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Bee richness and abundance in an altitudinal gradient of 1,250 meters in San Antonio de Oriente, Honduras

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Abstract

Bees are critically important due to the pollination services they provide, and the commercial products obtained by their cultivation. However, there has been a severe decline of their populations, which can be attributed to anthropogenic activity like the use of agrochemicals and may be exacerbated by the effects of climate change. The present investigation uses altitudinal gradients to evaluate the effect the rise of global temperatures may have in the richness and abundance of bee species. This was done during a period of 11 months where a total of 393 bees were collected, belonging to 64 morphospecies. A direct correlation between richness and abundance was found, and an inversely proportional relation was found between elevation and richness as well as elevation and abundance. Precipitation was found to have an influence in the abundance of bees, with less bees during dry season ($p = 0.0067$), while seasonality influenced their richness ($p = 0.0146$), obtaining higher richness during dry season. Results suggest that the main factor that affects bee richness and abundance is not elevation but other variables such as agricultural intervention and habitat. Further action for the preservation of biodiversity in agriculture should be taken, especially in the case of agrochemical use. Sustainable agricultural systems like that of the Zamorano agroecological farm should be expanded and promoted to adapt to climate change and preserve biodiversity.

Keywords: Abundance, altitudinal gradient, biodiversity, richness, seasonality

Resumen

Las abejas son de importancia crítica por los servicios de polinización que prestan y los productos comerciales que se obtienen de su cultivo. Sin embargo, se ha producido un grave declive de sus poblaciones, que puede atribuirse a actividades antropogénicas como el uso de agroquímicos y puede verse agravado por los efectos del cambio climático. La presente investigación utiliza gradientes altitudinales para evaluar el efecto que el aumento de las temperaturas globales puede tener en la riqueza y abundancia de las especies de abejas. Para ello se tomaron datos durante un periodo de 11 meses, obteniendo un total de 393 abejas pertenecientes a 64 morfoespecies. Se halló una correlación directa entre riqueza y abundancia, y una relación inversamente proporcional entre elevación, riqueza y abundancia. Se observó que las precipitaciones influían en la abundancia de abejas ($p = 0.0067$), con menos abejas durante la época seca, mientras que la estacionalidad influía en su riqueza ($p = 0.0146$), obteniendo mayor riqueza en época seca. Los resultados obtenidos sugieren que el principal factor que afecta a la diversidad y abundancia de las abejas no es la elevación, sino otros factores como la agricultura convencional y el hábitat. Deberían tomarse más medidas para la preservación de la biodiversidad en la agricultura, especialmente en el caso del uso de agroquímicos. Los sistemas agrícolas sostenibles como el de la Finca Agroecológica de Zamorano deberían ampliarse y promoverse para adaptarse al cambio climático y preservar la biodiversidad.

Palabras clave: Abundancia, biodiversidad, estacionalidad, gradientes altitudinales, riqueza

Introduction

Bees provide critical pollination services by moving pollen from the anthers of a flower to the stigma of another or the same flower, which in turn causes the fertilization of the gametes in their ovules (Arindam Das et al., 2018). The domestication and transport of bee species like *Apis mellifera* contributed to their broad distribution to almost the whole globe, where they serve not only for the commercial products obtained by their cultivation but also for their pollination services (Hung et al., 2018).

Wild bees play a vital role in agriculture as well as in ecosystem health, since they're the most relevant group of pollinators, due to their ability to pollinate most crop varieties. Because of their importance, serious concerns and losses have resulted from recently documented global declines (Widhiono et al., 2017). Declines in both wild and domesticated pollinators and in the plants that depend on their services have become evident in recent years (Potts et al., 2010 ; Ramos-Jiliberto et al., 2020). The conservation of bees continues to be a challenging task due to factors like anthropogenic activities and may be exacerbated by climate change. Anthropogenic threats to bee species include: habitat loss, introduced parasites/pathogens, emergent viral diseases, invasive plants, and agrochemicals (Grünewald, 2010).

In fact, the use of agrochemicals is one of the gravest factors related to bee mortality (Siviter et al., 2021). This is caused by the effects of lipophilic compounds like pyrethroids and organophosphates, which are associated with fungicides and herbicides (Belsky y Joshi, 2020). This not only threatens the health of bees but also contaminates the pollen and nectar that they produce (Mullin et al., 2010). In the U.S. alone, the number of commercial bee colonies dropped from 5.9 million to 2.7 million from the late 1940s to 1995. Additionally, there's an estimated 10% loss of production in the U.S. bee industry annually, caused solely by pesticides (Arindam Das et al., 2018). Moreover, throughout the past 70 years, bee occupancy has decreased by approximately 33%, which can be attributed to the intensification of agriculture (Duchenne et al., 2020).

While cultivated bees like *Apis mellifera* are widely investigated, wild bees suffer from a lack of research regarding the state of individual species and the trends for their decline, which can be attributed to their high diversity. Moreover, honeybees cannot be used as a model species to determine wild bees´ susceptibility to threats, because even though there are similarities between them, many of their responses vary, proving the need to further expand research on wild bees, and monitoring schemes directed solely to them (Wood et al., 2020). Furthermore, *Apis mellifera* could have a negative effect on native specimens, as it is an introduced species that competes for both nesting and food resources, especially considering its population increases rapidly (Cunningham et al., 2022).

Altitudinal gradients allow for predictions to be made about the impact that the rise of global temperatures can have on species. The importance of studies that use altitudinal gradients relies on promoting the preservation of species which are expected to be most affected by temperature changes (Hoiss et al., 2012). The decline of pollinators would not only have a direct impact on ecosystems, but also on the world's economy, for the total economic value of pollination worldwide is estimated to be EUR 153 billion, which is about 9.5% of the world's agricultural production used for human food in 2005 (Gallai et al., 2009).

Bees, like all animals, seek to adapt and survive. Therefore, when an increase in temperature is suffered, they tend to shift their distributions upslope, seeking optimal conditions and tracking their hostplants in the case of specialized species. This ability to adapt to changing environments is an evolutionary response to climate change. Nonetheless, it is not the altitude itself species adapt to, but rather the change in conditions that happens when they migrate (Montesinos-Navarro et al., 2011). On top of that, when it comes to climate seasonality, this can have an effect on richness of bees, since precipitation alters the availability of resources that bees engage with (Escobedo-Kenefic et al., 2020).

According to the United Nations Environment Programme, "temperature in Honduras is expected to increase by 1.0 - 2.5 °C by 2050 and increases of 1.0 - 1.5 °C in minimum and maximum monthly temperatures are projected for all times of the year by 2030”. This could have significant impacts on both diversity and abundance of bee populations in the region, bearing consequences in agricultural landscapes nearby, which could also affect crop production efficiency because of the pollination services these use to function properly. On top of this, changes in temperature can also affect diversity of plants, since many species are not able to migrate and adapt fast enough to survive the rise of temperatures, and bees are mutualists that depend on flora to feed on and survive (Jump y Peñuelas, 2005).

Studies of richness and abundance seek to fill gaps of information in ecosystems, which allows predictions to be made about changes in biodiversity due to climate change. The main objective of this study is to estimate how elevation, seasonality, or factors such as agricultural intervention affect richness and abundance of bee species. Moreover, the secondary objectives are to verify that very low bee abundance previously documented for low elevations on Zamorano campus, is not in whole or in part attributable to neighboring agricultural practices, and to determine the effect of seasonality in richness and abundance of bee species at 1,650 masl elevation.

Materials and Methods

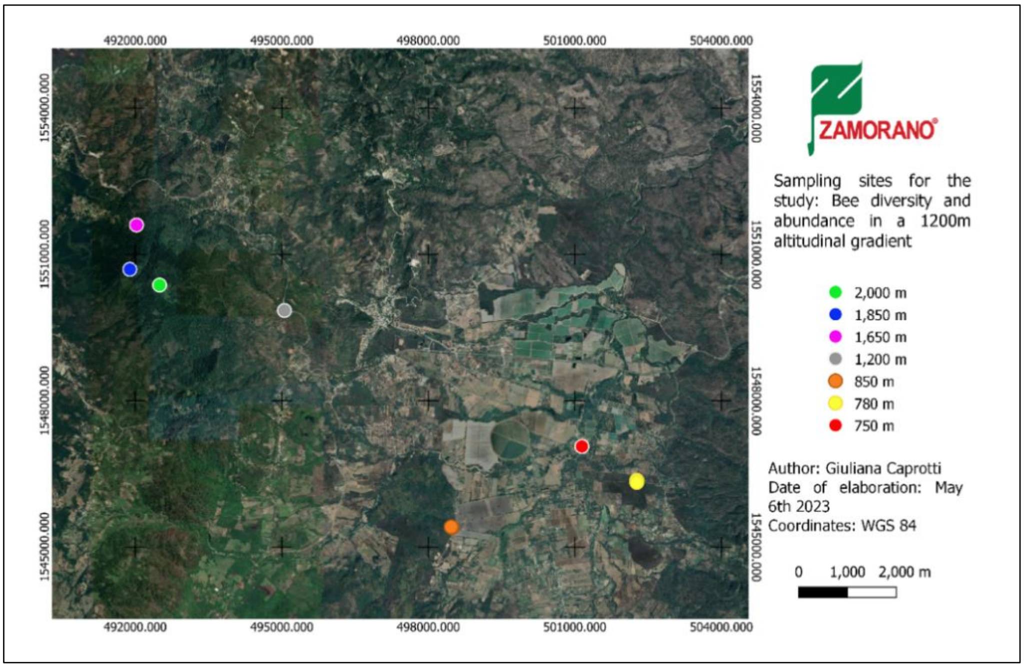
Study Area

The investigation took place in seven sampling sites, where the elevational gradient consisted of approximately 200 meters elevation intervals (Figure 1), starting at the Zamorano Agroecological farm 780 masl, moving to Zamorano campus (750 masl) and Masicarán reserve (850 masl), up to Uyuca biological reserve (1,200 - 2,000 masl). Precise intervals were not used because these don't always provide the proper environment for bees, so variations on such intervals allowed for a more ideal placement of the traps.

The sites chosen presented no agricultural intervention, since both Masicarán and Uyuca are conservation areas. However, Zamorano campus and Masicarán were within approximately 200 meters of large agricultural plots that use pesticides. An exception was made for the Zamorano agroecological farm, which, like its name suggests, uses sustainable agroecological practices, and does not use pesticides or fertilizers containing fossil-fuel based chemicals, but rather organic alternatives to these (Gliessman, 2018).

Figure 1

Location of study sites



Study Design

The present investigation was correlational, for it sought to find the relation between the variables of richness, abundance, and altitude. In addition, the study was observational. The design of the investigation was nonexperimental, as the variables were not manipulated. Furthermore, the study was longitudinal, since the malaise traps were monitored for a period of 11 months evaluating monthly results.

Malaise Traps

Malaise traps are widely used in biodiversity surveys, especially in the case of flying insects like Diptera and Hymenoptera. They work by intercepting insects with their fine mesh netting walls (Skvarla et al., 2021). Once caught within the walls, insects then fly up and to the sides of the trap where they accumulate in alcohol filled jars (Figure 2). The benefit of these traps is the fact that they are low maintenance, since they can be left in the field unattended for long periods of time (Fraser et al., 2008).

Figure 2

Malaise traps located at 1,650 masl, 2,000 masl and 800 masl, respectively.

An advantage when using malaise traps is the samples obtained are clean, meaning the bottle doesn't get contaminated and only has whole insects which remain perfectly preserved. This largely facilitates the identification process of the captures. Additionally, the traps are relatively impervious to the vagrancies of weather (Matthews y Matthews, 2017).

This methodology was based on Luis Callejas' study, which ended in May 2022 in Zamorano University, and the same statistical analysis was applied. It should be noted that the use of pan traps was not considered for this investigation since Callejas found that these were not as effective as malaise traps in obtaining clean utilizable samples, and there were several externalities that affected the proper function of the traps, such as rainfall and molestation by animals.

In addition to this, due to availability, both big and small malaise traps were used for the study. Big traps were used at 1,650 meters, 1,850 meters and the Zamorano Agroecological Farm. Small traps were used for 2,000 meters, 1,200 meters, 850 meters and 750 meters. This was then standardized for the analysis of data.

Identification of Captures

For the identification of the captures, the bees were separated from other captures present in the samples. Then, these were stored in fresh alcohol, keeping samples separate by elevation and date. Afterwards, the bees were pinned into entomological boxes to facilitate their identification, and ensure they were properly photographed. The latter was done with the use of a stereoscope, and the photographs obtained were uploaded to the iNaturalist platform for their identification. In addition to this, dichotomous keys were used to support identification results found through the iNaturalist platform. Specimens were separated into morphospecies, according to the genus or tribe they belonged to, following parameters such as size, general morphology, and color.

Data Analysis

The data was organized according to altitude, and each section included the number of individuals observed as well as all the different morphospecies identified. The analysis done included Spearman's correlation coefficient, to identify possible correlations between abundance, richness, and altitude; Linear regressions to generate prediction models; Qq-plots with use of residuals followed by the Varldent transformation to change the scale of the residuals when there was a lack of homogeneity; an Analysis of Covariance (ANCOVA) using general linear models to identify the possibility of significant differences between the altitudes; as well as a Least Significant Difference (LSD) Fisher´s test, to identify the optimal site for bee richness and abundance, with the use of precipitation as a covariable (Dowdy et al., 2004). The data was analyzed using the program InfoStat 2020 with an alpha of 0.05 to determine significance.

To measure a seasonal effect, monthly precipitation data was considered, to establish wet and dry season. According to precipitation data, the wet season lasted from June to November, while dry season from December through March. The 1,650 masl site was used for this analysis, since it was the only site that contained complete data from both seasons. Precipitation information came from three different sources: the Uyuca Biological Station, the agroecological farm and the "pivote", and were not gathered directly as a part of this study.

For the analysis, the 1,200 masl and 1,100 masl traps were merged as one, due to their vicinity and damages suffered to the 1,100 masl trap, caused by human malfeasance. Additionally, the 800 masl trap located on campus was removed entirely from the analysis since it suffered vandalism, yielding no utilizable data. Furthermore, the data was standardized with the use of Formula 1:

$$Captures\ per\ trap\ per\ day = \frac{c}{d} \quad [1]$$

Where:

c = Total number of captures per trap and

d = Days the trap was operating.

Since two sizes of Malaise traps were used for the study, the data also had to be standardized regarding small traps, which had a 1:5 relation with big traps (due to size of the trap), so Formula 2 was applied:

$$Adjusted\ captures\ for\ small\ traps = c \times 5 \quad [2]$$

Where:

c = Number of captures per small trap.

Results and Discussion

A total of 393 wild bees were captured, which were classified into 64 morphospecies. These belonged to two families: Halictidae and Apidae, the latter being the most dominant. The most abundant species were *Trigona fulviventris*, *Apis Mellifera,* Morphospecies *Bombus* 1, Morphospecies *Dialictus* 1 and Morphospecies *Augochlorini* 3, as shown in Annex A. The highest species richness and abundance was found at 780 masl, at the Zamorano agroecological farm. The second site with the most richness and abundance was 1,650 masl, the Uyuca Biological Station. The morphospecies with presence on most altitudinal gradients were *Apis mellifera*, *Trigona fulviventis* and Morphospecies *Dialictus* 2; as shown in Table 1.

Table 1

Distribution of morphospecies along the altitudinal gradient by elevation

Species	2,000 m	1,850 m	1,650 m	1,200 m	850 m	750 m	780 m
Trigona fulviventris		7	37		6		26
Apis mellifera	1	5	49	2	3		5
Centris varia							1
Nannotrigona perilampoides							1
Cephalotrigona zexmeniae							1
Morphospecies *Partamona*			8		1		3
Morphospecies *Paratetrapedia*							4
Morphospecies *Neocorynura*			11		2		
Morphospecies *Lasioglossum*	1		5		1		
Morphospecies *Bombus* 1		16	10		3		
Morphospecies *Bombus* 2		1					
Morphospecies *Augochlora* 1			1				
Morphospecies *Augochlora* 2			2		1		2
Morphospecies *Augochlora* 3			1				
Morphospecies *Ceratina* 1		3	4		1		
Morphospecies *Ceratina* 2			1				
Morphospecies *Ceratina* 3							1
Morphospecies *Sphecodes*			2				
Morphospecies *Dinagapostemon*					1		
Morphospecies *Thygater*			1				
Morphospecies *Halictus* 1			1		1		
Morphospecies *Halictus* 2							1
Morphospecies *Augochloropsis* 1		1	2				1
Morphospecies *Augochloropsis* 2			1				

Species	2,000 m	1,850 m	1,650 m	1,200 m	850 m	750 m	780m
Morphospecies *Agapostemon* 1			2				
Morphospecies *Agapostemon* 2			1				
Morphospecies *Trigona*							2
Morphospecies *Colletes*			1				
Morphospecies *Euglossa*			1				
Morphospecies *Augochlorella*			1				
Morphospecies *Dialictus* 1			58		1		4
Morphospecies *Dialictus* 2		1	4		1		2
Morphospecies *Dialictus* 3			1				
Morphospecies *Centris*							1
Morphospecies *Megachile*							1
Morphospecies *Calloceratina*			2				
Morphospecies *Eucerini* 1			2				
Morphospecies *Eucerini* 2		1	1				
Morphospecies *Halictini* 1			1				
Morphospecies *Halictini* 2		1					
Morphospecies *Halictini* 3		1	1				
Morphospecies *Halictini* 4			1				
Morphospecies *Halictinae* 1	1		5		1		
Morphospecies *Halictinae* 2					1		
Morphospecies *Halictinae* 3			1				
Morphospecies *Halictinae* 4		1					
Morphospecies *Halictinae* 5			1				
Morphospecies *Halictinae* 6			1				
Morphospecies *Halictinae* 7			2				
Morphospecies *Halictinae* 8							1
Morphospecies *Halictinae* 9							1
Morphospecies *Augochlorini* 1			1				
Morphospecies *Augochlorini* 2			1				
Morphospecies *Augochlorini* 3		1	16				7
Morphospecies *Augochlorini* 4			1				
Morphospecies *Augochlorini* 5			2				2
Morphospecies *Augochlorini* 6		2	1				
Morphospecies *Augochlorini* 7			1				
Morphospecies *Augochlorini* 8			4				
Morphospecies *Augochlorini* 9			2				
Morphospecies *Augochlorini* 10							1
Morphospecies *Augochlorini* 11							1
Morphospecies *Meliponini*			1				
Morphospecies *Anthophorini*		1					

Comparison of Richness and Abundance along the Altitudinal Gradient

Mean's split test for abundance and richness (Figure 3 and 4) showed that in terms of abundance, 780 masl and 1,650 masl had no statistically significant differences, though differences were found along the rest of the gradient. On the other hand, with richness, statistically significant differences were found between 780 masl and 1,650 masl, the first being the richest site.

Figure 3

LSD Fisher´s test for abundance of bees

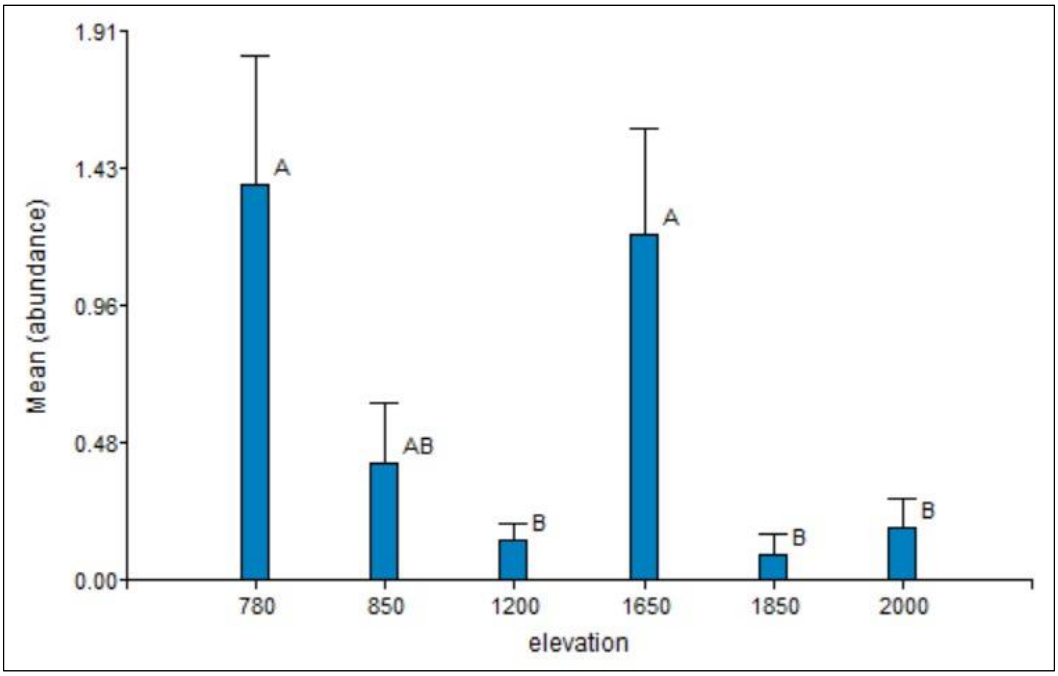
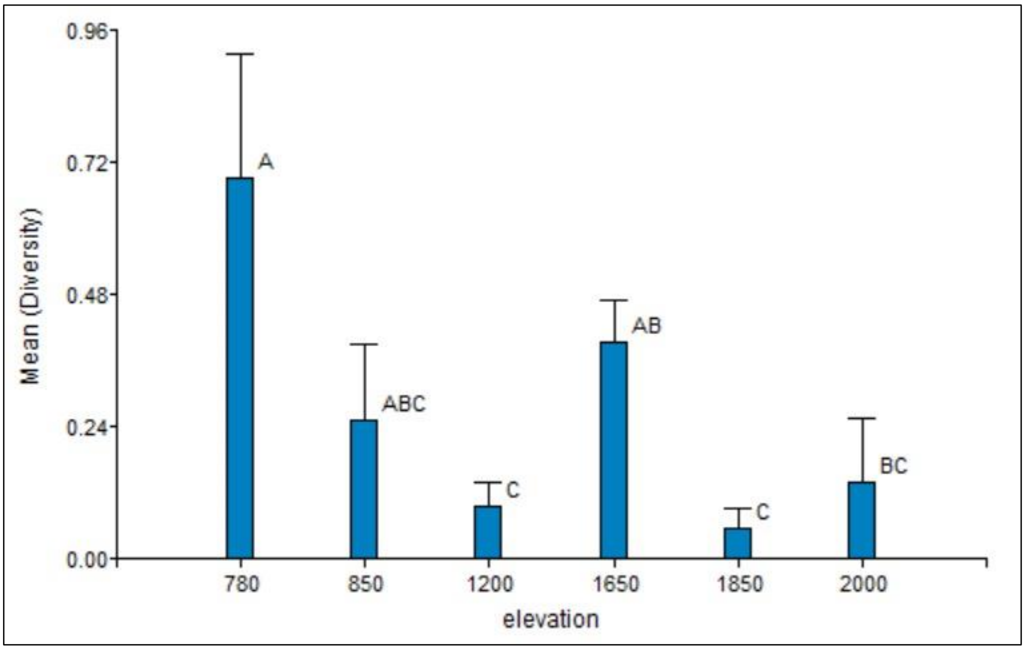


Figure 4

LSD Fisher´s test for richness of bees



Correlation Tests for Richness and Abundance

Although in this analysis, the only correlation found between variables was richness and abundance, low correlations between the rest of variables can be attributed to data found at lower altitudes, specifically the Zamorano agroecological farm. As shown in Table 2, this yielded an inversely proportional relationship between richness and elevation, and abundance with elevation. In addition to this, a simple linear regression was done, where the R^2 values for abundance and richness regressed against elevation were 43% and 49% respectively.

Table 2

Spearman's correlation coefficient for richness and abundance

Variables	Elevation	Precipitation	Richness	Abundance
Elevation	1.000	0.089	0.216	0.325
Precipitation	0.301	1.000	0.297	0.242
Richness	-0.221	0.187	1.000	0.000
Abundance	-0.177	0.21	0.974	1.000

It should be noted that the Agroecological Farm was not sampled sooner because other sites were considered more feasible. However, due to vandalism and theft, it was necessary to move to another low elevation site that provided security in the study to make up for lack of data for lower altitudes. The low abundance at Zamorano in the earlier study by Callejas can be attributed to the use of pesticides associated with agricultural practices in said areas and demonstrates why the agroecological farm didn't pose this issue. These effects have been proven by several studies, such as one that showed bee abundance had a notorious decrease in areas with pesticide use, even a year after their application (Park et al., 2015).

Callejas' results in 2022 for the Agroecological farm contrast from those obtained in this study since he found the Zamorano Campus to be the site with the least abundance and richness. However, his sampling methods differed since he used pan traps in addition to malaise. The results found by the present study clearly reveal the agroecological site to have much richer and abundant values. Although said variations with lower altitudes were found, data from higher elevations on Uyuca were consistent with those found by Callejas. Moreover, Callejas' lower elevation sites (such as the Zamorano eco-trail) were all directly adjacent to areas with conventional agricultural presence, which may have had a strong influence on his findings.

Some areas called "ecological buffers" pose safe havens for animals and insects alike when surrounding areas are inhospitable for them due to factors like agricultural intervention or pesticide use. However, little is known about the size requirements of buffers, to protect wildlife from pesticides. An example of that is the Zamorano Eco-trail, which has been sampled for bee communities by both Callejas (2022) and Mazariegos Palma (2022), with results that may indicate the need to further expand the width of the corridor.

Influence of Precipitation on Richness and Abundance

Sequentials tests were applied for both richness and abundance (Table 3), with the use of precipitation as a covariable. This, in turn, showed that precipitation influenced abundance ($P < 0.05$)

of bee species, though it had no effect on the richness (P > 0.05) of these. The results of a study published in 2021 by the United States Geological Survey and Native Bee Inventory showed that weather conditions are effective at predicting diversity and abundance of bees, compared to landscape conditions and topography of the site. Wild bee abundance in their study suffered a decrease in summer, where precipitation was low (Kammerer et al., 2021). In the case of richness, other factors come into play, like food presence, which may result in an acceleration of evolutionary processes linked to richness of species (Classen et al., 2015).

Table 3

Sequentials test: Abundance and Richness

Abundance	numDF	F-value	p-value	Richness	numDF	F-value	p-value
Elevation	5	3.59	0.014	Elevation	5	4.82	0.0032
Precipitation	1	8.75	0.0067	Precipitation	1	2.35	0.138

Seasonality

For the Uyuca Biological Station seasonality analysis, no statistically significant differences were observed for the variable abundance (p = 0.0629), unlike richness, where significant differences were found (p = 0.0146), resulting in higher richness for the dry season compared to wet season, which can be better appreciated in Annex D. Previous studies on seasonality and bees have proven that seasonal changes affect both the presence of bees and flowering plants. A study on climate drive and seasonal bee richness along a tropical elevational gradient showed that bee richness decreased with an increase in precipitation, and that it decreased linearly and significantly with elevation (Dzekashu et al., 2022). However, there are other factors which come into play for both abundance and richness, such as habitat, forest types, and anthropogenic activity (Quintero et al., 2010).

Conclusions

The best site in terms of both richness and abundance for this study was 780 masl at the Zamorano agroecological farm. Elevation was found not to be the most influential variable for bee richness and abundance, whereas other factors such as habitat and perhaps pesticide use associated with conventional agriculture may have had a greater impact on the presence and richness of wild bees.

Both high richness and abundance were found for lower elevations in the present study, which is why low bee abundance for lower elevation sites found by Callejas (2022) can be attributed to the vicinity of his sites with areas using conventional agriculture, and his sampling methods which were mostly with the use of pan traps.

Seasonality was found to influence richness of species, with higher richness identified during the dry season, however, it had no effect on abundance of wild bee species.

Recommendations

Sample the Zamorano Agroecological Farm for longer periods of time, to establish the consistency of the results found by this study and be able to compare seasonality for this site.

Sample other sites that use sustainable agriculture, to prove that the Agroecological Farm at Zamorano isn't a single occurrence.

Study the effects conventional agriculture can have on bee richness and abundance, specifically the use of pesticides.

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Annexes

Annex A

Captures by morphospecies for the experiment

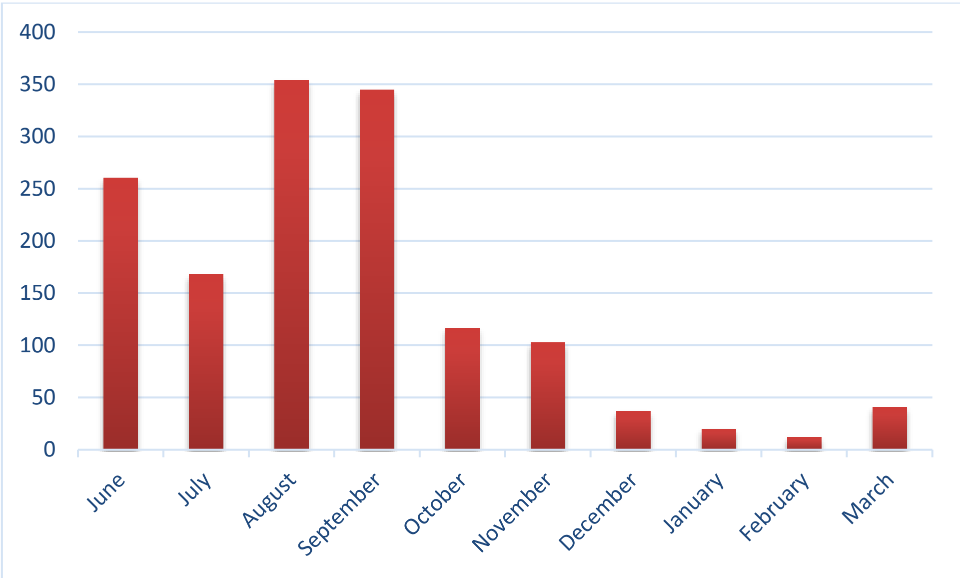
Species	Captures
Trigona fulviventris	77
Apis mellifera	65
Centris varia	1
Nannotrigona perilampoides	1
Cephalotrigona zexmeniae	1
Morphospecies *Partamona*	12
Morphospecies *Paratetrapedia*	4
Morphospecies *Neocorynura*	13
Morphospecies *Lasioglossum*	6
Morphospecies *Bombus* 1	29
Morphospecies *Bombus* 2	1
Morphospecies *Augochlora* 1	1
Morphospecies *Augochlora* 2	5
Morphospecies *Augochlora* 3	1
Morphospecies *Ceratina* 1	8
Morphospecies *Ceratina* 2	1
Morphospecies *Ceratina* 3	1
Morphospecies *Sphecodes*	2
Morphospecies *Dinagapostemon*	1
Morphospecies *Thygater*	1
Morphospecies *Halictus* 1	2
Morphospecies *Halictus* 2	1
Morphospecies *Augochloropsis* 1	4
Morphospecies *Augochloropsis* 2	1
Morphospecies *Agapostemon* 1	2
Morphospecies *Agapostemon* 2	1
Morphospecies *Trigona*	2
Morphospecies *Colletes*	1
Morphospecies *Euglossa*	1
Morphospecies *Augochlorella*	1
Morphospecies *Dialictus* 1	65
Morphospecies *Dialictus* 2	7
Morphospecies *Dialictus* 3	1
Morphospecies *Centris*	1
Morphospecies *Megachile*	1
Morphospecies *Calloceratina*	2
Morphospecies *Eucerini* 1	2
Morphospecies *Eucerini* 2	2
Morphospecies *Halictini* 1	1

Species	Captures
Morphospecies *Halictini* 2	1
Morphospecies *Halictini* 3	2
Morphospecies *Halictini* 4	1
Morphospecies *Halictinae* 1	7
Morphospecies *Halictinae* 2	1
Morphospecies *Halictinae* 3	1
Morphospecies *Halictinae* 4	1
Morphospecies *Halictinae* 5	1
Morphospecies *Halictinae* 6	1
Morphospecies *Halictinae* 7	2
Morphospecies *Halictinae* 8	1
Morphospecies *Halictinae* 9	1
Morphospecies *Augochlorini* 1	1
Morphospecies *Augochlorini* 2	1
Morphospecies *Augochlorini* 3	23
Morphospecies *Augochlorini* 4	1
Morphospecies *Augochlorini* 5	4
Morphospecies *Augochlorini* 6	3
Morphospecies *Augochlorini* 7	1
Morphospecies *Augochlorini* 8	4
Morphospecies *Augochlorini* 9	2
Morphospecies *Augochlorini* 10	1
Morphospecies *Augochlorini* 11	1
Morphospecies *Meliponini*	1
Morphospecies *Anthophorini*	1

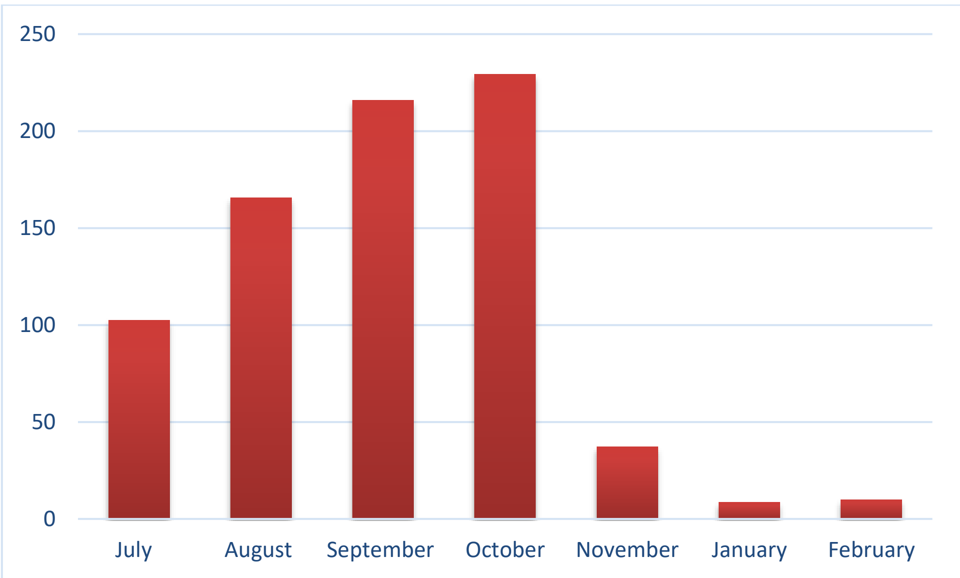
Annex B

Precipitation data from study sites

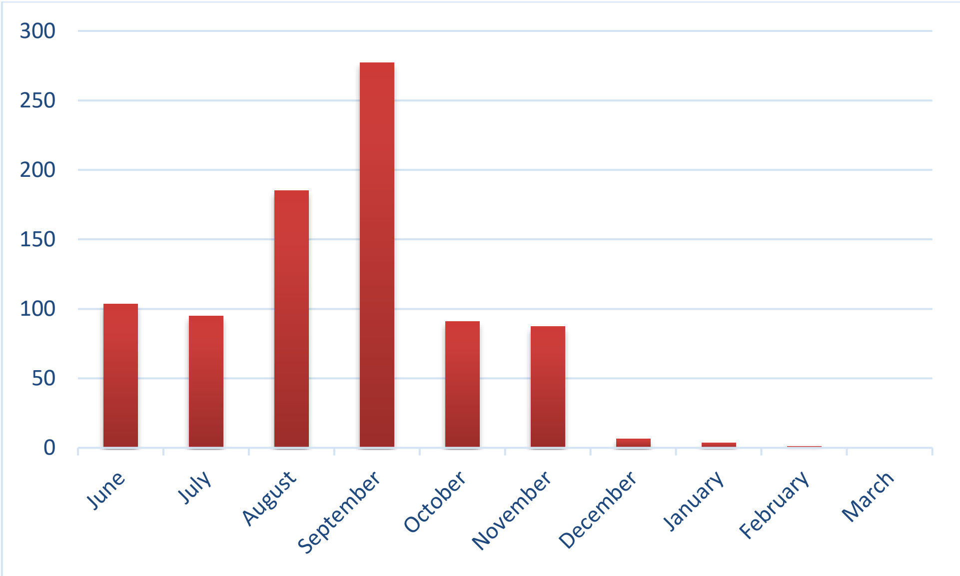
Site 1: *Monthly precipitation in Uyuca reserve in mm (2022-2023)*



Site 2: *Monthly precipitation in Agroecological farm in mm (2022-2023)*

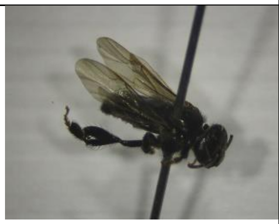
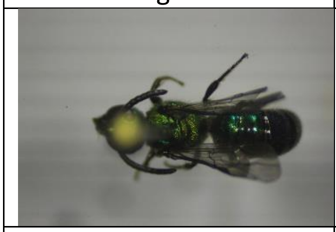
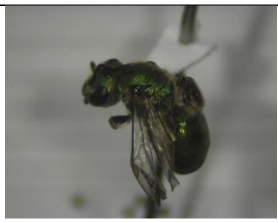


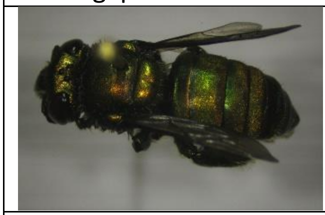
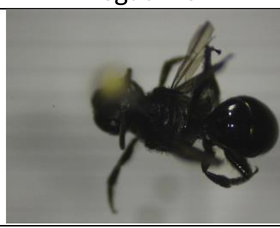
Site 3: *Monthly precipitation in Masicarán and campus in mm (2022-2023)*

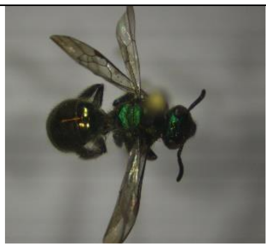
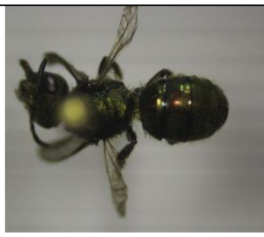


Annex C

Bee species and morphospecies for the whole experiment

			
Trigona fulviventris	*Apis mellifera*	*Centris varia*	*Nannotrigona perilampoides*
			
Cephalotrigona zexmeniae	Morphospecies Partamona	Morphospecies Paratetrapedia	Morphospecies Neocorynura
			
Morphospecies Lassioglossum	Morphospecies Bombus 1	Morphospecies Bombus 2	Morphospecies Augochlora 1
			
Morphospecies Augochlora 2	Morphospecies Augochlora 3	Morphospecies Ceratina 1	Morphospecies Ceratina 2
			
Morphospecies Ceratina 3	Morphospecies Sphecodes	Morphospecies Dinagapostemon	Morphospecies Thygater
			

Morphospecies Halictus 1	Morphospecies Halictus 2	Morphospecies Augochloropsis 1	Morphospecies Augochloropsis 2
			
Morphospecies Agapostemon 1	Morphospecies Agapostemon 2	Morphospecies Trigona	Morphospecies Colletes
			
Morphospecies Euglossa	Morphospecies Augochlorella	Morphospecies Dialictus 1	Morphospecies Dialictus 2
			
Morphospecies Dialictus 3	Morphospecies Centris	Morphospecies Megachile	Morphospecies Calloceratina
			
Morphospecies Eucerini 1	Morphospecies Eucerini 2	Morphospecies Halictini 1	Morphospecies Halictini 2
			
Morphospecies Halictini 3	Morphospecies Halictini 4	Morphospecies Halictinae 1	Morphospecies Halictinae 2
			
Morphospecies Halictinae 3	Morphospecies Halictinae 4	Morphospecies Halictinae 5	Morphospecies Halictinae 6

			
Morphospecies Halictinae 7	Morphospecies Halictinae 8	Morphospecies Halictinae 9	Morphospecies Augochlorini 1
			
Morphospecies Augochlorini 2	Morphospecies Augochlorini 3	Morphospecies Augochlorini 4	Morphospecies Augochlorini 5
			
Morphospecies Augochlorini 6	Morphospecies Augochlorini 7	Morphospecies Augochlorini 8	Morphospecies Augochlorini 9
			
Morphospecies Augochlorini 10	Morphospecies Augochlorini 11	Morphospecies Meliponini	Morphospecies Anthophorini

Annex D

Seasonal abundance and diversity of bees at 1,650 masl

Figure 1

Seasonal abundance

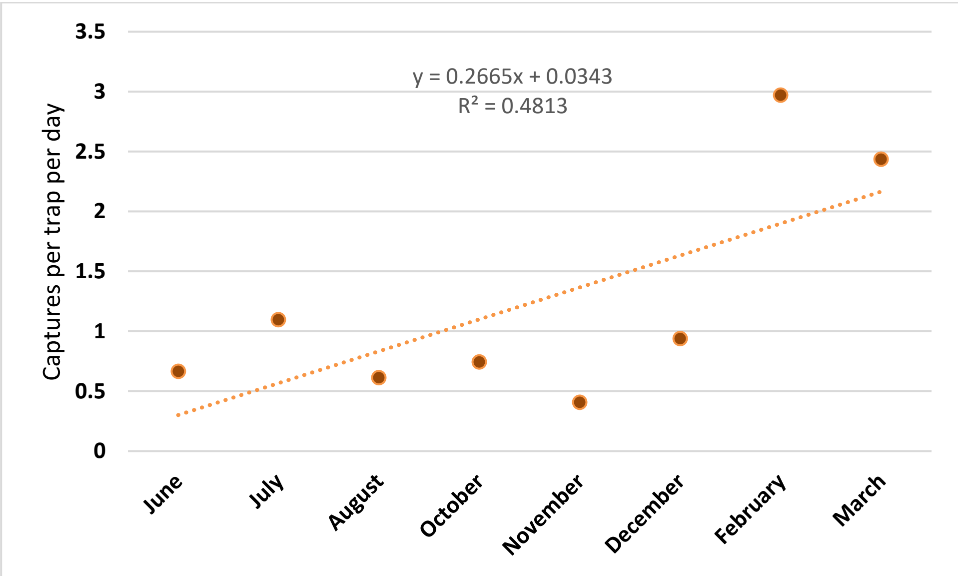


Figure 2

Seasonal richness