estudié la composición de las comunidades de insectos en dos fragmentos de bosques de diferentes tamaños, así como un bosque continuo y un pastizal. Utilicé dos métodos para colectar insectos: trampas de caída (pitfall) y barrido con red de mariposas, y colecté 888 insectos en total. Los fragmentos tenían números similares de insectos y morfoespecies, independientemente del tamaño. El pasto tenía la mayor cantidad de morfoespecies presentes. Además, los bordes del bosque mostraron consistentemente mayor abundancia y diversidad que los núcleos forestales. Esto indica que la reducción de áreas habitables no siempre reduce el número de individuos y especies, y en algunos casos puede aumentarlos. Solo cuatro de las 145 morfoespecies muestreadas se encontraron en todos los sitios, lo cual significa que el 2.8% de las morfoespecies eran lo suficientemente resistentes y generalistas como para existir en los diferentes hábitats. Esta investigación muestra que las barreras creadas por la fragmentación son excepcionalmente difíciles de cruzar por insectos. Futuras investigaciones deberían hacer muestras similares en diferentes regiones y épocas de año.

Forest fragmentation is a widely occurring event where deforestation for human development leaves a once continuous forest in a broken, patchy state. This causes the forest to undergo several changes, including a shift in plant communities and microclimate. These fragments create barriers for some species and can limit their mobility between patches. Species are hindered from travelling across fragments by the distance between habitats, abiotic barriers such as roads that separate the potential living space, and the differing conditions within each fragment. Fragmentation also creates two smaller habitats within each fragment. Forest fragment edges have different environmental conditions, such as higher sun and wind exposure, and therefore have different flora and fauna than core forest (Murcia 1995).

Multiple studies show the effect of forest patches on tropical insect diversity and abundance (Klein 1989, Hill 2003). These studies often correlate decreasing fragment size with decreasing populations of specific insects (Jenkins 2013). Fewer studies have examined the relationships of several close patches of forest in the context of insect communities and fragment size. Insect community studies suggest that there is not necessarily an overall species loss, but rather a species turnover in the composition of the community (Summerville 2004). When looking at several fragments, the overlap of species across sites can reveal the probability of certain species to travel across fragments and proliferate (Hill 2011).

I sampled insects in order to characterize insect community composition across several fragments and compare presence of morphospecies. This information allowed me to explore which insects are better able to travel and proliferate amongst divided patches of habitat. Knowing these species, and the mechanisms behind their distribution, is crucial to understanding the future of tropical insect communities. It is important to predict which insect groups could increase in presence as a result of fragmentation because insects exist at a low trophic level, and are a food and pollination source for a large amount of other tropical forest taxa. The layout of the insect community can also predict the future plant communities (Andresen 2003). This study explores how different fragment habitats affect insect communities, and which species are resilient enough to exist across multiple different sites.

MATERIALS AND METHODS

I established four test sites in the Monteverde area of Puntarenas, Costa Rica. Two of these sites were small (~two hectares) and large (~4 hectares) forest fragments (Finca Arces and Finca San Francisco, respectively). The third site was a grassy pasture that separates the two forest fragments. The fourth site was a large section of continuous forest across a road from the three other sites, in a reserve called the Santuario Ecólogico (Figure 1).

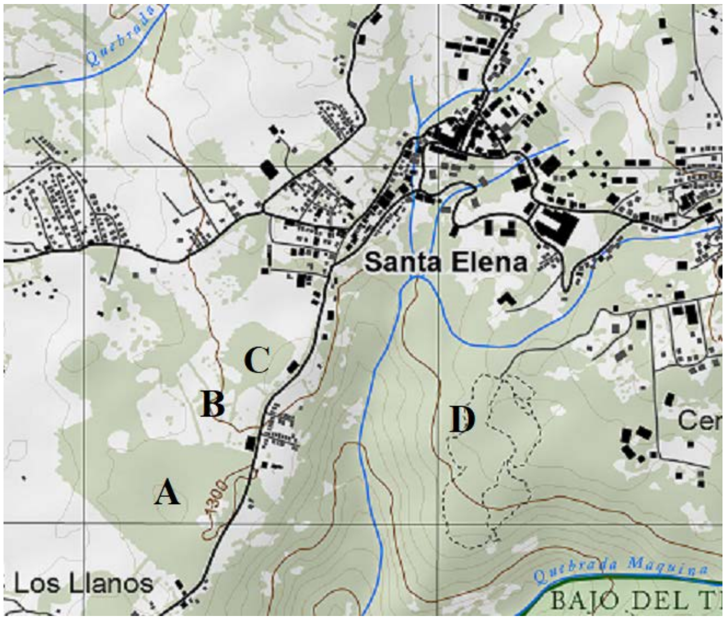


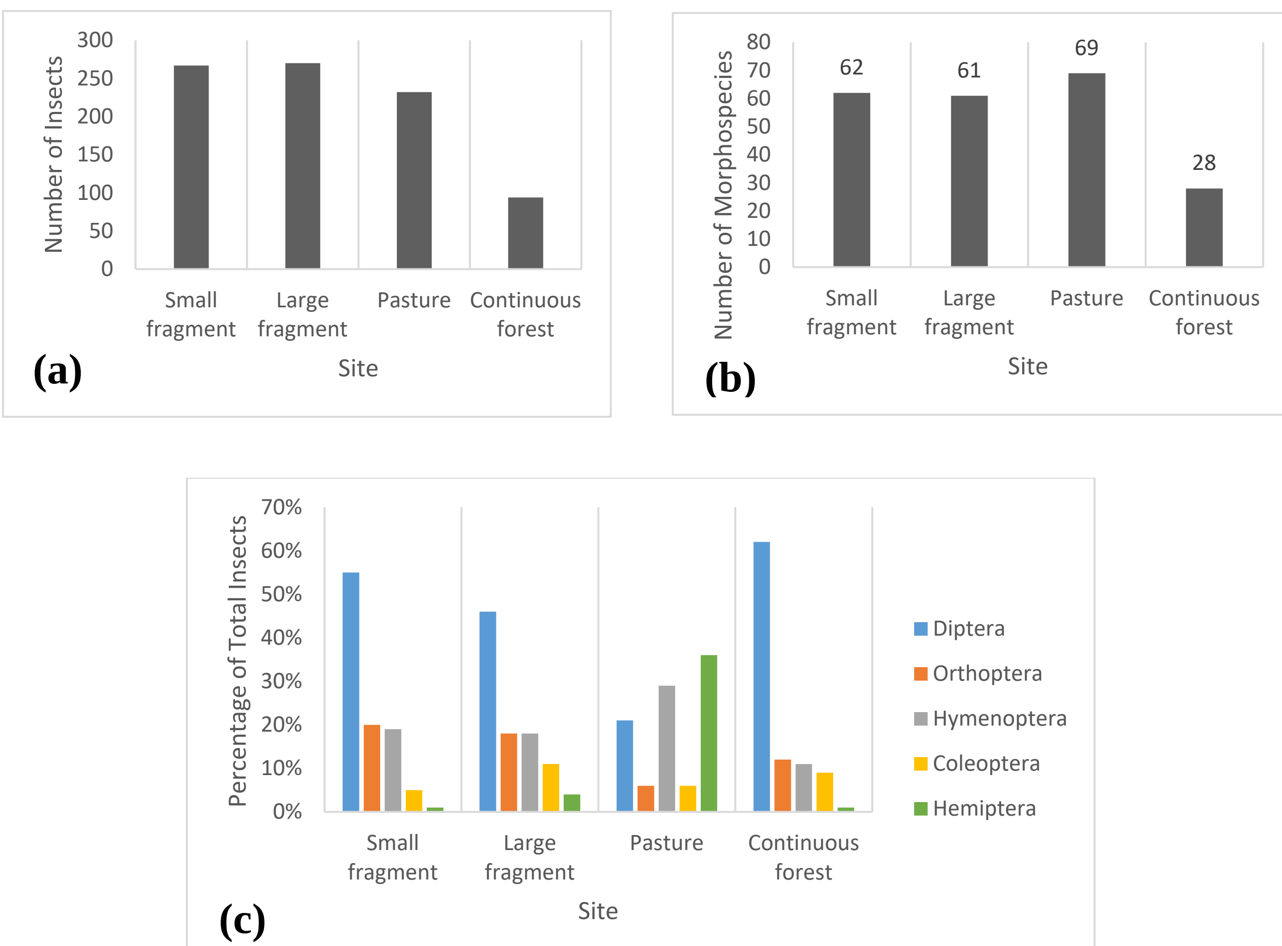
Figure 1 – The four study sites. A is the large fragment (Finca San Francisco). B is the pasture. C is the small fragment (Finca Arce). D is the continuous forest (Santuario Ecológico).

For each site, I used pitfall traps and sweep netting to collect samples. In the small and large fragments, I set ten pitfall traps along the forest edge (within 15 meters of the tree line) spaced between five and ten meters apart. I then set ten pitfall trap in the forest core (~100 meters away from the edge) with similar spacing between traps. In the pasture, 20 pitfall traps were set all along the edge, as the pasture core was not conducive to setting traps. In the continuous forest, 20 pitfall traps were placed along the trails running through the core of the forest. The pitfall traps all had an opening of ~5cm. Each trap was filled with ~2 centimeters of a mixture of 80% water, 20% ethanol, and several drops of soap. The pitfall traps were collected 24 hours after being buried. The contents were strained and the insects were separated from the leaves, soil, and crustaceans that had fallen into the traps.

For sweep netting, I defined three different areas (~10x10 meters each) to sweep. In the small and large fragments, these three sites were located on the edge, ~50 meters from the edge, and in the core. In the pasture, these sites were along the edge bordering the small fragment, the edge bordering the large fragment, and the core. In the continuous forest, these three sites were dispersed through the core. For each site at around 11:00am I would swing the butterfly net in a figure eight pattern while slowly moving along the 10x10 meter area. I would vary the height of the net as I swept along the vegetation. After sweeping the full area, which usually took around 15 minutes, I would place the mass of plant matter and insects that had accumulated in the net into a labeled plastic bag. I placed the sweep net samples in a freezer for at least 12 hours before handling. All sweep netting was done in close vicinity to the pitfall traps in the area. Sampling occurred between 12 November 2017 and 25 November 2017. I pinned all collected samples and separated them based on location and trap type. The collection was identified to order and sorted to morphospecies using a decimal code, and all information was entered into Excel. I then compared morphospecies layouts amongst all sites, as well as examined data based on abundances.

RESULTS

In total, 888 insects were collected across seven orders and 145 morphospecies. The two fragments and the pasture had similar numbers of insects, while the continuous forest had significantly less (Figure 2a). Similarly, the fragments and pasture had similar numbers of morphospecies present, while the continuous forest had less (Figure 2b). The pasture had the most morphospecies present, despite having less individuals than the fragments. Diptera (flies) was the most prevalent order overall, but Hemiptera (true bugs) was more abundant within the pasture (Figure 2c). The fragments and continuous forest follow similar patterns of order distribution, while the pasture has a different layout. Each site had a subset of "isolated" species that were only found at that specific site. The pasture had the most isolated species present, while the two fragments had similar levels of isolated species (Figure 2d). The pasture was the most diverse area, based on the reciprocal Simpson's index (22.0). The small fragment (18.7) was more diverse than both the large fragment (9.8) and the continuous forest (14.9).



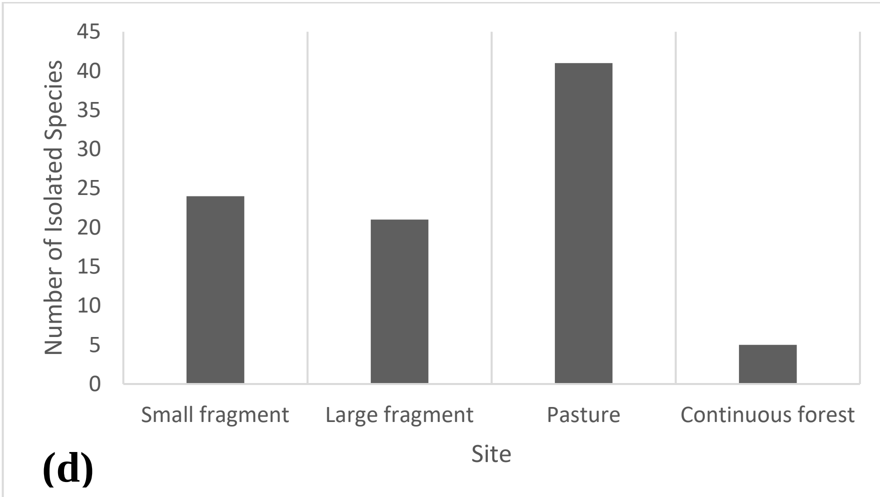


Figure 2 – (a) the total number of insects across all sites. (b) the total number of morphospecies in each site. (c) the number of each insect order across all sites. (d) the number of "isolated" morphospecies for each site.

There was a consistent difference between the communities of edge forest and core forest. Across both fragments, edge samples always contained more individual insects than core samples (Figure 3a). Additionally, edges (n=31) had higher numbers of isolated species than forest cores (n=20) (Figure 3b).

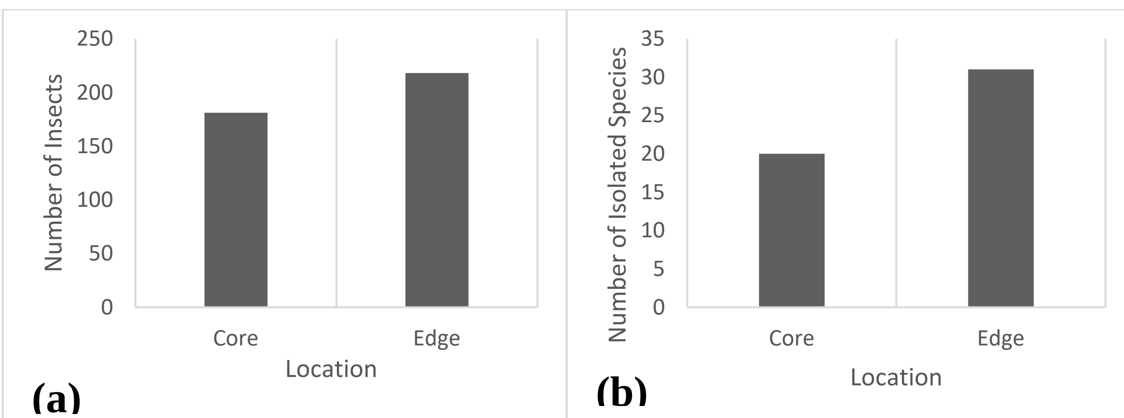


Figure 3 – (a) the total number of insects in edges and cores. (b) the number of morphospecies only found in edges and cores.

In order to examine the permeability of the natural borders that form when forests are fragmented, I observed the overlap of species amongst all four sites. Only four morphospecies were found in all four sites, 2.8% of the total morphospecies (Figure 4). In addition, only 12 species were found in three of the four possible sites. This means 11% of the total unique morphospecies were found in at least three sites simultaneously. Every other species was either isolated to one site, or was found in two of the four sites. The four species that were found in all sites were also highly concentrated within either the core of the forest fragments, or the core of the continuous forest (Figure 5). Three of the species have low concentrations in the other site locations, except in the case of one Diptera species, which has high abundance in the core and the edge locations. The four species had even abundances in the continuous forest, while the other sites had differing numbers of each species (Figure 6).

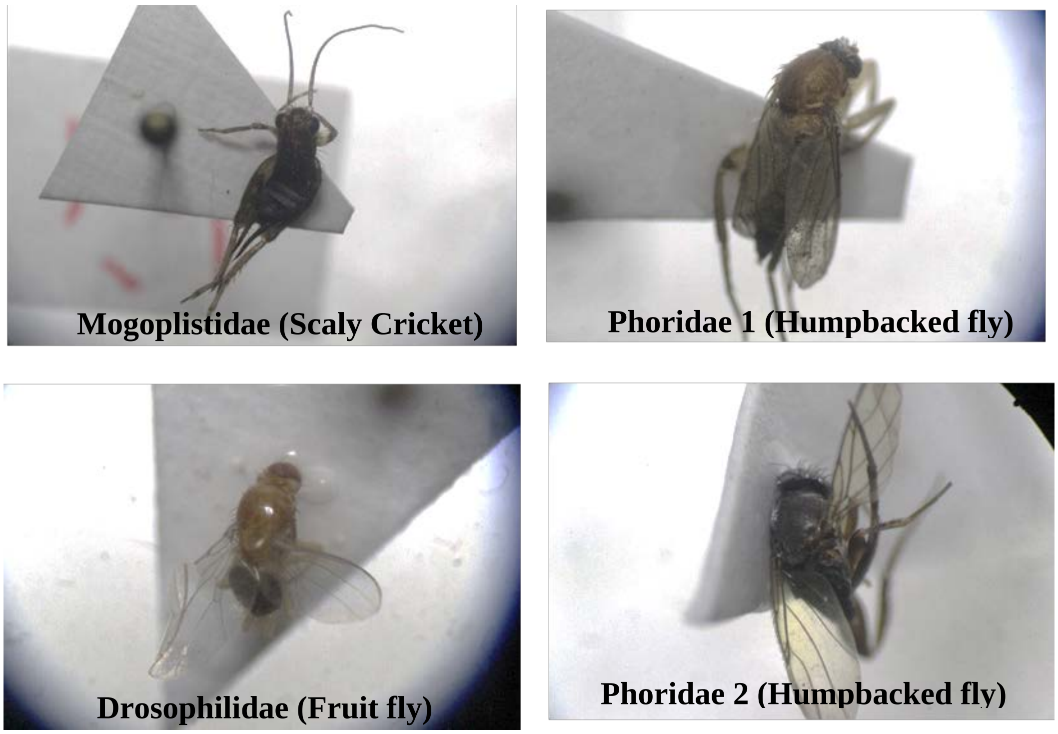


Figure 4 – The four morphospecies found in every site

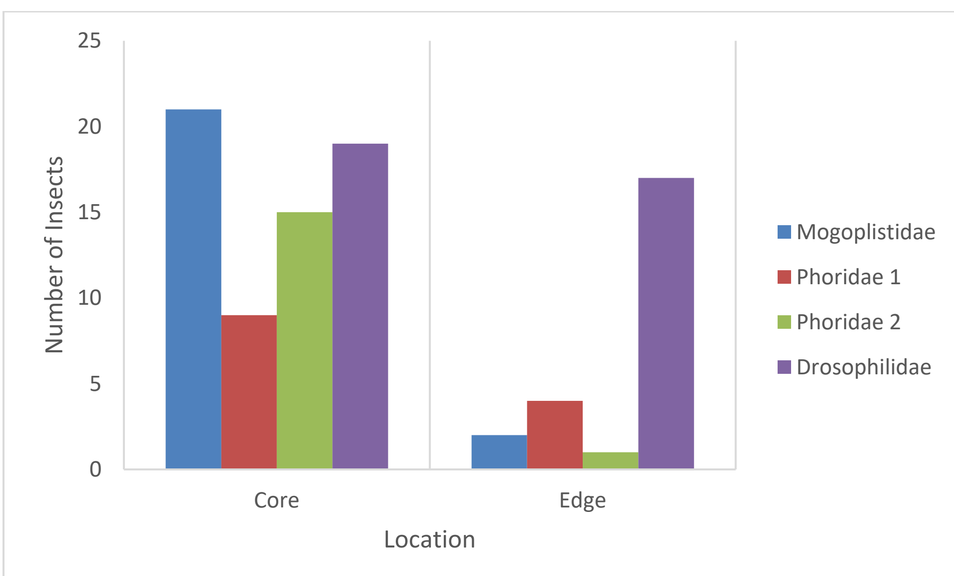


Figure 5 – The distribution of the "shared" morphospecies across core and edge forest

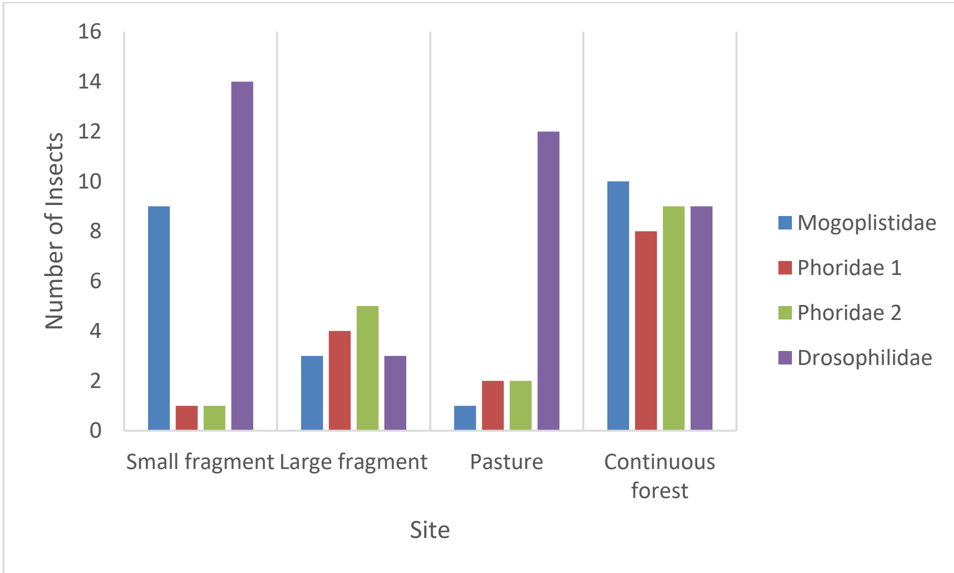


Figure 6 – the distribution of the four "shared" morphospecies across all sites

DISCUSSION

Insect communities showed several trends across the different sites. The number of insects present as well as the number of different morphospecies in each site is relatively constant in every site other than the continuous forest (Figure 1a) (Figure 1b). This serves to clarify the effect that edges and pasture land can have on community compositions, as forest fragments can actually increase the diversity and abundance of insects. Fragments usually experience moderate to high levels of disturbance, which have been shown to encourage greater varieties of plants and animals (Ross 2002) (Laurance 2011).

While any species loss caused by deforestation is a massive problem, the overall communities are seemingly more likely to experience a turnover event as opposed to a net loss, where different species are beginning to occupy niches that have been altered or vacated. Figure 1d shows that the pasture had the most species that were "isolated," meaning they were only found in one of the locations. This is likely because the pasture offers many habitat characteristics that are not found in forest settings, and thus creates unique morphospecies. This difference between forest and pasture is also supported by figure 1c. The fragments and the continuous forest show a similar pattern of insect order composition, likely because they are similar environments, whereas the pasture has a completely different composition of insect orders.

While the pasture and the small fragment showed greater diversity than the continuous forest, this does not necessarily mean those communities are stable or healthy. Most forest fragments have only been fragmented recently, and thus have not yet had time to fully recover from the disturbance and settle into an equilibrium. Davies describes certain traits of populations that lead to a higher probability of extinction in fragments. "Rare" species with low occurrence rates in fragments are more likely to disappear from the ecosystem in later years than species with high abundances (Davies 2000). The two fragments and the pasture had more than double the amount of morphospecies with only one or two individuals sampled (rare species) than the continuous forest did. This could mean that, while the fragments and pasture technically have higher diversity and abundance at this moment, many species could decline heavily in the future in these locations. This pattern, where abundance and richness temporarily increases and then rapidly declines, has been shown in previous studies with insects (Larson 2008). The species turnover event, therefore, could only be a temporary phenomenon before species declines.

The two forest fragments also exhibited significant differences between core and edge locations. Edges had more total insects, and more isolated species than cores (Figure 3a) (Figure 3b). Edges are exposed to different conditions than core forest, such as increased sunlight and wind exposure (Murcia 1995), and this creates a higher degree of disturbance and consequently can create higher diversity and abundance (Harper 2005). The forest edge also acts as a meeting point where pasture species and core species can overlap, increasing the overall number of insects sampled. One possible explanation for the high number of isolated species involves total area of habitat for these species. Species that prefer edge habitat are more likely to be sampled than species that prefer core forest habitat, because there is less total edge area, and therefore a smaller possible range available for the species to be found within.

Out of 145 morphospecies, only four were sampled within all study sites. This seems to indicate that each site is separated enough, by distance and environmental conditions, to require differing characteristics among its inhabitance. These differing conditions limit the ability of species to persist across all sites. The four species were also primarily found in core forest conditions, with the greatest concentration in the continuous forest. The four "shared" morphospecies were also found with relatively even numbers in the continuous forest, while the other sites had inconsistent abundances (Figure 6). This pattern could be an indicator of ecosystem stability. The continuous forest experiences less total disturbance, and has had time to settle into a form of equilibrium. The fragments and pasture have been recently disturbed, from an ecological point of view, and are still settling into an equilibrium. Once those locations have had more time for the species to find their proper niches and outcompete other species, maybe the pattern of abundance for the fragments and continuous forest will more closely match. The fragments are similar habitats to the continuous forest, yet the pattern of abundance for the four morphospecies do not match, in the way that the insect order layouts match (Figure 2c). The presence of a greater degree of edge could also be skewing these pattern, as the edge habitat creates different species layouts than core (and continuous) forest habitats.

It is important to examine why so few species are found across all sites. Three of the shared morphospecies were diptera, in the families Phoridae and Drosophilidae. The fourth morphospecies is an orthopteran in the family Mogoplistidae. Although not much can be said for these four specific "shared" morphospecies, as there can be a lot of variance in the ecology of species within a family, it has been shown that generalist species are better able to proliferate in fragmented landscapes (Larson 2008). At least in the case of Phoridae, they can eat a wide variety of food sources, and some genera are even parasitoids (Disney 1994).

The "shared" species need to be able to eat many possible food types, and also need to have a resilient larval stage. Specific requirements for egg laying and larval development could significantly hinder species from proliferating in fragmented sites. This low "success rate" of cross-site species could indicate that most insects have some degree of specialization to their environment, and they have not yet had time to adapt to the new, patchy landscape.

Future Research

Future research should seek to explore the ecological niches that the insects that are found across all fragments are filling. Once the environmental role of these insects is characterized, our understanding of the future of these fragments will be enhanced. It is also crucial to repeat this system of sampling across different sites, both in Costa Rica and in other tropical forests. Every fragment and forest has its own context and set of details that could be affecting the data presented here. If other fragments show similar patterns, then the shared characteristics of all forest fragments are likely having a greater effect than whatever individual characteristics displayed by the location. Lastly, similar research needs to be done with greater taxonomic specificity. Identification to morphospecies helps with comparisons amongst a single collection, but without actual species identification the applicability of the research is reduced.

Conclusion

Forest fragments have far-reaching, lasting consequences for all communities of organisms. Fragmentation creates wildly different communities and ecological structures due to the wide variety of habitats that spawn from deforestation practices. This separates species and restricts their ability to intermix between sites. As humans continue to deforest and fragment, we will shape the evolutionary future of untold numbers of organisms. The species we displace and speciate through the creation of barriers will always adapt to the change. Humans, however, may reach the end of their adaptive ability if these deforestation practices continue. It is the hope of this researcher that studies similar to this one will build the case against fragmentation, and will lead to greater conservation efforts.

"But man is a part of nature, and his war against nature is inevitably a war against himself."

— Rachel Carson

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