Sección de Biología
Universidad de La Laguna

Grazing impacts on pollinator insects

Impactos del pastoreo en insectos polinizadores

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Trabajo de Fin de Grado

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Resumen

Los polinizadores son cruciales para los ecosistemas naturales y agrícolas. Sin embargo, la mayoría de grupos de polinizadores están en declive debido a varios factores antrópicos como la intensificación del uso del terreno. El pastoreo supone el mayor uso del terreno a lo largo del planeta, y afecta a los polinizadores reduciendo su principal fuente de alimento. En las islas Canarias, el pastoreo ha sido una actividad desde que los primeros humanos llegaron a las islas, pero sus efectos en los frágiles ecosistemas del archipiélago no han sido analizados en profundidad. En este estudio, se colectaron polinizadores mediante el uso de *pan traps* en diferentes localidades pastoreadas y no pastoreadas a lo largo de diferentes unidades de vegetación, y se tomó información de otras variables que podrían explicar la interacción con el pastoreo. Los resultados revelaron que el pastoreo tuvo un impacto negativo en los insectos polinizadores. Además, un análisis de GLM mostró qué variables predecían mejor nuestros resultados. Este efecto negativo puede deberse principalmente a la corta historia del pastoreo y a la aridez de la isla.

Abstract

Pollinators are crucial for natural and agricultural ecosystems. However, most pollinator groups are in decline due to several anthropic drivers such as the land use change and land use intensification. Grazing is a major driver of land uses change across the world and affects pollinators reducing their main supply. On the Canary Islands, grazing has been an activity since the first settlers arrived, but their effects on the fragile ecosystems of the archipelago have not been analyzed. In this study, we collected pan traps from different grazed/ungrazed localities through different vegetation units, as well as other variables that could be interacting with grazing. Several analyses at R software were made. The results revealed that grazing had a negative impact on insect pollinators. Moreover, a GLM showed what variables predicted better the results. This negative effect could be mainly due to the short history of grazing and the aridness at the island.

Keywords: conservation, pollination, land-use

Introduction

Introduction

The pollinators play a crucial ecological role in all terrestrial ecosystems, since angiosperms cannot reproduce without them (Potts et al. 2016, Ollerton 2017, Requier 2022). In fact, more than 87.5% of the flowering plants and 75% of crops depend on animal pollination, including some so important like coffee or almonds (Potts et al. 2016). Besides, it is estimated that pollinators have an average economic value of 235-577 billion dollars per year (Hevia 2016, Potts et al. 2016, Millard et al. 2021), and agriculture gives employment to 1.4 billion of people, especially important in poorer rural areas (Potts et al. 2016). Moreover, many of these plants are our main source of many products like medicines as well as vitamin A and C, calcium, fluoride, and folic acid, so the loss of pollinators would imply a decline of global health (Potts et al. 2016, Requier 2022). Knowing all that, it is difficult to think that pollinators are not crucial to human well-being through the maintenance of natural and agricultural ecosystems.

The most diverse group of pollinator insects are Lepidoptera and Coleoptera, followed by Hymenoptera and Diptera (Ollerton 2017). Despite that, due to their behavior and specific adaptations, Hymenoptera and Diptera constitute the most efficient pollinator groups, being the bees the most important ones. Bees visited more than 90% of the leading crop types and flies visited around 30% of them (Ollerton 2017). Although there are a few managed species, like the honeybee, which is important in many crops, the vast majority are wild species (around 20.000) that have a key role as pollinators in both natural and agricultural ecosystems (Hevia 2016, Potts et al. 2016, Shapira 2019). Diptera pollination is also important because true flies can pollinate at colder temperatures and have a broader foraging range, although their importance is not recognized (Davis 2023). Many studies have pointed out that abundance and diversity of pollinators increases both quantity and quality of crop yield (Garibaldi et al. 2016).

Despite the importance of pollinator insects, its abundance and diversity are in decline (Potts et al. 2016, Ollerton 2017, Cardoso et al. 2022,). There is an increasing interest by science, politics and the general public, but the lack of information is problematic (Potts et al. 2016). There have been identified several causes of its decline like the loss and fragmentation of its habitat (Shapira 2019, Showket 2021, Cardoso et al. 2022), the land use intensification causing the reduction of resources (Millard et al. 2021), the climate change or pollution due to pesticides (Showket 2021, Cardoso et al. 2022), among others. However, the main driver of pollinator decline is the intensification of agricultural and farming systems, either indirectly by change of land use or directly by the use of pesticides and herbicides (Potts et al. 2016, Goulson 2015). This driver is exacerbated on oceanic islands due to their vulnerable ecosystems. Islands have particular abiotic (limited area and natural fragmentation) and biotic characteristics (demographic, genetic and evolutionary features) that made island biota disproportionately vulnerable to anthropogenic pressures, harboring a boundless amount of threatened and extinct species (Fernández-Palacios et al. 2021).

Grazing is a major driver of land use change across the world occupying approximately 25% of earth surface (Pérez 2012). The proliferation of livestock grazing worldwide, particularly in arid regions, is recognized as a significant peril to the diversity of pollinators (Winfree et al. 2009, Maestre et al. 2022). However, its impacts on ecosystems are not well-known yet due to complex interaction of variables such as climate, soil, biodiversity, grazing history, productivity, etc. (Fernández-Palacios 2013, Maestre et al. 2022). Therefore, there is an open debate in the scientific community about its benefits and negative impacts.

Several negative impacts of grazing have been identified such as decrease in vegetation cover, change in soil composition, soil compaction and, finally, soil erosion (Vulliamy 2006). Grazing clearly modifies the vegetation due to the constant loss of photosynthetic tissue, reducing the growth, reproductive performance and survival of vulnerable species. Knowing that plants are the base of every ecosystem, this will consequently affect pollinators in one way or another. The main negative effects that have been attributed to the grazing on pollinators are the impact mediated by the abundance and composition of floral resources. But there could be other impacts such as nesting destruction, alteration of nesting availability, water resources, or by killing them directly (Lázaro 2016, Tadey 2015, Shapira 2019). Also, the reduction of abundance on dominant species could lead to the invasion of opportunistic exotic species, or the reduction of floral resources could promote the abandonment of the area by pollinators to search for better places (Tadey 2015). However, moderate grazing intensity has shown positive effects on pollinators diversity and abundance (Vulliamy 2006, Tadey 2015, Lázaro 2016, Herrero-Jáuregui & Oesterheld 2018, Lasway et al. 2022). The reduction of grasses and dominant shrubs often leads to an increase in plant diversity and the availability of floral resources, increasing pollinator abundance and diversity (i.e. Tadey 2015). This situation support the Intermediate Disturbance Hypothesis that proposes a gaussian bell as response to the perturbation, so the diversity is minimum at one side because of stress, and at the other side is minimum because of competitive exclusion (Milchunas 1988, Bermejo 2012, Huston 2014). So, this will imply that, depending on the level of grazing intensity and how this correlates with other factors, grazing can cause positive or negative effects. The majority of empirical studies provide evidence to support the Intermediate Disturbance Hypothesis, indicating that at intermediate level of grazing, the flowers resources increased both in abundance and diversity, resulting in higher abundance and diversity of pollinators (Vulliamy 2006, Tadey 2015, Lázaro 2016, Lasway 2022).

However, there are multiple factors that can modify the response and the intensity of disturbance, such as i) lineage specific traits, ii) climate conditions, iii) species composition, and iv) grazing history. First, **lineage-specific traits**, such as the ecology, morphology, behavior and life cycle requirements between different pollinator groups can be determinant on the lineage response. Second, **climate** had a high impact on the effect of grazing, from local parameters but also spanning across large geographical regions. The most important climatic factors that modulate the effect of grazing are temperature and precipitation. So overall, in arid regions, where the productivity is low, the diversity will decrease as grazing intensity gets stronger. Third, **species composition** in the ecosystem can affect in different ways to the impacts too. The extinction of generalist species could not have an impact on the ecosystem, as their role would be replaced by another one (Shapira 2019). If, on the contrary, a specialist species becomes extinct, it would imply a decrease of unique interactions, loss of a functional group, increase in the importance of the dominant plant and superposition of ecological niches (Rakosky 2022). Something similar occurs with oligolectic and polylectic bees, since polylectic ones will be able to survive without some particular plant (Lasway 2022).

The **grazing history** could be important to understand the pollinator response. For example, in the Mediterranean Basin the increase in abundance and diversity of both pollinators and floral resources was given at high intensity of grazing instead of at medium intensity, due to the long history of grazing made the plant communities to be adapted to this pressure (Vulliamy 2006, Lázaro 2016). The decline of pollinators in arid regions with low productivity will be modulated by grazing history. Meanwhile, in wet regions, where the productivity is high, a higher grazing intensity will increase the diversity, no matter the history of grazing (Bermejo 2012). The effect of grazing on diversity based on the intermediate disturbance hypothesis has been modeled showing that the most important variables to explain the response of diversity was the combination of water availability, productivity index and grazing history (Bermejo 2012, 2019).

In the Canary Islands, grazing has been an activity since the first settlers arrived in the islands, 2500 years ago. Several unknown factors should be considered in order to evaluate the historical effect of grazing over the Canary Island ecosystems, such as the density of stock on each island, how it changed over time, as well as the intensity and distribution of grazing in different vegetation communities (de Nascimento et al. 2021). At present, the archipelago has the highest density of goat population in Spain, and even continues growing (Bermejo 2012).

In terms of biodiversity, the Canary Islands represent a major hotspot of pollinator biodiversity. The archipelago with 7,500 km2 represents a 0.5% of European surface, however it accounts in the European territory for 17% the endemic Apoidea (Nieto et al. 2014) and 11% of the endemic Syrphidae (Gilbert et al. 2022). Protecting this community is crucial to maintain this unique biodiversity and the whole ecosystem on the archipelago, as pollinators fulfill a fundamental role. As mentioned above, grazing can have beneficial or negative effects on pollinators, so it is important to analyze the effect of grazing on this unique community of pollinators in order to develop appropriate conservation measures.

Objectives

Objectives

The main objective of this study is to evaluate the impact of grazing on the pollinator communities of pine forests in Gran Canaria. As a secondary objective, we intend to analyze the interaction of grazing and other environmental variables such as vegetation, soil, with the richness and abundance of pollinators.

Material and Methods

Material and Methods

<u>Study area</u>

The study was made in Gran Canaria, an island located on the eastern side of the Canarian Archipelago, on the Atlantic Ocean, in front of the north coast of Africa. The climate in this island is subtropical, with dry summers and wet and smooth winters. The mean temperature is 21,1ºC and the average precipitation is 151 mm. However, due to the complex topography, the island contains a variety of microclimates and ecosystems.

The study area is located in the northwest-center zone, ranging between 400 meters to 1875 meters above sea level, so there is a notable variation in climatic and vegetation. Climatic conditions range from 218 mm to 732 mm of precipitation and from 12ºC to 18ºC the mean temperature. On the other hand, the vegetation goes from lowlands dominated by succulent plants adapted to arid regions (*Euphorbia canariensis, Euphorbia lamarckii*), to forest formed mainly by pines, passing through shrublands with a high percentage of introduced species (*Opuntia* sp., *Agave americana*).

<u>Field work</u>

In this study, an experimental design of independent sampling units was carried out to observe the effects of grazing on pollinators. These sampling units were setted up through three different vegetation units: pastures, substitution shrublands and pine forests. Pastures were formed mainly by annual and perennial herbs. Substitution shrublands were formed by several associations of shrubs. Finally, pine forest was sampled both in natural and repopulated areas. The impact of grazing was measured by means of farmer surveys that made it possible to establish which areas were being grazed. Additionally grazing intensity was measured by analyzing a Kernel distribution of spatial data provided by GPS devices carried by several herds.

In total, 45 localities were studied, however, two localities were removed later from the analysis due to sampling failures, and another additional three because no pollinators were collected. Therefore, a total of 40 localities were considered, of which thirteen were grazed and twenty-seven were ungrazed [Figure 1]. Overall, 5.000 ha of grazed area were included, that represent the 75% of grazed areas in Gran Canaria.

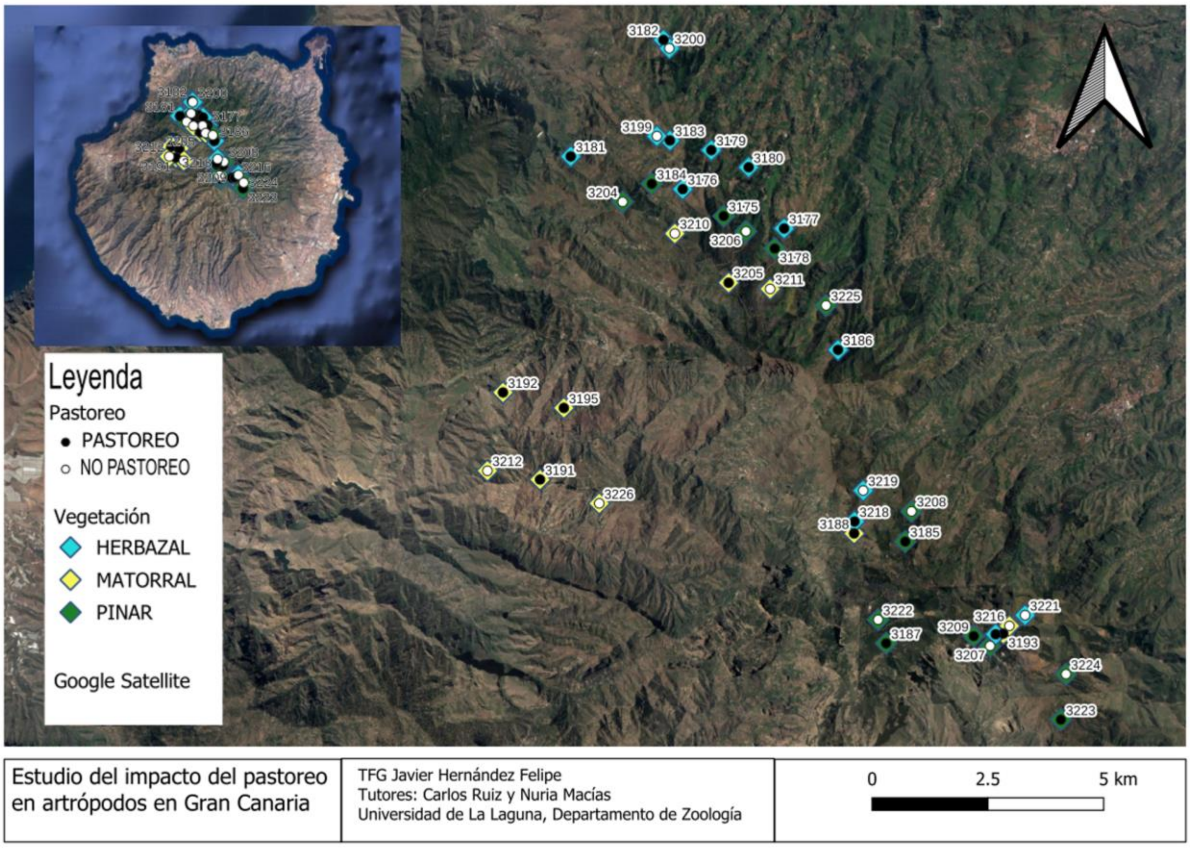

Figure 1. Study area and sampling localities on Gran Canaria.

In addition to grazing variables, other environmental variables were measured to evaluate the interaction with grazing. Climatic variables measured were temperature, precipitation and altitude. Vegetation variables used were forest canopy, abundance and richness of plants and flowers. For those related with vegetation, it was used the point-quadrat methodology, that consists of making a lineal permanent transect of 30 to 50 or 50 metres length, and collecting each 0,3-0,5 metres. The data collected along every transect to discover diversity, vegetation covering, abundance and composition were relative frequencies, vegetative covering, and heterogeneity. Other anthropogenic variables were taken into account such as, previous fire (both natural and provoked), high Risk Wildfire Zones as well as natural and anthropic areas. A soil variable (sand percentage) was considered because it can have some effect on wild bee nesting sites. All the sampling was carried out in spring 2022 (may to july) matching with the flowering peak in the area.

Two teams formed by three people sampled the small plots, alternating between grazed and ungrazed areas to avoid the sampling bias. Moreover, to control the phenological effect of the climate due to the long sampling period, the sampling followed the flowering peak from the south lowest zone to the highest area at north orientation.

For collecting pollinators a single passive method, the pan traps, was used to avoid researcher's bias. To attract a wide range of pollinators, triplets of pan traps were employed, comprising three pan traps of distinct colors (blue, white, and yellow). Three triplets were placed in each sampling unit representing a total of 360 pan traps, of which 117 pan traps were placed at grazed localities and 243 at ungrazed localities. The pan traps were filled with water and some soap to break the surface tension, and remained active for 8 hours. All individuals collected were deposited in tubes with absolute alcohol for its conservation and posterior identification at the laboratory.

Laboratory work

The collected material was sorted, and all individuals were identified at family level using a binocular stereoscope. Then, the samples were stored in eppendorf with absolute ethanol and assigned a code number and were introduced in a database. These were kept in boxes in a -20ºC freezer.

Finally, all the individuals of selected groups of pollinators (families Apidae, Andrenidae, Halictidae, Megachilidae, Tachinidae and Bombyliidae) were identified at species level with the help of dichotomous keys and taxonomists' knowledge (https://nathistoc.bio.uci.edu/hymenopt/Wasps.htm, https://sites.google.com/view/mikes-insect-keys/mikes-insect-keys?authuser=0).

Data analysis

An initial matrix with 26 environmental explanatory variables, related with climate, vegetation, management and soil were collected. To explore the correlation between different variables a Pearson correlation analysis with the library *corrplot* in R software (Wei 2021) was carried out. Exploratory analyses were done with the package *esquisse* (Meyer 2022) in R, searching for the relation between explanatory and response variables and interactions between them. Any interesting result was contrasted with the T-test in R with the library *Hmisc* (Harrel 2023).

To further explore the response of pollinators to grazing a presence absence matrix was built and PCA analysis was made with the library *factoextra* (Kassambara 2020).

Finally, the interaction between selected explanatory variables and response variables were analyzed using the General Linear Model (GLM) with the library *MASS* (Venables 2023), assuming a negative binomial distribution, based on the Akaike Information Criterion (AIC).

Results

Results

Structure of pollinator communities

In total, 777 specimens corresponding to 51 species were collected. Most of the pollinator collected belong to bees (Hymenoptera: Apoidea) accounting 721 specimens (93% of the samples) and 34 species (67%) distributed in four families (Halictidae, Apidae, Megachilidae and Andrenidae). The pollinator flies (Diptera) were less abundant and diverse (56 specimens and 15 species) belonging to the families Bombyliidae (24 exx., 5 spp) and Tachinidae (32 exx., 10 spp).

Specifically, the family Halictidae was by far the most abundant (548 individuals) and accounting for 70% of the sampling. This is mainly due to the presence of a dominant endemic species *Lasioglossum viride* that represents 59% of the captures within this family. Halictidae was also the family with higher richness (12 spp; 24% of species collected). It was followed by Apidae and Megachilidae in abundance, (both with 134 individuals), and by Tachinidae (10) and Megachilidae (9) in number of species. Finally, the less representative families in the sampling were the dipteran Tachinidae (32) and Bombyliidae (24) in abundance and Bombyliidae (5) and Andrenidae (4) in richness [Figure 2]. Sixteen specimens were not identified at species level so they were removed from posterior analyses. Of the 51 species captured, 24 of them (47%) were endemic, belonging 16 to Apoidea and 8 to Diptera.

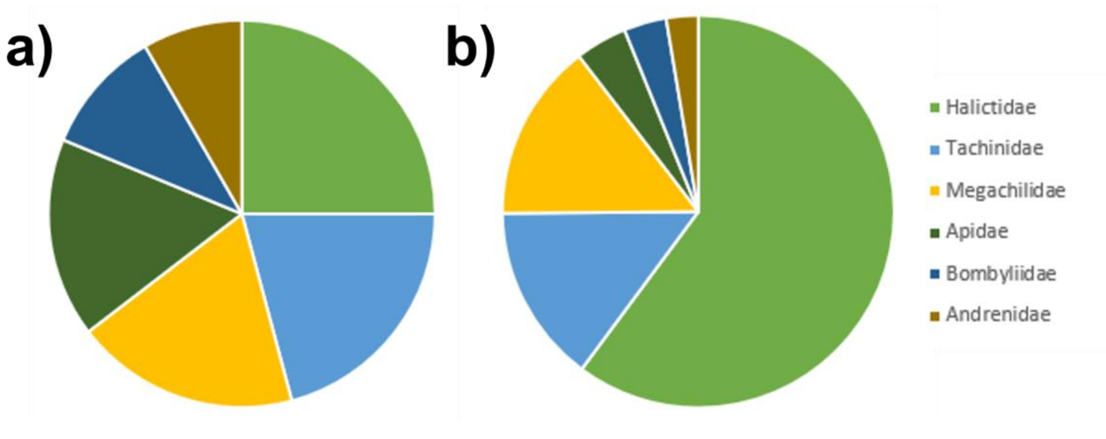

Figure 2. Total richness (a) and abundance (b) of Apoidea and Diptera pollinator families

When the data was analyzed by vegetation unit, the pine forest is the ecosystem with more abundance (mainly due to Halictidae), followed by grassland and finally shrubland, which has a very low pollinator abundance. Regarding richness, the number of species on each ecosystem is pretty similar, varying only in one unit. Although pine forest and grassland have the most diversity in each family.

Grazing impact on pollinator communities

Our results showed a significant negative impact of grazing on the richness of wild bees (p=0,0042) (Figure 3c). On the other hand, there is no effect on abundance of bees (p=0,96) or on the abundance (p=0,38) and richness (p=0,38) of dipteran pollinators (Figure 3a, 3b, 3d).

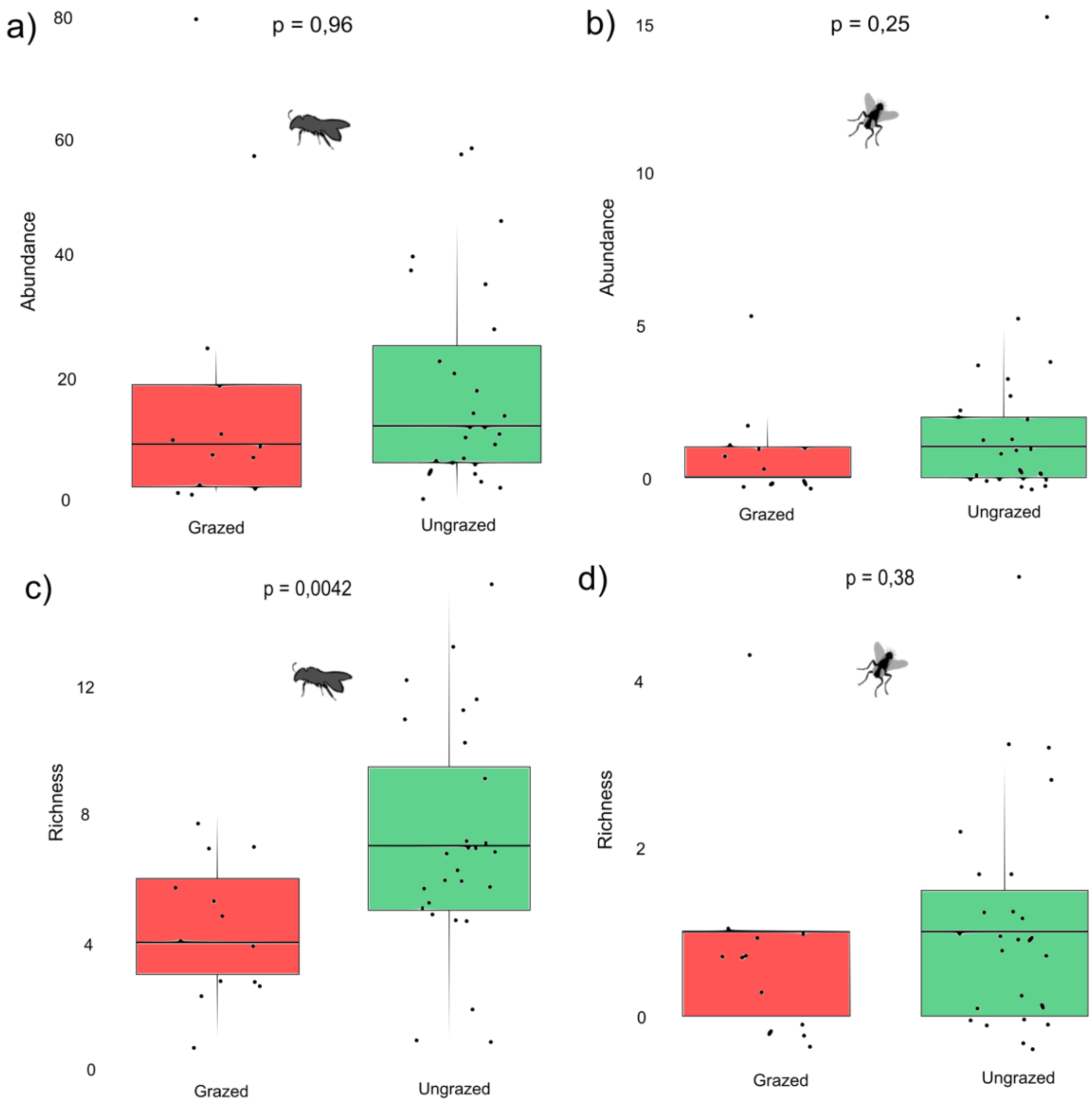

Figure 3. Box-plot of abundance (a, b) and richness (c, d) between grazed and ungrazed sites for Apoidea (a, c) and Diptera (b, d) pollinators.

To further explore this effect within Apoidea, when the three different vegetation units are taken into account, it is observed that there was a significant negative effect of grazing in the richness of Apoidea in shrublands (p=0,044) (Figure 4), also a similar trends, but not significant, appeared in abundance in shrublands, as well as in pine forest.

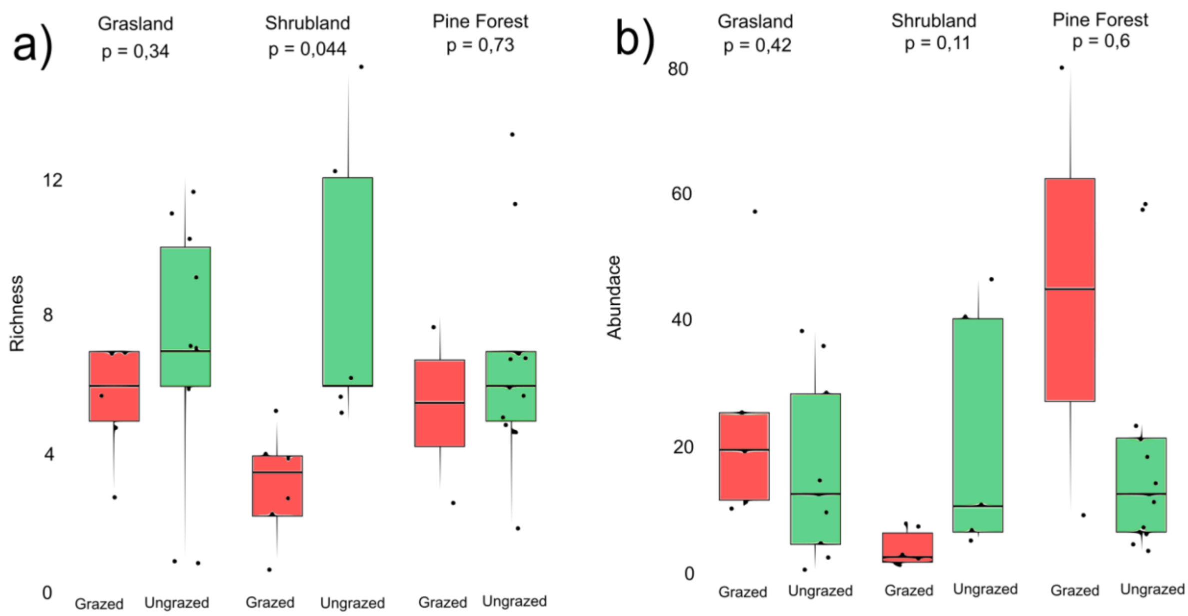

Figure 4. Boxplot comparing the Apoidea richness (a) and abundance (b) between grazed and ungrazed sites across different vegetation units.

When the category of origin was taken into account, comparing endemic and non endemic species, the analyses showed that the negative effect of grazing was mainly due to its impact on endemic Apoidea species (Appendix Fig. 1).

<u>Grazing correlation with other variables</u>

After exploratory analyses, six independent environmental variables were taken into account: grazing, grazing intensity, protected natural area, plant abundance, altitude and vegetation unit. Although the grazing intensity was negatively correlated with pollinators richness and abundance, there was no significance. For the remaining variables, there was no correlation with grazing nor with pollinators abundance or richness.

The PCA analyses of the presence/absence pollinator matrix showed that pollinators of grazed locations were a subset of the total pollinators. Most of the variation was on the PC1 axis (19.7%), and the PC2 axis recovered a lower proportion of the variance (10.4%). Moreover, the endemic species were mostly associated with ungrazed localities, while the introduced or abundant native species were associated with grazed localities (Figure 5a). When protected natural areas were taken into account, the PCA showed that unprotected areas were a subset of grazed areas, being the endemic species characterizing the ungrazed and protected areas (Figure 5b). Therefore the PC1 axis was clearly associated with anthropic variables (both grazing and unprotected areas) and the endemic species were clearly associated with undisturbed areas as opposed to *Apis mellifera* whose vector appeared in the opposite direction.

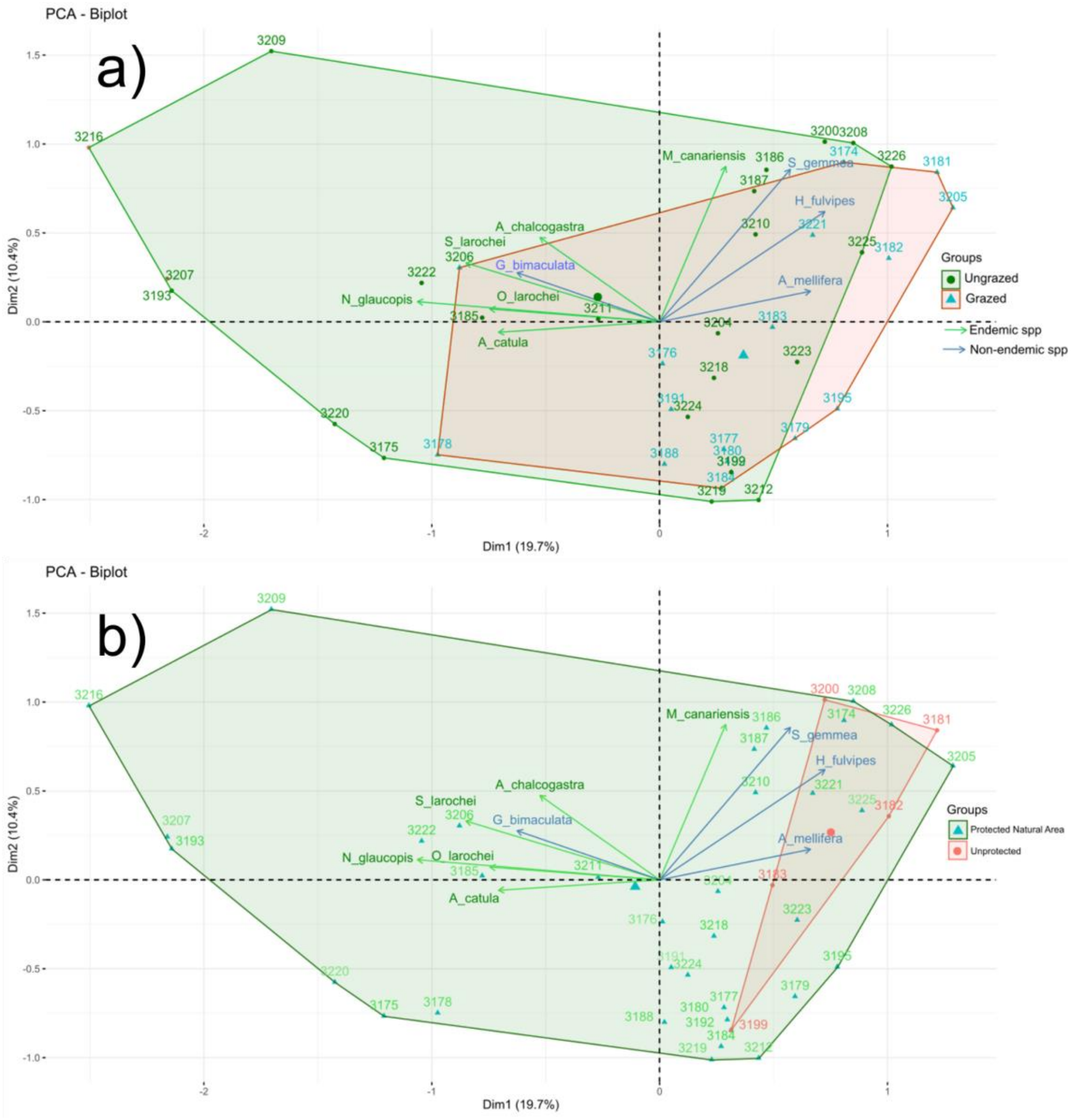

Figure 5. PCA analysis, distribution of the species according to (a) grazing, and (b) Protected Natural Area.

Finally, several models were explored considering different combinations of the variables (vegetation unit, altitude, grazing, grazing intensity and plant abundance). GLM results showed that the best model to explain bee abundance was best predicted by the following combination of explanatory variables: grazing (presence/absence), grazing intensity, altitude and plant abundance (AIC = 80.781, Null deviance: 37.4131 on 16 degrees of freedom).

Discussion

Discussion

This study showed that grazing activity generates significant declines in bee species richness. Specifically, this activity is mainly affecting endemic bee species in the substitution shrublands. On the contrary, there were no significant effects on the abundance and species richness in other vegetation units, nor on the diptera species.

Although no significant differences were observed, the abundance of pollinators tends to be higher at ungrazed localities, which could indicate that grazing may negatively affect the pollinators. These results are contrary to most studies where increased richness and abundance of species was observed at intermediate level of grazing (Vulliamy 2006, Tadey 2015, Lázaro 2016, Millar 2021, Lasway 2022). Moreover, it must be taken into account that many of the studies that found positive effects of grazing on pollinators, found negative effects at high levels of grazing (Millard et al. 2021, Lasway 2022, Rakosy 2022). In our study grazing intensity was not available for many of the localities so it could not be properly tested, but one possible explanation is that most of our grazing localities studied were at high intensity, which would agree with previous studies. Besides grazing intensity, there are several factors that influence the effects of grazing such as climate conditions and grazing history that should be taken into account in order to compare with other studies. Climate conditions are an important driver modulating the impact of grazing. Gran Canaria, due to its proximity to the continent is one of the most arid islands, and the pine forest ecosystem suffers low water availability compared with western islands. Regarding grazing history there is no knowledge of the density of stock on each island since the first settlements (de Nascimento et al. 2021), so there could be a higher effect if the plant communities are not adapted to grazing. Recent studies indicate that during the last 2000 years the pine forest underwent a notable decline probably related to introduced herbivores, in parallel with burning practices and the expansion of scrubs and grassland vegetation. This anthropic pressures increased after the Castilian conquest, with the subsequent rural development (Ravazzi et al. 2021). So, both the aridness and the low adaptation of the ecosystem to the perturbation could prevent the recuperation of the species (Bermejo 2012, Milchunas 1988). Further studies that take into account all these variables in detail are needed in order to fully understand the effect of grazing on Gran Canaria pollinators.

The impact of grazing is concentrated on the endemic species. This agrees with the idea that the endemic species are the most vulnerable to anthropogenic perturbation (Weeks 2022). In fact, the PCA analysis showed that PC1 may be related with anthropic change, where endemic species like *Andrena chalcogastra* or *Nomada glaucopis* are more alike to ungrazed and protected sites, while native/introduced species like *Apis mellifera* or *Halictus fulvipes* are more related to grazed and un protected sites. This could mean that these two factors are correlated, or maybe even there are more anthropogenic or climatic factors contributing too. There may be several reasons why endemic pollinators decrease under these conditions. For example, endemic solitary bees can be more specialized in particular flora with narrow niche diets and restricted foraging range will be more vulnerable to herbivores. This will not occur to native or introduced social species that are generalist polylectic, with large foraging range and adapted to anthropic impacts such as *Apis mellifera* (Shapira 2019). Although it is less probable, this could be to the destruction of nesting sites too. As a result of this effect, grazing results in the loss of endemic species, resulting in a biotic homogenization, with dominant generalist species, both natives and introduced ones that are adapted to anthropogenic areas (Rader et al. 2014).

The impact of grazing seems to be concentrated at shrubland, where the abundance and richness of bees decreased. This could be due to the fact that shrubland is more vulnerable to grazing than grasslands because goats prefer shrubs rather than grasses (Fernández Lugo 2013, Vulliamy 2006). However, the shrubs could have for that reason more defenses to herbivores, like the reduction of palatability (Vulliamy 2006). Also, herbaceous species are mostly annual, so they can regenerate faster by seed banks, and there is no effect on pollinators (Fernández Lugo 2013). Contrary to what has been said previously, the history of grazing in the Canary Islands could have caused the disappearance of the more vulnerable species to herbivores, so the community composition does not get modified when exposed to grazing (Fernández Lugo 2013). Moreover, in these shrubland substitution communities, there are many Mediterranean species that are clearly more adapted to herbivory (Vulliamy 2006, Fernández Lugo 2013).

As goats act by opening the vegetation, they can create gaps that can be replaced by other less competitive species, increasing heterogeneity, or promoting bare soil (Fernández Lugo 2013). For that reason, it was expected that at grazed localities, the percentage of bare soil will be higher and so it will favor solitary bees that make their nests in the ground, like the ones of the family Halictidae, as it occurs in others studies (Tadey 2015, Vulliamy 2006). However, it was not seen any increment or decrease comparing Halictidae abundance and richness and percentage of sand, as it occurs in others studies (Shapira 2019, Lasway 2022).

Contrary to expected, while many studies supported that diversity and abundance of flowers increase pollinator abundance and richness (Lázaro 2016, Vulliamy 2006, Lasway 2022) this study did not show any correlation between these variables. However GLM supports this effect, as one of the most important variables for the model was the abundance of plants, which is indirectly correlated with the floral resources availability. This could be due to a methodological artifact since the availability of floral resources was not measured accurately but rather a rough estimate was made of the abundance and diversity of flowers in the area that could be subject to sampler bias.

The results make it clear that the abundance and richness of bees are higher than pollinator flies. This does not have to mean that Diptera are not important, since it is demonstrated that diptera pollinators are important in abundance as well as bees (Davis 2023). But, this could be due to the fact that flies are more resilient to perturbation due to their biological traits (high mobility, an absence of parental care, a low specialized diet, and higher affinity to anthropized environments), so they do not modify their abundance and richness (Tadey 2015, Millar 2021, Davis 2023). Additionally, there could also be a methodology bias, like the types of traps that were used.

Further studies that consider the grazing intensity are crucial to understand the effect of grazing on insect pollinators. Also, it would be interesting to analyze the effect of different collection methods to obtain a more accurate picture of the impacts of grazing activities.

Conclusions

Conclusions

This study highlights the importance of understanding the response of pollinators to grazing effects in pine forest ecosystems. Endemic solitary bees are the ones most vulnerable to grazing activities being replaced by generalist native or introduced species such as *Apis mellifera*. Our results show the need to preserve natural areas of pine forest from human activities in order to protect these vulnerable communities.

Conclusiones

Este estudio destaca la importancia de entender la respuesta de los polinizadores a los efectos del pastoreo en los ecosistemas de pinares. Las abejas endémicas solitarias son una de las más vulnerables a las actividades del pastoreo, siendo reemplazadas por especies generalistas introducidas o nativas como *Apis mellifera*. Nuestros resultados muestran la necesidad de preservar las áreas naturales de pinares de la actividad humana en pinares para proteger estas comunidades vulnerables.

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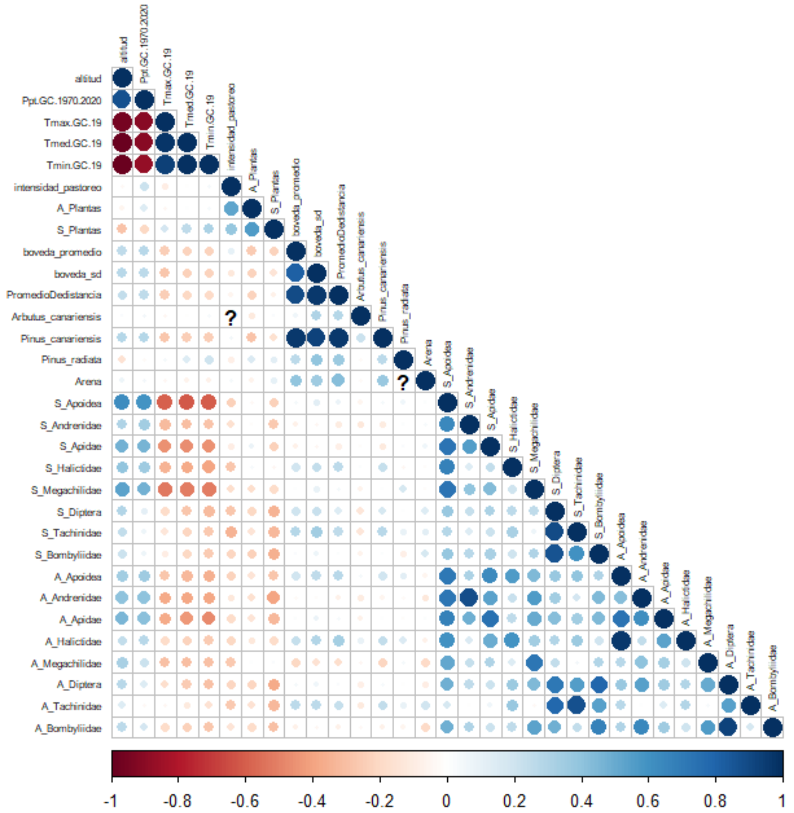
Appendix

Appendix



1

Figure 1. Pearson correlation between all variables, both independent and dependent, excluding abundance of each species separately.