The Effect of Distance from the Forest Edge on Lepidoptera and Hymenoptera Abundance and Diversity in the Peruvian Amazon

Charlotte Brené [1, 2]

[1] L'Institut Agro Rennes-Angers, Ecole nationale supérieure des sciences agronomiques, agroalimentaires, horticoles et du paysage - 35000 Rennes, France

[2] Alliance for a Sustainable Amazon (ASA), Las Piedras, Madre de Dios, Peru

Corresponding mails : brenecharlotte@gmail.com / charlotte.brene@agrocampus-ouest.fr & info@sustainableamazon.org

Abstract

The Amazonian rainforest the biggest and the most biodiverse tropical forest in the world. However, anthropic activities have strongly affected this habitat in the past two decades. In Peru, slash-and-burn agriculture is one of the major causes of deforestation and land degradation. Thus, the resulting fragmented habitats lead to a decrease in fauna and flora biodiversity. Large distance between habitats creates inhospitable lands, limits exchanges, isolates populations and deteriorates habitat quality. An increasing distance from the forest edge also negatively affects the abundance and biodiversity of species by creating various microclimates along a distance gradient. This study focuses on the effect of distance on species abundance and diversity, focusing on Lepidoptera and Hymenoptera as insects represent the majority of animal life on Earth. It aims to understand the interaction of the species with a fragmented environment in order to manage anthropized areas by maintaining a good biodiversity. Data collection was collected in Finca las Piedras, a biological station located in Madre de Dios, Peru. Lepidoptera abundance and diversity was measured by capturing adults in transects placed at three different distances from the forest edge. Hymenoptera abundance and diversity was measured using bowl traps to catch wasps at three different distances from the forest edge. The results shows that there were a higher abundance and diversity in the primary forest compared to the regenerative forest with no real effect of the distance from the forest edge. Hence, a reasonable forest management and community awareness are necessary to preserve the existing habitats.

Introduction

The Amazon is the natural region of South America with the largest rainforest in the world. This incredible ecosystem, which stretches across 9 South American countries, is also home to exceptional biodiversity. Nevertheless, in the past 50 years, human activities have strongly affected this habitat. Deforestation from slash-and-burn agriculture, timber extraction, gold mining and cattle ranches resulted in 17% of forest loss (Gatti et al., 2021). In Peru, slash-and-burn agriculture is one of the major causes of deforestation (Olsson, 2009). This type of practice, very frequently used in the country, aims to create new plots for crops or cattle. However, this is not a sustainable process since it depletes the land, forcing farmers to start again a few years later. Once a plot is no longer usable, another area is cleaned leaving the old one abandoned.

The resulting open areas created lead to a decrease in biodiversity as most forest species require forest coverage and do not tolerate habitat fragmentation and agricultural intensification. In 2018, habitat fragmentation was the third cause of biodiversity loss as it reduces the habitat into small and dispersed fragments with inhospitable lands in between (Cavanzón-

Medrano et al., 2018). Moreover, a large distance between habitats leads to a lack of connectivity that isolates populations and limits their exchanges (Baguette et al., 2000), prevents re-colonization events and deteriorates habitat quality (Fahrig, 2003). In fact, under a threshold between 30% and 40% of forest dominance, biodiversity decreases quickly (Decaëns et al., 2018). In the case of intensive agricultural areas, it has already been shown that the abundance and diversity of plant species (for example Epiphytes - Moorhead et al., 2010) and animal species (for example Butterflies - Norfolk et al., 2017) decreases considerably compared to primary forest areas. Hence, the type of environment is an important parameter in the abundance and diversity of fauna and flora.

However, an increasing distance between open areas and primary forest also negatively affects the abundance and the diversity of species as it has already been shown with epiphyte abundance and diversity (Moorhead et al., 2010), pollinator diversity (Ricketts, 2004) and pest diversity in an anthropized area (Klein et al., 2006). One of the reasons would be the creation of numerous microclimates along a distance gradient, all of them defined as unique ecosystems with different parameters (wind, light, soil properties, plant species stratification, predatory pressure).

This study focused on the effect of distance from the forest edge on Lepidoptera and Hymenoptera abundance and diversity as insects represent the majority of animal life on Earth (Zhang, 2011) and are deeply affected by habitat fragmentation (Steffan-Dewenter and Tscharntke, 2002, Krauss et al., 2009). Our goal was to understand and quantify the effect of distance from the forest edge on deforested places, wondering if there was an edge effect in the areas next to the forest compared to the ones far away. Thus, we wanted to know if distance would affect or not species composition and distribution among fragmented habitats. Moreover, given the increasing rate of deforestation with the creation of new interfaces (forest edges) and open areas, it is necessary to understand the ecological effects of those habitats on the abundance and diversity of animal life in general. Indeed, understanding the interaction of those two orders of insects with their environment and their resilience to habitat fragmentation will help us to manage anthropized areas by maintaining a good biodiversity.

Methods

Study site

The study took place at Finca Las Piedras, Madre de Dios, Peru, a research station belonging to the NGO Alliance for a Sustainable Amazon located within western Amazon rainforest. The site has different Amazonian habitats but we only focused on : the tropical rainforest selectively logged ca. 25 years ago ("the primary forest" I refer to in this study) and the grassland called "the regenerative forest", a deforested area following forest fires that took place in 2016 and destroyed nearly 15 hectares near the research station. Today, this area has been partially reforested, largely with pasture. However, it still been an open area with little vegetation and stratification compared to primary forest, hence its interest for this study.

Lepidoptera as a study group

In the case of Lepidoptera, we already know that deforested areas tend to decrease Lepidoptera species abundance and diversity since they are more subject to predation, lack of resources and destruction of habitat (Summerville and Crist, 2001). So, to know the effect of the distance from the forest edge on the abundance and species diversity, Lepidoptera are good bioindicators, easy to sample, because of their abundance and diversity within the Amazon : for example, more than 7,000 species of butterflies are present in the Neotropics, of which 3,500 are found in Peru (Lamas, 1997). In addition, the role of Lepidoptera as pollinators as adults and their use of specific host plants for their development in the larval stage allow to assess the health of their habitat (Ehrlich and Raven, 1964). They are therefore very sensitive to many environmental parameters such as light, temperature, humidity and wind, which are often affected by environmental disturbances (Murphy et al., 1990, Didham et al., 1996, Koh and Menge, 2006). Thus, an increase of the sunlight, wind speed, predation pressure, lack of resources and a raise of the temperature along an increasing distance from the forest edge would explain why Lepidoptera might suffer from it (Koh and Menge, 2006) as some areas don't meet their environmental criteria. So, Lepidoptera abundance and development in the larval stage allow to assess the health of their habitat (Ehrlich and Raven, 1964). They are therefore very sensitive to many environmental parameters such as light, temperature, humidity and wind, which are often affected by environmental disturbances (Murphy et al., 1990, Didham et al., 1996, Koh and Menge, 2006). Thus, diversity is expected to be negatively correlated to the distance from the forest edge.

We also compared the Lepidoptera composition found in the deforested areas (open area, forest edge) with those present in the primary forest. This additional study allowed us to know which families could benefit from deforested areas by adapting them to this environment as Lepidoptera can have several host plants.

Data collection : Lepidoptera

To determine the species richness and the abundance of Lepidoptera in relation to distance from the primary forest, 18 transects have been studied (Figure 1). They were split into three categories : forest edge transects located in the regenerative forest and having their nearest point 20 m from the forest edge, open areas transects also located in the regenerative forest and having their nearest point 120 m from the forest edge and primary forest transects located in the intact forest and having their nearest point 60 m from the forest edge. Each transect measured 100 m long and was at least 80 m away from the others. Each zone has been visited in the morning between 10:00 a.m. and 12:00 p.m. during

Figure 1 : Map of Finca las Piedras. Trails are indicated in white, blue transects represent open area transects, red transects represent forest edge transects and green transects represent primary forest transects.

Figure 2 : Map of Finca las Piedras. Trails are indicated in white, blue spots represent open area traps, red spots represent forest edge traps and green spots represent primary forest traps.

the dry season, on warm (T > 20°C) and cloudless days since the weather affects the activity of diurnal Lepidoptera (Pollard, 1988). We caught every observable individual using a net along 5 meters on either side of the transect. An individual was collected if it interacted with the area by exhibiting any of the following behaviors : nectarine, perching, walking, basking, ovi-positing, drinking, or mating (non-flight). For each individual collected, a picture of the ventral and the dorsal wings was taken (when it was possible) in the field. We also took note of the date, the hour, the temperature, the cloud cover, the ID number of the individual, the type of transect, the ID of the area studied, the family of the individual and if possible, the genus or the specie (after analysis in the laboratory). To avoid doble-counting, every individual collected was marked with a red dot on the ventral wings. Individuals flying for a distance of 20 m in straight line above the transect were also counted as some Lepidoptera could use certain areas only to fly from one type of environment to another without interacting with it. For each area, the number of individuals, morpho-species and flying individuals have been counted as well as the number of individuals and morpho-species for each Lepidoptera family.

Hymenoptera as a study group

Hymenoptera were chosen as a second study group. We focused on wasps as ecological indicators to know the effect of the distance from the forest edge on abundance and species diversity. Indeed, wasps are easy to sample and really abundant and diverse within the Amazon : for example, among the 974 species of socials wasps on the globe, 552 are found in America (Carpenter and Andena, 2013). Moreover, they perform many environmental services by acting as predators of insect pests (Prezoto and Machado, 2009), pollinators of many species of angiosperms, floral visitors (Clemente et al., 2012), and bioindicators of habitat quality (Souza et al., 2010, Gonçalves et al., 2014). For those reasons, wasps also suffer from fragmented landscapes which host many environmental disturbances (Graça and Somavilla, 2018). Hence, the abundance and diversity of wasps is expected to decrease as the distance from the forest edge increase.

A comparison of the composition of wasp's superfamilies in the different habitats (open area, forest edge and primary forest) was also made to know the use of the fragmented ecosystems by those insects. This study allowed us to learn about which families could suffer from deforested areas or not.

Data collection : Hymenoptera

To determine the species richness and the abundance of Hymenoptera (wasps, bees) in relation to distance from the primary forest, we created 9 bowl traps aimed to attract pollinators (Figure 2). It consists to coloured bowls, that mimic coloured flowers, which reflect the light and are filled with soapy water to cut the surface tension between the water and the pollinators' tarsus when they land. In this study, we used blue and yellow bowl traps as they are the most efficient colours to attract wasps (Acharya et al., 2021). Soapy water was made by adding some drops of dish soap in the water and each 500 mL bowl was filled with 400 mL of it. Bowl traps were set up by pairs (one blue bowl trap and one yellow bowl trap) on the ground and splited into three categories : forest edge bowl traps located in the regenerative forest 20 m from the forest edge, open areas bowl traps also located in the regenerative 120 m from the forest edge and primary forest bowl traps located in the intact forest 80 m from the forest edge. Each trap was at least 100 m away from the others. All traps were checked every day at 9:00 a.m. for 16 days during the wet season. Soapy water was changed every day after every checking. Wasps were collected from the bowl traps and placed in envelopes to take it back to the laboratory. For each individual collected, a picture was taken in the laboratory with a white background. We also took note of the date, the hour, the temperature, the weather, the ID number of the individual, the type of bowl trap, the ID of the bowl trap, the description of the individual and if possible, its superfamily. Every day and for each category, the number of individuals and morpho-species have been counted as well as the number of individuals and morpho-species for each wasp superfamily.

Data analysis

Specific diversity was determined for each group (Lepidoptera and Hymenoptera) and for each area (open area, forest edge, primary forest) using the Shannon-Weiner diversity index. This index goes from 0 to 1 or above, 0 meaning no diversity and greater than 1 meaning diversity presence. It is used as an indicator of the diversity of a population, taking in account the number of species and the abundance in a given area.

Shannon-Weiner diversity index formula :

$$\boldsymbol{H = -\sum_{p=1}^{S} p_i \ln p_i}$$

p = Proportion of a specie in one area.

For each Lepidoptera and Hymenoptera data, ANOVA (ANalysis Of VAriance) tests and pairwise comparisons between areas using the estimated marginal means were carried out on R Studio to determine the effect of distance on the abundance and the Shannon diversity index (and the number of individuals flying for the Lepidoptera).

ANOVA tests and pairwise comparisons between areas using the estimated marginal means were also performed on R Studio to determine the effect of distance on the abundance of each Lepidoptera and Hymenoptera family.

Rarefaction curves for both orders of insects were modelled on R Studio.

QGIS was used to set up the Lepidoptera transects and the Hymenoptera traps.

Table 1 : Summary of Lepidoptera abundance, diversity and family composition in each area

Area	Individuals	Morpho-species	Papilionidae	Pieridae	Lycaenidae	Riodinidae	Nymphalidae	Hesperidae	Erebidae
Open area	40	18	0	0	3	0	19	17	1
Forest edge	40	21	0	0	2	2	14	19	3
Primary forest	113	63	0	3	17	29	28	3	33

Results

Lepidoptera results

At the end of this study, 193 individuals were collected among 95 morpho-species (Table 1).

The average abundance for every open area and forest edge transects was 6.67 and 18.8 for every primary forest transect (Figure 3). There was a significant effect of the habitat on the abundance ($P = 6.58.10^{-6}$). No significant difference between the open area and the forest edge was noted but there was a significant difference between those two areas and the primary forest ($P < 0.0001$).

Among the open area transects, there was a mean diversity of 1.46, among the forest edge transects, there was a mean diversity of 1.35 and among the primary forest transects, there was a mean diversity of 2.50 (Figure 4). Habitat had also a significant effect on the Shannon diversity index ($P = 3.96.10^{-8}$). There was a difference between the primary forest and the regenerative forest (forest edge, open area) ($P < 0.0001$) but no difference within the habitats of the regenerative forest.

The mean of flying individuals for the open area, the forest edge and the primary forest were 15.8, 17.5 and 3 respectively (Figure 5). There was a significant effect of the area on the abundance of individuals flying ($P = 0.0067$). Again, a significant difference between the primary forest and the regenerative forest ($P < 0.05$) is seen whereas there was no significant difference between the open area and the forest edge.

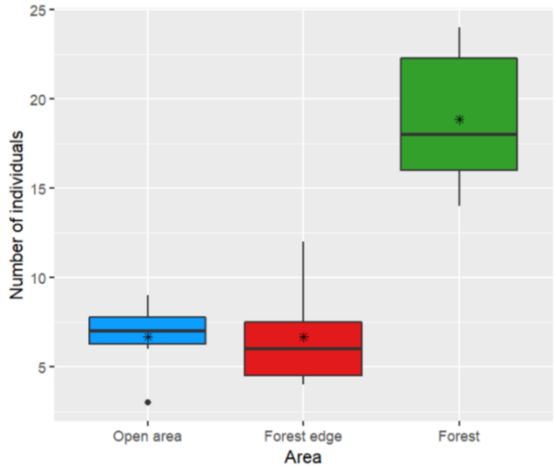

Figure 3 : Boxplot of the Lepidoptera abundance among the different habitats

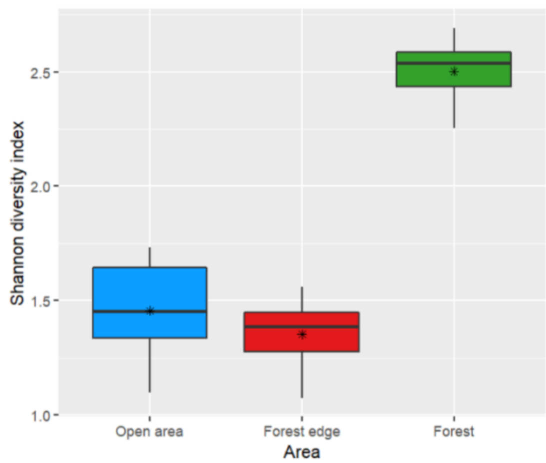

Figure 4 : Boxplot of the Lepidoptera diversity among the different habitats

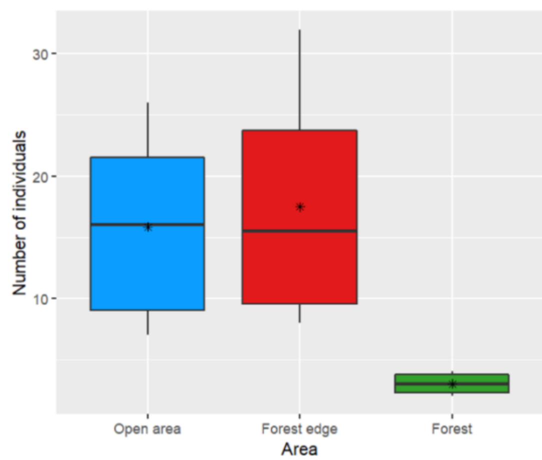

Figure 5 : Boxplot of the Lepidoptera flying individuals among the different habitats

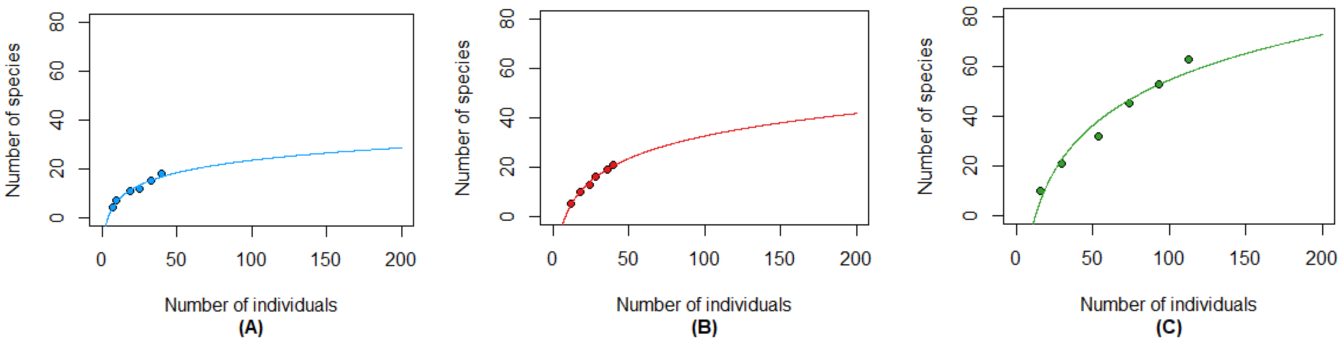

Figure 6 : Rarefaction curves of cumulative increase of Lepidoptera morpho-species for the open area (A), the forest edge (B) and the primary forest (C)

After modelling the Rarefaction curve of cumulative increase of species richness for each habitat (Figure 6), we clearly remarked a difference in the speed at which the curve reaches its plateau. In fact, it's already quickly reached for the open area and the forest edge and doesn't seem to have a significant difference between those two areas. For the primary forest, the plateau it's higher and it's reached slower than the two other curves. Therefore, it's possible to assume a significant difference between the species richness of the primary forest and the regenerative forest.

The Lepidoptera family composition was also different within the three areas (Figure 7). For Erebidae, Lycaenidae and Riodinidae, area influenced their distribution (P < 0.01). There was a significant difference between the primary forest and the regenerative forest (P < 0.01). However, there were no relevant difference sbetween the open area and the forest edge. For Hesperiidae, habitat had also an effect on their distribution (P = 0.035). There was a significant difference between the primary forest and the forest edge (P = 0.044) and no significant difference between the open area and the forest edge. Between the primary forest and the open area, there seemed to be a difference even if it can't be considered significant (P = 0.082). For Nymphalidae,

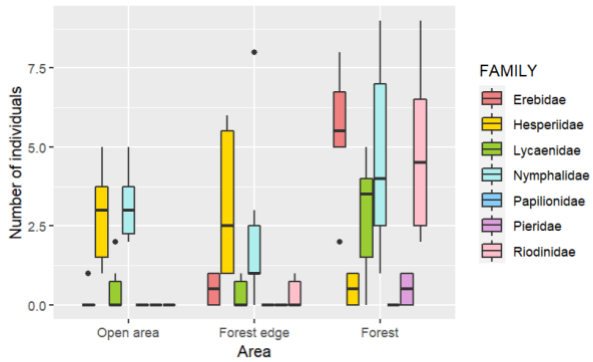

Figure 7 : Boxplot of the Lepidoptera families distribution among the different habitats

there was no effect of the area on their distribution. For Pieridae and Papilionidae, there weren't enough individuals to make a conclusion of their distribution among the habitats.

Table 2 : Summary of Hymenoptera (wasps) abundance, diversity and superfamily composition in each area

Area	Individuals	Morpho-species	Unknown	Ichneumonoidea	Diaprioidea	Chalcidoidea & Mymarommatoidea	Platygastroidea	Cynipoidea
Open area	28	16	12	1	0	0	0	0
Forest edge	56	27	20	7	2	1	6	0
Primary forest	115	62	38	32	7	21	7	1

Area	Evanioidea	Chrysidoidea	Vespoidea	Pompiloidea	Tiphiodea	Apoidea
Open area	1	0	0	6	0	8
Forest edge	2	1	0	3	0	14
Primary forest	1	1	2	3	1	1

Hymenoptera results

At the end of the data collection, 199 wasps were captured among 90 morpho-species (Table 2).

The average daily abundance for the open area traps was 1.69, 3.5 for the forest edge traps and 7.25 for the primary forest traps (Figure 8). Habitat had a significant effect on the abundance (P = 0.00013). There was a relevant difference between the primary forest and the regenerative forest (P < 0.01) but there was no difference among the regenerative forest habitats.

Among the open area daily collects, there was a mean diversity of 0.455, among the forest edge daily collects, there was a mean diversity of 0.85 and among the primary forest daily collects, there was a mean diversity of 1.63. (Figure 9). Habitat had also a significant effect on the Shannon diversity index (P = 0.00013). No significant difference was noted between the open area and the forest edge but there was a significant difference between those two areas and the primary forest (P < 0.05).

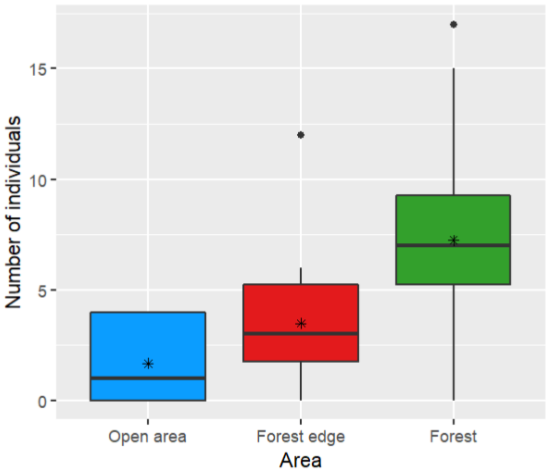

Figure 8 : Boxplot of the wasps abundance among the different habitats

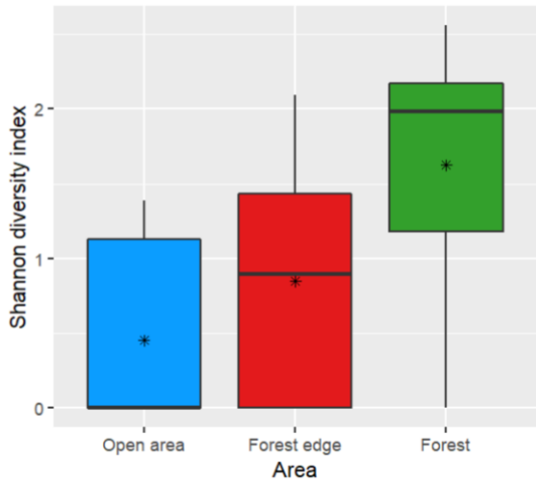

Figure 9 : Boxplot of the wasps diversity among the different habitats

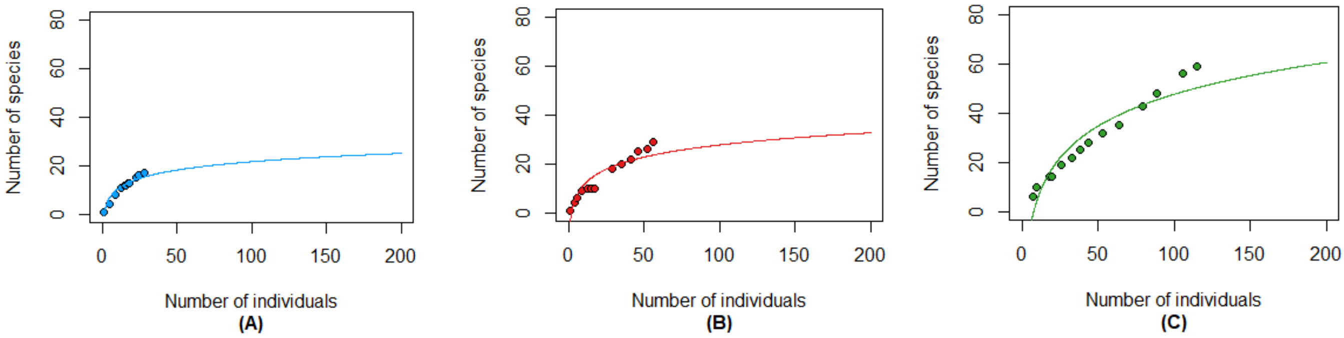

Figure 10 : Rarefaction curves of cumulative increase of wasps morpho-species for the open area (A), the forest edge (B) and the primary forest (C)

After modelling the Rarefaction curve of cumulative increase of species richness for each habitat (Figure 10), we remarked that the primary forest curve reaches its plateau slower and with a higher number of individuals compared to the open area and forest edge curve. It doesn't seem to have a relevant difference between the open area and the forest edge curves. So, we can state a significant difference between the primary forest and the regenerative forest.

The wasp's superfamily distribution was also different among the three the habitats (Figure 11). For Ichneumonoidea and Chalcidoidea & Mymarommatoidea, there was a significant effect of the area on their distribution (P < 0.0001). A significant difference between the primary forest and the regenerative forest was noted (P < 0.001) but there was no significant difference between the open area and the forest edge. For Apoidea, there was also a significant effect on the area on their distribution (P = 0.026). There was a significant difference between the primary forest and the forest edge (P = 0.019) and no significant difference between the open area and the forest edge (P = 0.40). Between the primary forest and the open area, there seemed to be a difference even if it can't be

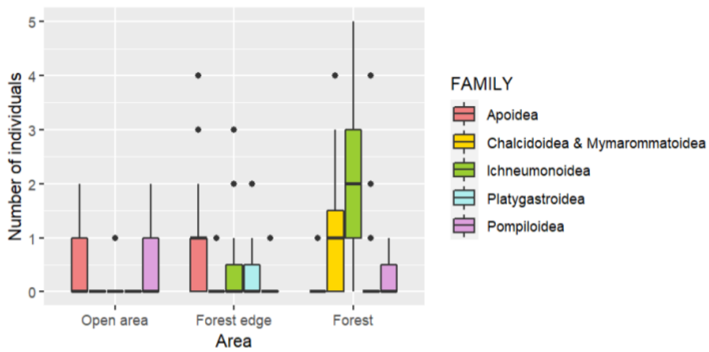

Figure 7 : Boxplot of the wasps superfamilies distribution among the different habitats

considered as significant (P = 0.20). For Platygastroidea and Pompiloidea, there wasno relevant effect of the habitat on their distribution. For Diaprioidea, Cynipoidea, Evanoidea, Chrysidoidea, Vespoidea and Tiphiodea there weren't enough individuals to make a conclusion of their distribution among the habitats.

Discussion

Lepidoptera community

The most abundant and diverse Lepidoptera community was found in the primary forest, as well as the higher species richness. Open area and forest edge presented less abundance and diversity with a lack of statistically significant difference between these two habitats. So, it's not possible to state that there is a real effect of the distance from the forest edge on Lepidoptera abundance and biodiversity. However, there is an effect of the type of habitat on the abundance and diversity for Lepidoptera communities.

First, this result could be explained by the lack of plant diversity in regenerating forest compared to primary. African cattle grass (*Brachiaria brizantha*), an invasive species, was the main plant species present in the regenerating forest. Introduced for cattle grazing, it grows fast and doesn't allow the development of other plants in this habitat because of the shade it creates. The environmental parameters of the regenerative forest also explain its plant composition : higher temperature and light availability, greater effect of the wind, less humidity, soil composition, nutrients. Moreover, most plant species present in the regenerative forest aren't native species of the Amazon so they may doesn't correspond to the host plant of Lepidoptera communities that are found here. Then, the primary forest vegetation creates various microclimates among the forest stratification that can host many specialist or generalist Lepidoptera species, protect from predation and contain a lot of resources compared to the regenerative forest.

The environmental conditions could also explain Lepidoptera distribution because of their habitat needs (moderate light availability and temperature, high humidity, little wind). Nevertheless, it can't be generalized to all the Lepidoptera population. In fact, even with a high abundance and diversity in the primary forest, different distributions among the Lepidoptera families were noted showing that Lepidoptera can colonize several habitats. On the one side, Lycaenidae, Riodinidae and Erebidae were almost exclusively caught in the primary forest unlike Hesperiidae, mostly found in the regenerative forest. These families can be considered as specialist since they only live in habitats with certain conditions. Hesperiidae seem to like high sunlight availability and the resources found in the regenerative forest. Lycaenidae, Riodinidae and Erebidae prefer shade and were, most of the time, using the leaves to hide themselves in the forest understory. On another side, Nymphalidae didn't have any pattern and were seen in both habitats. This family would be considered as generalist since they can live in many habitats. Nymphalidae is also the Lepidoptera family with the higher abundance.

Another reason why it's impossible to generalize Lepidoptera needs is because this study compared the Lepidoptera composition of the primary forest understory with the Lepidoptera composition of the regenerative forest that have no stratification because of the cattle grass. With this species, other types of plants like trees or bushes can't grow to create different stages of vegetation in order to make shade and avoid invasive species. That explains the big difference of environmental conditions between the two habitats. However, the conditions found in the regenerative forest are also found in the canopy of the primary forest where we can find Lepidoptera species that only live there. For example, *Zaretis*, a Neotropical butterfly genus, is adapted to the canopy of the forests (fast flight, leaf-shaped camouflage) and can only be found in this part of the forest. Thus, further studies that compare Lepidoptera composition in the regenerative forest and the canopy of the primary forest should be done.

An interesting observation was that even if Lepidoptera interact less with the regenerative forest, they can use this habitat to move around. There were more individuals flying over the regenerative forest transects with a long and straight trajectory than over the primary forest transects. So, even if Lepidoptera doesn't interact with this habitat, they don't avoid it and can use it to reach other habitats (another primary forest, aguajal). Nevertheless, this result could be influenced by the fact that it's more difficult to count Lepidoptera flying in the primary forest because of the high tree density.

Hymenoptera community

Primary forest was the habitat that hosted the higher wasp abundance, diversity and species richness. Regenerative forest had less wasp abundance and diversity with no significant difference between the open area and the forest edge. So, distance didn't have a real effect in this study. However, the type of habitat influenced wasp abundance and diversity.

This result is linked with the environmental characteristics of the primary forest : higher resources, water availability, various nesting places. As some wasps pollinate certain angiosperms, the lack of plant diversity in the regenerative forest due to the dominance of the invasive cattle grass and the environmental conditions, as explained for the Lepidoptera, resulted in low wasp abundance and species richness in this habitat. Moreover, some wasps are parasitoid species or predators that strictly depend on their host or their prey. Most parasitoid wasps utilize other insects including other wasps : for example, Ichneumonidae wasps can parasitize some butterfly species (Audusseau et al., 2020, Hochberg et al., 1998). Hence, they are influenced by the abundance and diversity of insect populations and insect populations, such as Lepidoptera, are strongly affected by fragmented habitats.

Even if a global pattern could be described assuming that wasp abundance and diversity is higher in the primary forest, population distribution in three habitats was different among the wasp's superfamilies. There were specialized families : Apoidea that preferred open spaces and Ichneumonoidea, Chalcidoidea and Mymarommatoidea, mostly found in the primary forest. There were also generalized families : Platygastroidea and Pompiloidea which habitat didn't influence their abundance among the three habitats. This result attest that wasps can colonize fragmented areas but with low abundance and diversity as observed by Graça and Somavilla, 2018. However, to confirm these results, more collects of the different superfamilies should be done.

Limits and opening

Future studies should continue to survey Lepidoptera and Hymenoptera communities throughout a one year period, as these study was restricted to a little amount of time during the dry or the wet season. More transects and traps in each habitat should also be set up, so habitats could be better represented. Making more samples in a longer time should highlight the real effect of the distance from the forest edge. In fact, more samples would allow us to understand better the edge effect and the influence of the distance from it in the regenerative and the primary forest. The edge effect also depends on the size of the fragments : the smaller the fragment is, the stronger the edge effect is (Porensky and Young, 2013). It should explain the little influence of it in a place, like Finca las Piedras, with big forest fragments. In addition, an identification of the Lepidoptera and wasp individuals could lead to interesting ecological patterns among the families.

For wasps communities in general, there is little information on the effect of fragmented areas on their abundance, distribution and diversity so more studies should be done.

Conclusion

As a conclusion of the present study, habitat fragmentation has a negative effect on Lepidoptera and Hymenoptera abundance and diversity. Hence, it's necessary to preserve the existing habitats and put efforts in doing reforestation work to increase the vegetation areas. By creating new corridors between the fragmented areas, fauna and flora can recolonize those habitats. In fact, a reasonable forest management and community awareness is mandatory to maintain abundance and biodiversity in the Amazonian rainforest. Even if the distance didn't really influenced the results in this study, it's necessary to avoid the edge effect as it changes abiotic and biotic factors and may result in species lost (Lovejoy et al., 1986). Generally, fragmentation would benefit to generalists and invasive species while specialists and native populations would suffer from it. Moreover, these invasive species could disrupt the ecosystem composition among the forest fragments. However, we don't know yet the real influence of the edge effect on the habitats, even if some methods have been already assessed (Harper et al., 2005).

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