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# Temporal and spatial variation of floral resources of woody species in a *vereda* ecosystem: Uniformity and habitat complementarity

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ABSTRACT

Floral resource distribution, pollinator community structure, and flowering season are essential for maintaining and preserving pollination services in ecosystems. In humid Cerrado areas, *veredas* are considered hygrophilous communities, marked by the presence of the *Mauritia flexuosa* palm tree emerging in the wetter zones. Waterlogged portions present dense hygrophilous forests, whereas open areas predominant present herbaceous and shrubby components. We identified the pollination syndromes of woody species in a *vereda* ecosystem and characterized the pollination resource availability between habitats (hygrophilous forest and open area). The study was conducted on a *vereda* located in the north of Minas Gerais, Brazil. We characterized pollination syndromes using information on floral attributes, pollinator observations, and a literature survey. We performed phenological monitoring for 24 months and examined the occurrence of flowering using circular statistics. The differences in pollination syndrome occurrence among months and habitats were determined using modularity analysis. We found eight pollination syndromes, with melittophily being the most frequent pollination type among the woody species in the studied *vereda*. Flowering occurs throughout the year in the community and peaks from September to November during the transition from the dry to the wet season. In hygrophilous forest the species flowered preferentially in November, whereas in open area, preferentially between September and October. The syndromes distribution differed between the habitats, as well as resource availability. This difference between habitats can influence pollinator diversity. Modularity showed complementarity among the habitats, with continuous resource availability throughout the entire ecosystem. Species present in the hygrophilous forest provide their resources mainly during the rainy season, whereas species from the open area, during the dry season. Information on these interactions is necessary to understand the functionality of a *vereda* ecosystem, through the characterization of the resource's availability, and maintenance of pollination services in the ecosystem. In addition, our results demonstrate the importance of the *vereda* ecosystem as an important area in the availability of resources for the Cerrado formation. This information can strengthen protection laws and contribute to sustainable practices that boost the conservation of pollinators in the biome.

## 1. Introduction

Biodiversity includes species richness in a habitat and their interactions (Sabatino et al., 2010; Ballantyne et al., 2017). Pollination is a mutualistic interaction where flowers provide food and pollinators provide pollination service (Maruyama et al., 2013; Rech et al., 2014; Wardhaugh, 2015). Within pollination interactions, we can define pollination syndromes that consist of a set of floral characteristics (floral resources, colors, fragrances, and morphology) that are associated with the attraction and utilization of a possible specific group of animals as

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pollinators, with the floral characteristics correlated through independent evolutionary events (Fenster et al., 2004). In relation the different types of pollination syndromes and potential interactions between plants and possible pollinators, spatial and temporal variations combined with the abundance and distribution of floral resources are structuring factors for pollinator communities (Olesen et al., 2008;Burkle and Alarcon, 2011; Carstensen et al., 2014). Therefore, resource availability, conditioned by the flowering season, is essential for interactions and the maintenance of pollination (CaraDonna et al., 2014, 2017; Kantsa et al., 2018).

Several plant communities have different flowering seasons among their species, making resources available over a prolonged period (Dorado and Vazquez, 2014). Distinct species with sequential flowering seasons provide continuous resources for pollinators (Rosas-Guerrero et al., 2014). However, some regions might present restricted pollination seasons, resulting in seasonal variations in the diversity and frequency of pollination systems (Cortés-Flores et al., 2017; Genini et al., 2021). These environments present more diverse pollination systems, especially during flowering peaks. The diversity of consumers increases with the variety of resources (Cortés-Flores et al., 2017). The synchronicity between flowering and pollinators' activity is still poorly understood in ecosystem services. However, these interactions are valuable for maintaining biodiversity, and information about them aids understanding of the functionality and maintenance of pollination services and ecological processes (Morellato et al., 2016).

The Cerrado is a Neotropical savanna with a high floristic diversity (Mendonça et al., 2008; Silva et al., 2012; Maruyama et al., 2013). Field studies in this biome revealed a diversity of pollination syndromes, with bees as the leading pollinators (Oliveira and Gibbs, 2000; Barbosa and Sazima, 2008; Ishara and Maimoni-Rodella, 2011; Baronio et al., 2021). Although the Cerrado presents well-drained soils throughout most its plant formations, it also has seasonally waterlogged areas, e.g., *veredas* (Araújo et al., 2002; Nunes et al., 2015, 2022). *Veredas* are an important source of water and food for wildlife (Bahia et al., 2009; Alencar-Silva and Maillard, 2011) owing to the seasonal climate characteristics of the Cerrado (Malheiros 2016). These ecosystems are considered hygrophilous communities presenting variations in floristic composition and zoned structure according to humidity and depth of the water table, which characterize distinct microhabitats (Araújo et al., 2002; Nunes et al., 2015, 2022). Commonly, there is a dense hygrophilous forest in the center of the *vereda*, where water logging is continuous around streams, and tree species predominate. In the open areas, the soil is wet, and the vegetation is composed of shrubs, undershrubs, herbs, and grasses (Nunes et al., 2015, 2022).

Anthropic disturbances and climate changes have damaged many *vereda* areas before we understand their composition, structure, ecosystem services, and functional diversity (Fagundes and Ferreira, 2016; Nunes et al., 2022; Silva et al., 2022). Identifying pollination syndromes and characterizing resource availability along the year in a *vereda* ecosystem will enable a better understanding of the reproductive dynamics in these environments in relation the plant species. It is important to highlight that this type of study is the first in the studied ecosystem. Here, we focus on woody species selected based on a previous phytosociological study (Nunes et al., 2022) carried out in a *vereda* ecosystem. We did not include the herbaceous layer which is dominated by plants from the Poaceae and Cyperaceae which are pollinated by the wind (Friedman and Barrett, 2009; Rech et al., 2014; Linder et al., 2018), even though some establish interactions with potential pollinators (Schulze-Albuquerque et al., 2020). Therefore, we sought to answer the following questions: (i) which woody species pollination syndromes are present in veredas? (ii) are resources continuously available in this ecosystem? and (iii) do the distribution of pollination syndromes and seasonal resource availability differ among the *vereda* microhabitats (hygrophilous forest and open area)?

## 2. Materials and methods

### 2.1. Study site

We studied the Almescla *vereda* in the environmental protection area of the Pandeiros River (APA Rio Pandeiros) (15°20′54.9″ S, 44°53′84.5″ W), Bonito de Minas, Minas Gerais, Brazil (Fig. 1a). The *veredas* in the northern region of the state of Minas Gerais present an Organosol and Melanic Gleysol, which are soils formed by the accumulation of plant residues in varying degrees of decomposition and in environments with prolonged water saturation. The Almescla *vereda* presents a Mesic Organosol (soil consisting of organic matter, saturated with water; Nunes et al. 2015; Veloso et al. 2018). The present study considered two different habitats: hygrophilous forest (HF) on wet soil with predominant tree species and open area (OF) on wet to dry soil with the predominance of shrubs (Nunes et al., 2022; Fig. 1).

The Köppen classification defines the regional climate as Aw: tropical, with a dry winter and a rainy summer (Alvares et al., 2013). The dry season lasts for 5 months (May to September). The rainy season occurs from November to January (Azevedo et al., 2014). The annual rainfall is 920 mm, and the average temperature is 26.8 °C (Azevedo et al., 2014). In the region, rainfall starts in October and is higher between November and April. In May, the weather transitions from rainy to dry, lasting until September. Between March 2018 and February 2020, the average temperature increased from 18 °C (July) to 37 °C (November). The rainiest month was November 2018, with 294.8 mm (Fig. 2).

### 2.2. Species, floral attributes, and pollination syndromes

We selected the woody species of angiosperms, including trees, shrubs, subshrubs and also palm species, according to a previous phytosociological study carried out in the Almescla *vereda* in 2017 (Nunes et al., 2022). For the phytosociological study, plots distributed in the *vereda* in transects parallel to the watercourse were used. In the habitat characterized as a hygrophilous forest, 30 plots of 10 *m* × 20 m were distributed along a transect, with a distance of 150 m between them. All tree and shrub individuals within these plots with DBH ≥ 5 cm (diameter at breast height – measuring 1.30 m above ground level) were identified and marked with numbered aluminum plates. Within each plot, smaller plots of 5 × 5 m were also delimited for sampling tree-shrub individuals from the lower and/or regenerating strata. In these subplots, all tree-shrub individuals with a DBH ≥ 3 cm were also registered and numbered with aluminum plates. In the habitat defined as an open area, two transects were allocated separated by 20 m. In these transects, 38 plots of 10 m × 20 m were distributed, with a distance of 150 m between them, arranged parallel to demarcated plots in the hygrophilous forest. All shrub individuals with DBS (diameter at the base of the soil) ≥ 5 cm were marked and registered with aluminum plates. Likewise, subplots of 5 m × 5 m were allocated within these plots to sample shrub-subshrub individuals. Thus, all individuals with DBS ≥ 3 cm were marked and registered using aluminum plates. Individual identification was carried out in the field and through collected material (vegetative or reproductive) for identification through specialized literature (Nunes et al., 2022). The present study analyzed 86.9 % of the species found in the phytosociological survey; 29 species in the hygrophilous forest and 31 in the open areas. For the other species, due to the absence of reproductive material, data collection *in loco*, and information in the literature, it was not possible to identify the pollination syndrome.

We analyzed the species *in loco* during flowering and recorded the shape/type (dish, campanulate, flag, gullet, tube, brush and inconspicuous), color (white, red, greenish, yellow, orange, lilac/violet, pink), and scent (characterized as pleasant, unpleasant, or imperceptible). Flower anthesis for each species was determined using information available in the literature or observations during diurnal sampling (Tables S1 and S2). The observations were conducted between 7 AM and 6 PM, and for the nocturnal species, information about anthesis and

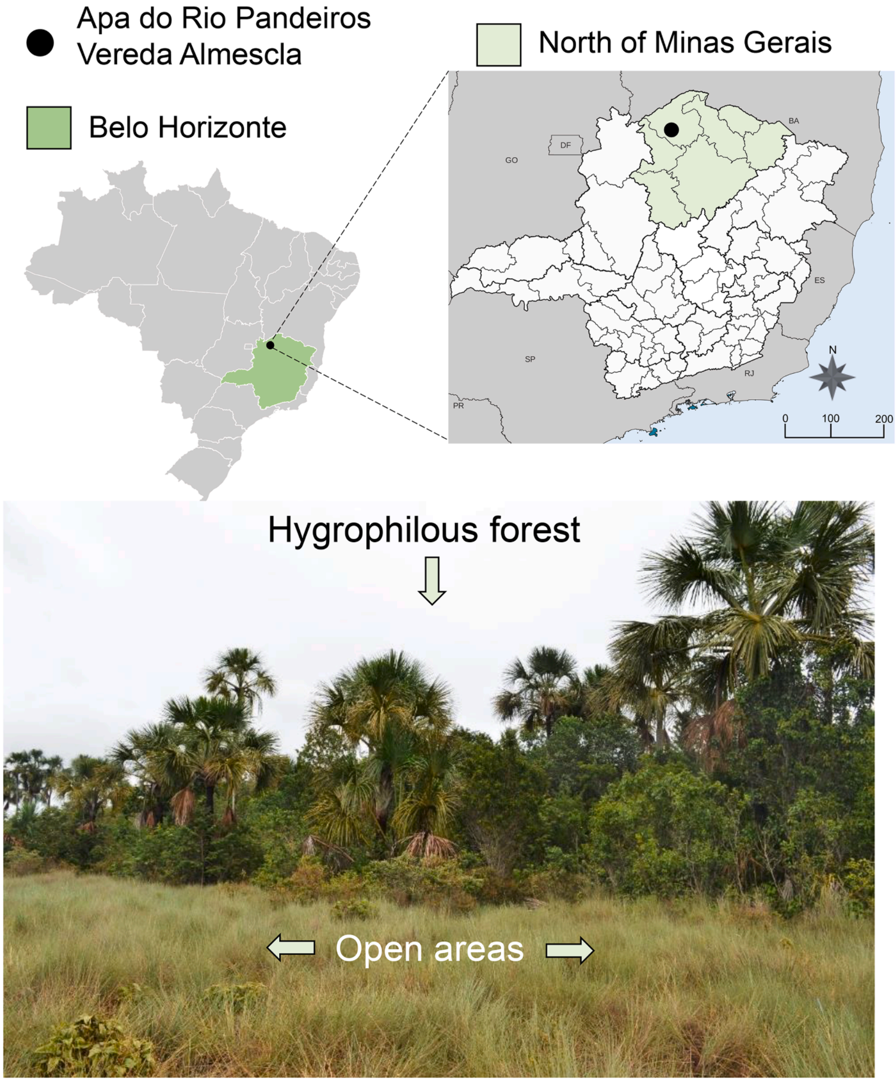

**Fig. 1.** Location of the Almescla *vereda*, APA Pandeiros, Bonito de Minas, MG, Brazil. Almescla *vereda*: hygrophilous forest and open area. The hygrophilous forest is composed of a dense forest community, and the open area is composed of shrubs, herbs, and grass.

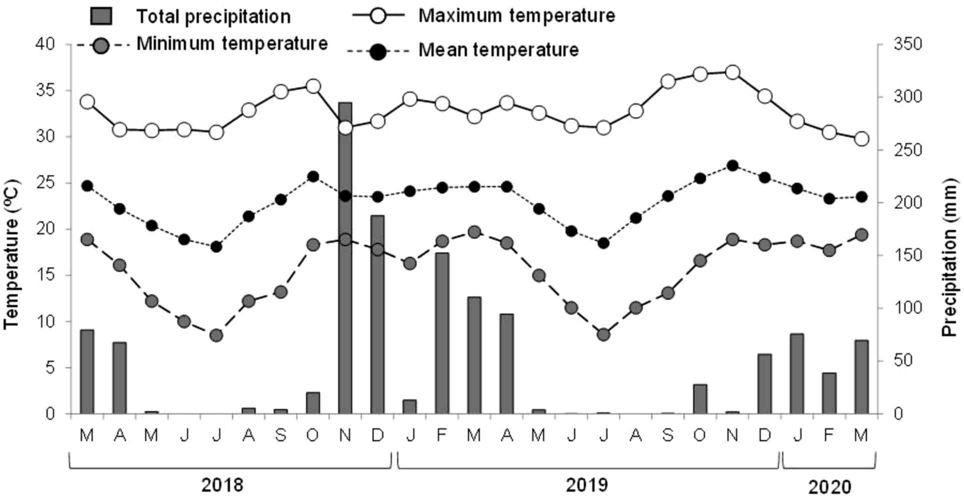

**Fig. 2.** The total monthly rainfall (bars) and the average minimum, mean, and maximum temperatures (lines) from March 2018 to March 2020, collected by the meteorological station installed in the Almescla *vereda*, Bonito de Minas, MG, Brazil.

main pollinator was determined through information collected in the literature and the characteristics that the flowers presented as typical of nocturnal pollination syndromes. We gathered literature information whenever reproductive material was absent. We conducted our search to gather information in the literature using Web of Science (https://login.webofknowledge.com/), Scopus (https://www.scopus.com/), Google Scholar (https://scholar.google.com.br/), and Scielo (https://www.scielo.br/). We used a combination of the following keywords in English (and their equivalents in Portuguese/Spanish): "pollinators", "pollination syndromes" and "pollination", always together with the name of the plant species. In addition to observing the floral attributes of the evaluated plant species, we also made phytocentric observations of floral visitors and potential pollinators. During the monthly observations for flowering characterization, we performed ten minutes of focal observations of each flowering plant within the plots. The observation time was variable for each species, depending on occurrence, phenology, and abundance. To include variations in the timing of plant-pollinator interactions, we recorded all plots at different times throughout the day during the sampling period (Souza et al., 2017, 2018, 2021). Thus, the pollination syndrome characterization considered floral attributes and pollinator sightings through field observations and literature: cantharophily (pollination by beetles), phalaenophily (moths), sphingophily (hawkmoths), psychophily (butterflies), melittophily (hymenoptera), myophily (flies), ornithophily (birds), chiropterophily (bats) (Faegri and van der Pijl, 1979), anemophily (wind pollination), and ambophily (anemophily + melittophily) (Bullock, 1994) (Table S2). Some plant species showed more than one pollination syndrome; that is, the species was pollinated by several groups of pollinators, which is why they were classified as multiple pollination syndromes.

### 2.3. *Resource availability*

Phenological data were collected every month over 24 months (March 2018 to February 2020). We recorded, during observations, the presence of flowers in each individual (Bencke and Morellato, 2002). The estimated occurrence and intensity of flowering distribution allowed us to evaluate the season and duration of resource availability and determine the seasonality over the study period. To estimate the intensity of flowering and supply of resources in the different evaluated habitats of *vereda*, all flowering individuals were quantified, and the sum of these individuals was calculated to identify the intensity of the flowering peak and assess the seasonality in each habitat. We calculated the circular standard deviation, circular mean, and vector length (r) to represent data grouping around the mean for flowering period (as proposed by Morellato et al. 2010). The Rayleigh test (z) indicated a unimodal distribution at $p < 0.05$, i.e., seasonality in the flowering pattern (Zar, 2013). Angles represented the months: e.g. January = 0°, February = 30°, December = 330°, in 30° increments. The circular analysis was conducted in the Oriana 4.0 software (Kovach, 1994).

We used the modularity index to evaluate how pollination syndrome occurrences differ among the sample months by quantifying the abundance of species with a particular syndrome in a particular month ( modified from Genini et al. 2021). In this way, modularity quantified the prevalence of species with certain syndromes in specific months, and whether the syndromes would occur more in specific months than in others, forming modules. The modularity was calculated using the DIRTLPAwb+ algorithm (Beckett, 2016) and the *computeModules* function in *Bipartite package* (Dormann et al., 2008). In addition to the raw modularity, we used the Patefield null model, which fixes the matrix size and the marginal totals, which is species richness/syndromes and observed months, while shuffling occurrence randomly (Patefield, 1981). We consider the modularity and consequent separation of the syndromes in the different modules to be significant if the observed value was greater than those generated by the null model. For each *vereda* area, we conducted a separate modularity analysis (hygrophilous forest and open area).

## 3. Results

Animals pollinated a large proportion of woody plants in the Almescla *vereda*, which were included in eight pollination syndromes. Bee pollinated species (mellitophily) were the most frequent, representing 83 % of all species. Beetles (cantharophily) and Butterflies (psychophily) accounted for accounted for 4 % of species each, and the other syndromes for only a single plant species each (Table S1). Melittophily was the most frequent syndrome in both habitats, in 87 % of the open area species and 79 % of the hygrophilous forest species. Cantharophily and psychophily were present in both *vereda* habitats. Cantharophily occurred among species of the same genus: *Xylopia aromatica* (Lam.) Mart. in the open areas and *Xylopia emarginata* Mart. in the hygrophilous forest. Pollination by birds and moths, ambophily, and anemophily remained restricted to the hygrophilous forest. Sphingophily occurred only in the open areas.

Different species with flowers were present throughout the year, with flowering concentrated between September and November, a period of transition from the dry season to the rainy season. Flowering peaks occurred in October in both years (Fig. 3), when the temperature also increased (Fig. 2). Flowering in the hygrophilous forest was seasonal in the first year ($r = 0.557$), with a peak in October, and irregular during the second year ($r = 0.389$). Although the second year did not show significant seasonality, species preferably flowered in November (Fig. 4). Open areas presented irregular flowering in both years ($r = 0.339$ and $r = 0.276$, respectively). Again, even though the vector (r) did not indicate seasonality, species preferably flowered between September and October (Fig. 4), a transition between the dry and rainy seasons (Figs. 2 and 3).

Although flowering occurred throughout the year, resource availability was continuous only for melittophily and cantharophily. Resources were available for cantharophily throughout the year only occurred due to *X. aromatica* extended flowering, which is present in both environments. Species with floral attributes related to psychophily, sphingophily, chiropterophily, phalaenophily, and ornithophily did not have continuous resource offer. Flowering occurred only for a few months, especially between July and October (Table S; Fig. 3).

The distribution of pollination syndromes among different sample months followed a modular pattern, considering species richness and abundance. Modularity was significant in both environments (hygrophilous forest: species richness $Q = 0.21$, $p < 0.03$; abundance $Q = 0.32$, $p < 0.01$. Open area: species richness $Q = 0.39$, $p < 0.01$; abundance $Q = 0.13$, $p < 0.01$. Fig. 5a and b), generating three to four modules. Some modules included more than three months, corresponding to the longer flowering period of a given syndrome.

These results showed that the variety of pollination syndromes in the hygrophilous forest generated three modules. The first module (rainy season) was dominated by melittophily and also included anemophily, ambophily, and cantharophily. The second module (dry season) was also dominated by melittophily, but all other pollination syndromes were present, and was the only module containing ornithophily, phalaenophily, chiropterophily, and psychophily. The last module (transition between the rainy and dry seasons) revealed less dominance by mellitophily, and greater representation by ambophily and cantharophily. Syndrome abundance modularity in the hygrophilous forest showed a similar pattern. A module in the rainy season was associated with melittophily. The second one occurred mainly during the dry season and associated abundance with ambophily, ornithophily, phalaenophily, chiropterophily, and psychophily. The third module (transition between seasons) was associated with cantharophily and anemophily (Fig. 5a).

Open areas presented contrasting resource availability compared with the hygrophilous forest. There were four modules for the diversity of pollination syndromes. The first, during the dry season, was associated with melittophily, whereas the second, in September, with

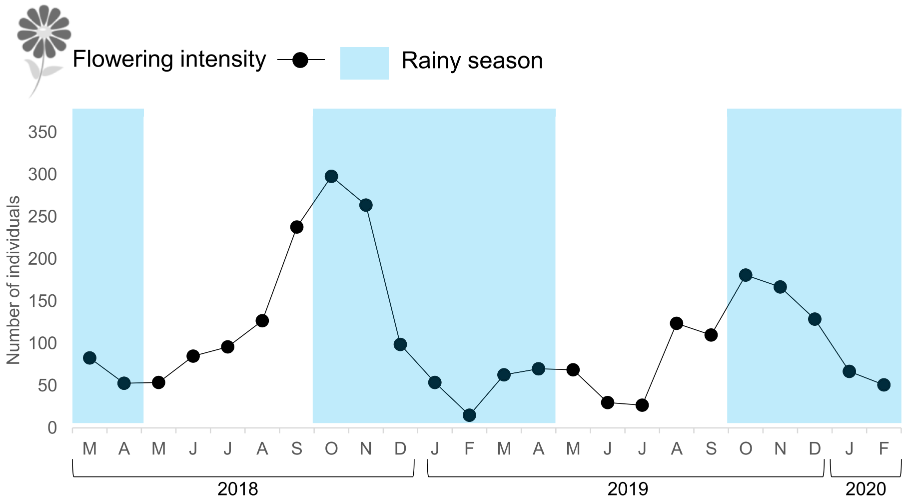

**Fig. 3.** The number of flowering individuals between March 2018 and February 2020 in the Almescla *vereda* community, Bonito de Minas, MG, Brazil.

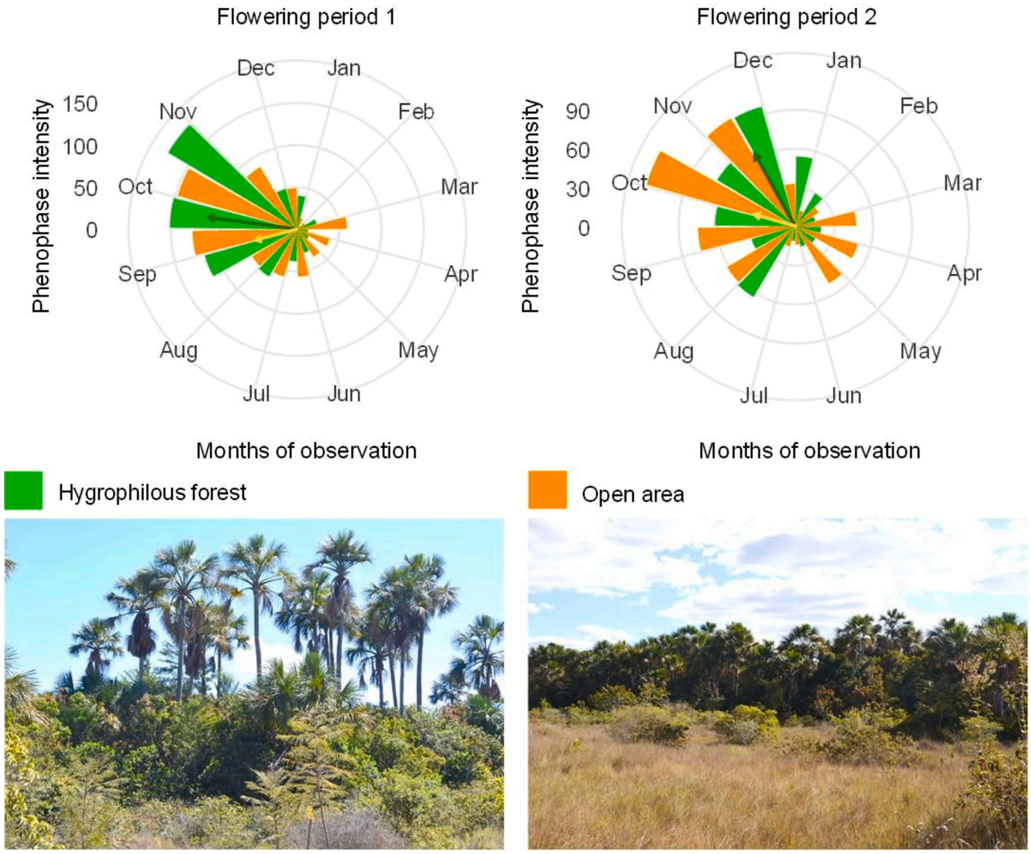

**Fig. 4.** Circular histograms: flowering peak frequency (number of flowering individuals) in the hygrophilous forest and open area habitats in the Almescla *vereda* community over 2 years (March 2018 to February 2020: Period 1 = March/2018 – February/2019; Period 2 = March/2019 – February/2020). Arrows indicate the mean angle, and their lengths correspond to the mean vector (r) value or the degree of seasonality.

ambophily, chiropterophily, and psychophily. The third and fourth modules occurred mainly during the rainy season and were associated with cantharophily and sphingophily, respectively. Abundance of syndromes had only two modules. The first, also during the dry season, was associated with melittophily and psychophily. The second, mainly during the rainy season, was associated with ambophily, chiropterophily, cantharophily, and sphingophily (Fig. 5b).

## 4. Discussion

This study revealed that the Almescla *vereda* woody plant community had a high richness of pollination syndromes, with melittophily as the most frequent type, followed by cantharophily and psychophily. Melittophily was more representative in this system than reported in other tropical seasonal environments, both wet and dry. It is important to highlight that in our study we only analyzed the woody species present in the environment. Additionally, we limited the study only to pollinator

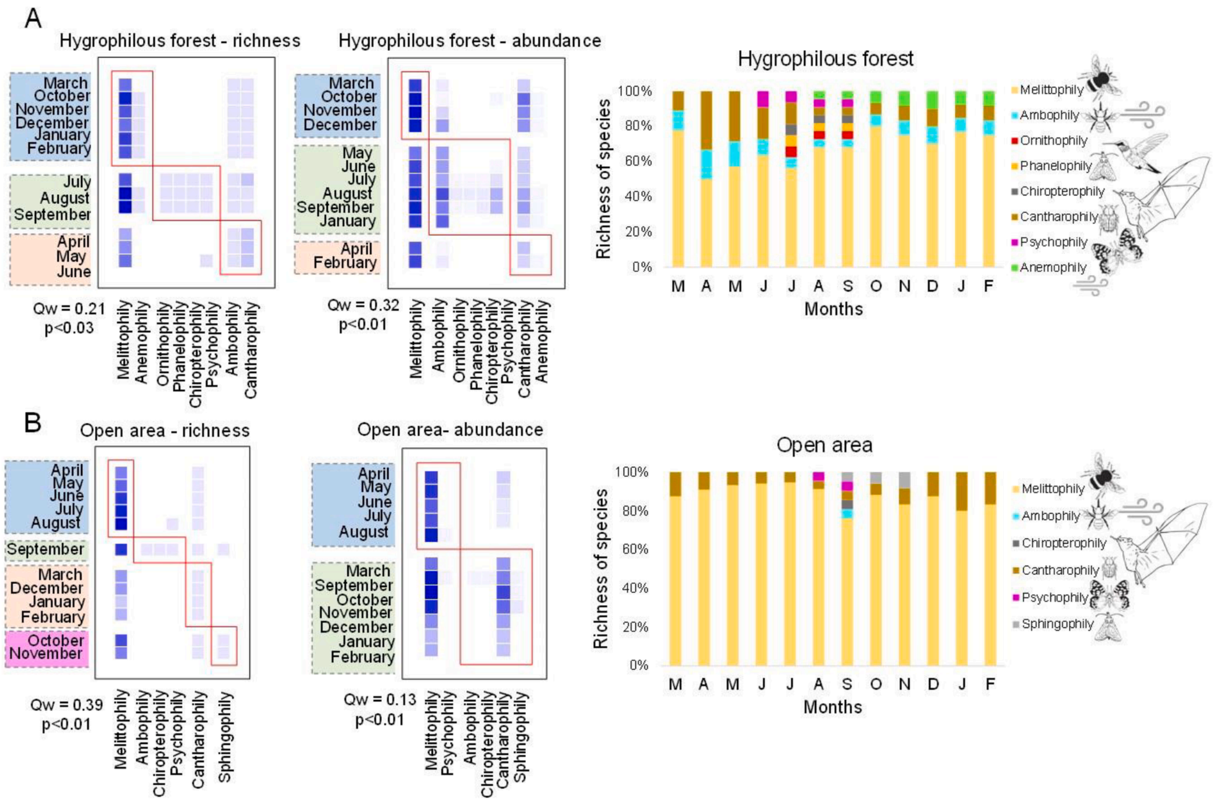

**Fig. 5.** Modularity results quantifying the prevalence of species richness with a determinate syndrome during both years in the hygrophilous forest and open areas (March 2018 to February 2020). On the left is the distribution matrix of the different syndromes between the twelve months of the year, and each square and color correspond to a different module. On the right side we have the percentage of occurrence of syndromes (species richness) between the different months sampled. The stronger the shade of blue, the high the frequency of occurrence of that syndrome in the indicated month (richness or abundance) Pollinators images were obtained from www.divulgare.net.

groups and pollination syndromes, since we did not perform the identification of pollinator species. We therefore emphasize the importance of studies that also include herbaceous species of the *vereda*. Bees are the main pollinators of arboreous-shrubby species in the Cerrado (Oliveira and Gibbs, 2000; Ishara and Maimoni-Rodella, 2011). Melittophily includes most of the plant species in the cerrado *sensu stricto* (Reis et al., 2012; Silva et al., 2012; Gottsberger and Silberbauer-Gottsberger, 2018), and also with bees dominating pollination in rupestrian grasslands (Santos et al., 2020; Martins et al., 2021; Monteiro et al., 2021). In dry tropical forests, species with floral attributes related to bee pollination accounted for 57 % of the total number of species (Cortes-Flores et al., 2017). In wet environments, e.g., riparian forests, the most frequent pollination syndromes are melittophily and cantharophily (Martins and Antonini, 2016). The high species richness of tropical communities encourages pollination by animals, favoring interactions and a diversity of pollination syndromes (Ollerton et al., 2011), and thus a higher dependency on biotic pollination (Ollerton et al., 2006; Dorado and Vazquez, 2014). Among them, entomophilous interactions caused the radiation and specialization of plants with modern flowers (Wardhaugh, 2015), with bees and beetles as the most frequent pollinators (Bawa et al., 1985; Wardhaugh, 2015; Souza et al., 2016, 2017; Moreira and Freitas, 2020).

Melittophily and cantharophily, the overall most frequent syndromes, were also common in both habitats on the studied *vereda*. Studies indicate that species pollinated by bumblebees and beetles comprise trees, shrubs, and herbs, whereas smaller insects such as small bees prefer the lower portions of vegetations (Gottsberger and Silberbauer-Gottsberger, 2018). The distribution of other pollination syndromes differed among environments, with the majority being recorded in the hygrophilous forest during the dry season. This environment presented a higher diversity of species with flowers, sustaining more diverse pollination syndromes. Furthermore, this environment showed high availability of resources for several types of pollinators during a time when floral resources are generally scarce in the environment and the surrounding landscape. Thus, the hygrophilous forest potentially acted as a refuge for pollinators. However, it is worth noting that, despite the richness of pollination syndromes found in this environment, a single species, *Inga vera* Willd. (Fabaceae), supplied resources for birds, moths, and bats, and was classified under all three syndromes. In the open area, we observed the opposite of what was registered for the syndromes in the hygrophilous forest, with melittophily occurring mainly during the dry season and the remaining syndromes modulated in the rainy season. Therefore, resource availability seasons and habitats differed among themselves. This arrangement in different environments in a *vereda* ecosystem can influence pollinator diversity. Higher plant species richness and pollinator interaction result in a broader ecosystem function (Cardinale et al., 2012; Bartomeus et al., 2013). Butterflies, sphingids, moths, and bats can also act as potential pollinators mainly because they can be the main pollinators for trees and shrubs in Cerrado physiognomies (Gottsberger and Silberbauer-Gottsberger, 2018). Phalaenophily and sphingophily are common in lower and open vegetations that can benefit from resource extraction by these animals (Reis et al., 2012). Furthermore, because the Cerrado is a mosaic of different formations, where we observe the complementarity of habitats (Maruyama et al., 2014), the migration of these species to other areas when the *vereda* is in periods with scarce diversity of species with different syndromes is possible.

Although flowering occurred throughout the year, a continuous resource availability of woody species occurred only for melittophily and cantharophily, indicating that each season provided favorable and unfavorable conditions for each pollinator group of woody species. Plants of the *Byrsonima* (Malpighiaceae) and *Miconia* (Melastomataceae), present in both habitats, stood out in melittophily by presenting flowering mainly during the dry season, whereas *X. aromatica* (Annonaceae) supplied cantharophily resources throughout the year. Flowers pollinated by bees throughout the year may be associated with the variety of strategies in the flowering period presented by different species in that system (Genini et al., 2021). Other pollinators of woody species had resources available for only a few months, with some species flowering only during a specific season. Restricted flowering tends to adjust the diversity of pollination syndromes in seasonal environments (Genini et al., 2021). However, periods with insufficient food supply can lead to network disruption and decreases in the diversity and abundance of pollinators (Abrahamczyk et al., 2011). Incompatibility between resource availability and pollinator foraging activity can cause reductions in pollination services (Petanidou et al., 2014), affecting seed production (Satake et al., 2013).

Resource availability seasons also differed among the environments. Although we used the activity index, which evaluates only the presence or absence of flowers in the individuals, the sum of individuals manifesting flowering allows us to assess the intensity and resource availability at a given time and in each environment. In the hygrophilous forest, flowering occurred mainly in October and November, when the rainy season begins. In the open area, flowering was more intense earlier, in September and October, with temperature increases and the transition from the dry to the rainy season. Therefore, we observed that species from the hygrophilous forest behaved similar to those from riparian forests, whereas species from the open area behaved similar to those from the Cerrado, with solid seasonality and flowering of frequent species occurring during the dry season (Oliveira 2008; Pirani et al., 2009). Many species from riparian forests present flowering peaks during the rainy season and under higher temperatures that can stimulate flowering in tropical species (Talora and Morellato, 2000; Reys et al., 2005). The predominance of animal pollination is related to higher temperatures and rainfall because these conditions increase nectar production as a resource for pollinators (Rech et al., 2016).

Our results for the woody species of the studied *vereda* indicate that the two types of habitats (hygrophilous forest and open area) complement their resource availability for pollinators. Species from hygrophilous forest supply their leading pollinators (Hymenoptera) during the rainy season, whereas species from open area supply their pollinators during the dry season. Therefore, resources are continuously available throughout the entire ecosystem. The same occurs for the other syndromes. However, each syndromes occur specifically in each environment. Studies have highlighted the importance of maintaining populations of pollinators and plant species, preserving these interactions, and ensuring the function and stability of ecological communities (Säterberg et al., 2013). Changes in the flowering start, peak, and duration, along with the activity and life cycle of consumers, can influence the scarcity of resources and collapse the consumer population (Berg et al., 2010; Donnelly et al., 2011). The richness of pollinator functional groups increases the reproductive success of plants, thereby increasing the production of fruits and seeds (Albrecht et al., 2012). Therefore, the number of pollinators increases plant diversity, and the diversity of pollinators increases the capacity and persistence of plants in the community over time (Albrecht et al., 2012). However, it is worth noting that some studies have reported that an increase in the number of floral visitors can lead to a reduction in the number of interaction links, modifying the structure of interactions between plants and pollinators, and affecting the reproductive success of plant species (Valido et al., 2019; Page and Williams, 2023).

## 5. Conclusion

The analyzed *vereda* woody plant community presented a richness of pollination syndromes related to floral complexity, with melittophily as the most frequent. The distribution of pollination syndromes differed among the habitats of this ecosystem, and only a few occurred in both environments. The same was observed for resource availability. In the community, flowering occurred throughout the year, with peaks during the transition from the dry season to the rainy season. However, resources were continuously available only for melittophily and cantharophily. The modularity in both environments showed complementarity among them. In the hygrophilous forest, the leading pollinators were present in the rainy season, whereas in the open areas, they were present during the dry season. It is important to highlight that the results of this study are related only to the *vereda* in question, and that these results may differ in other similar environments. The *vereda* presented conditions to sustain pollinators in a diversified manner, being fundamental for the reproductive and functional dynamics of the ecosystem and for preserving biodiversity. In addition, these results demonstrate how essential the ecosystem is as areas for the availability of resources in the Cerrado. In addition, these results demonstrate how essential this ecosystem is as areas for the availability of resources in the Cerrado. It is important to reinforce that this study is the first in a *vereda* ecosystem. The information from this study can strengthen and assist in sustainable management practices that promote the conservation of pollinators in the Cerrado areas.

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## CRediT authorship contribution statement

**Andressa Laís Lacerda Luna:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Camila Silveira Souza:** Conceptualization, Formal analysis, Writing – original draft. **José Gustavo Santana Neves:** Data curation. **Yule Roberta Ferreira Nunes:** Conceptualization, Data curation. **Paulo Eugênio Oliveira:** Formal analysis, Writing – original draft. **Islaine Franciely Pinheiro de Azevedo:** Conceptualization, Data curation.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.flora.2023.152425.

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