Conditions of Urban Green Areas Influences Bee Guilds Responses †

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Abstract: The deforestation consequent of urban sprawl is one of the causes of decline of wild bee communities and the urban green areas (UGA) can be important refuges for bees. This study analyzed the influence of UGA conditions and their surroundings in bee guilds responses in a medium-sized Brazilian city (Campos dos Goytacazes, RJ). The bees were sampled for 12 months (2017–2018) in 12 UGAs; bee abundance and richness were evaluated in guilds considering: sociality (eusocial, intermediate and solitary), nesting (cavity and soil) and foraging (generalist and specialist). We used as explanatory variables conditions of UGAs—number of trees (NT), DBH, flower cover (FC), plant richness (PR), percentage of paving (PV)—and of their surroundings—paving (SPV) and number of buildings (NB). Results showed 80% of eussocial and generalist bees and 13% solitary; 82% nest in cavities and 20% were specialists. From all explanatory variables PV, NB, FC and SPV explained the responses of different guilds in study areas. This study confirms different responses by the guilds analysed. In order to conserve bee diversity, the management of UGAs must consider the abundance and richness of flowers, maintenance of exposed soil areas and the density of trees.

Keywords: conservation; environmental management; pollinators; urban spraw

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1. Introduction

The UN estimates that the urban population will exceed 60% by the year 2050. The changes resulting from this growth affect mainly medium-sized cities (between 500 thousand and one million inhabitants) where half of the world's urban population currently lives. The great challenge for these cities is the sustainable growth that guarantees housing, transport system and energy for population, combined with environment preservation and conservation of biodiversity [1]. The urbanization process causes drastic changes in the landscape, often irreversible, such as the increase of impervious areas(pavement, asphalt, buildings) and the destruction of natural areas [2]. Studies carried out around the world show that the expansion of urban areas is identified as one of the main causes for the decline of pollinators [3–5]. The destruction of natural areas means for pollinators the loss of nesting and foraging sites. the isolation of populations and interruption of ecological interactions [6]. Among the affected pollinators are all bee species (Hymenoptera. Apoidea). Which are considered important for the pollination of most species of native. exotic and cultivated plants [7]. The bees loss has the direct consequence of losing several plant species [8].

In this context, urban green areas such as squares, parks, forests and gardens can be bee-friendly spaces [9,10] with potencial to act like refuge for bees, with foraging and nesting conditions [4,11,12]. In other to this occour. It is necessary to manage these areas considering the different biological and functional bee traits as their nesting habit. Degree of sociality and specialization or generalization regarding the choice of resources [13–15].

Grouping bees in guilds can provide data that increase the efficiency of management and conservation of bees and plants species [16]. However, little is known about how the different bee guilds respond to conditions found in urban areas [13]. Thus, knowing how bee communities are structured and how the conditions of urban green areas and their surroundings influence this structure can contribute to the management and strategies for preserving biodiversity. Therefore. this work aims to answer the following questions: (1) What is the community structure found in urban green areas associated to a medium-sized city in Brazil?; (2) What are the environmental conditions of urban green areas and their surroundings?; (3) How do the different bee guilds respond to the conditions of urban green areas?

2. Materials and Methods

2.1. Study Area

This study was conducted in Campos dos Goytacazes. RJ. Brazil. the largest municipality in the interior of Rio de Janeiro state with approximately 4.037 km^2 and an urban area of 87.73 km^2. The total population is 507.548 thousand inhabitants and almost 85% of population lives in the urban area [17]. The climate is hot and humid tropical AW (Köppen-Geiger classification), with dry winter (April to September) and rainy summer (October to March); average annual rainfall between 800 and 1200 mm [18]. The average temperature is around 26 °C in the hottest months and 19 °C in the coldest ones.

2.2. Bee Sampling

We sampled the bees with entomological net in the 12 UGAs between October 2017 and September 2018, twice in the rainy season and twice in the dry season at each UGA. Sampling at each site was carried out by two collectors, who walked along the 12 UGAs in search of flowers in three periods of about one hour each, between 7 am and 1 pm, and visiting bees were captured. Bee species were identified and deposited at UENF Zoological Collection. They were classified by: (1) Nest location (soil or pre-existing cavity); (2) Nesting behavior (solitary, intermediate, eussocial); (3) Trophic specialization (generalist, specialist), according to the literature.

2.3. Environmental Conditions

In order to determine which variables influence the richness and abundance of species in the UGAs, we measured: paved area, richness of plants visited by bees, flower coverage, number of trees, DBH of trees with more than 30 cm in circumference and total impervious area. The identification of the plant species where the bees were captured was done with the help of specialized literature [20,21] and the Flora Brasil project [22]. Flower coverage was estimated for all flowering species on the days of bees sampling, through percentage covered by flowers related to the total area occupied by the plants. The average percentage of the four sampling days was considered as an estimate of flower coverage for each sample area. The areas of pavedsoil were measured using the Google Earth polygon tool.

For the analysis of the conditions found around the AVUs. The variables paved area and number of buildings with more than three floors were considered. These variables were measured within a 500 m radius (buffers) from the center of each of the 12 AVUs [23,24]. The paved area inside each buffer was measured with the polygon tool and the count of buildings with more than three floors was done with street view. Both tools from Google Earth Pro (2019).

2.4. Data Analysis

We tested the effects of environmental variables (predictors: paved area, DBH of trees, plant richness, flower coverage, paved area around and number of buildings with more than three paviments) on species richness and abundance using multivariate generalised

linear models (GLMs). We tested the collinearity between the predictors variables using the variance inflation factor (vif) of the car package. The best model was selected using the lowest value of Akaike information criterion (AIC). These analyzes were performed using the R version 3.5.1 program. assuming a 95% significance level [25].

3. Results

3.1. Bee Community

In total, 1163 individuals were collected. Apidae was the family with the greatest richness (19species) and abundance (991 individuals). The tribes with the greatest species richness were Augochlorini (13) and Meliponini (5). The most abundant species were *Apis mellifera* (32% of individuals sampled*), Trigona spinipes* (26%) and *Plebeia droryana* (13%), all eusocial species. Among the non-eusocial species, the most abundant were *Dialictus* sp1 (4%). *Augochlora thalia* (3%) and *Xylocopa frontalis* (2%). Of the individuals sampled, 80% showed eusocial behavior, 13% belong to solitary bee species and 5% bees of species with intermediate level of sociality. Bees that nest in pre-existing cavities represented 82% of the bees collected. In addition, 80% of bee species were generalists in the foraging habit and 20% specialists.

3.2. Environmental Conditions

Six studied UGAs presented more than 50% of their inside area paved and only one of the 12 UGAs had less than 50% of the surround area paved. The average of flower coverage in each UGA varied between 6.57 m² (U4) and 82.52 m² (U7). The largest number of trees was registered at the U11 and the highest DBH (median = 63) at the U7 sample unit. Three of the 12 areas studied did not have buildings with more than three floors (Table 1).

Table 1. Environmental conditions of 12 urban green areas (UGA) studied in Campos dos Goytacazes/RJ. Inside UGA: percentage of paving (PV), number of trees (NT), diameter in breast height (DBH), plant richness (PR), flower coverage in m² (FC). Surround conditions measured inside a buffer of 500m from UGA center: surround percentage of paving (SPV) and number of buildings with more than three paviments (NB).

Conditions	Urban Green Areas											
	U1	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**	**U11**	**U12**
	61.3	92.5	50.4	37.3	35.9	27.8	0	63.0	90.3	19.4	8.7	70.9
NT	34	36	33	22	46	78	22	33	15	63	369	17
DBH	23	27	16	22	26	35	63	30	53	22	32	32
PR	13	11	12	6	13	14	17	9	10	14	18	14
FC	60.8	47.5	10.6	6.5	42.6	33.7	82.5	22	22.7	26.7	21.3	11.7
SPV	63	96	87	71	92	97	45	51	72	84	75	89
NB	12	0	11	14	60	37	4	0	8	0	7	10

3.3. Data Analysis

Flower coverage was the predictor variable that influenced five of the guilds analyzed in this study. The percentage of paving and the number of buildings with more than three floors explained the abundance and richness of solitary bees, respectively. The DBH had a negative effect on the abundance of specialist bees and the richness of solitary and generalist bees, presenting a positive result only for the richness of eussocial bees (Table 2).

Table 2. Parameter estimates of a generalized linear model, assessed as most parsimonious according to AIC, explaining abundance and richnees of bee guilds in urban green area (UGA) in Campos dos Goytacazes/RJ. Inside UGA: percentage of paving (PV), number of trees (NT), diameter in breast height (DBH), plant richness (PR), flower cover in m² (FC). Surround conditions measured inside a buffer of 500 m from UGA center: surround percentage of paving (SPV) and number of buildings with more than three paviments (NB).

Variables	Model	NT	FC	DBH	PR	PV	SPV	NB	Intercept	df	AICc	ΔAICc	Weight	AdjR²
Abundance														
Eusocial	5		1.079						40. 42	3	126.5	0	0.191	0.341
Intermediate	5		0.109						2.188	3	66.8	0	0.396	0.438
Solitary	17					0.143			9.282	3	96	1.51	0.164	0.110
Soil	33						0.374		43.88	3	92.2	0	0.438	0.386
Cavity	5		1.162						44.16	3	127.3	0	0.263	0.359
Specialist	13		0.106	−0.157					3.221	4	68.7	1.04	0.149	0.461
Generalist	5		1.235						55.28	3	126.7	0	0.279	0.399
Richness														
Eusocial	33			0.05			0.039	0.034	−1.938	5	34.5	0	0.334	0.876
Intermediate	5		0.089						1.618	3	51.1	0	0.276	0.333
Solitary	73			−0.108				0.076	9.827	4	61.4	0.1	0.152	0.50
Soil	5		0.045						1.618	3	51.1	0	0.276	0.333
Cavity	3	0.0137							4.537	3	59.4	0	0.121	0.300
Specialist	5		0.013						0.125	3	37.7	2.2	0.083	0.461
Generalist	9			−0.065					12.65	3	66.2	2.48	0.082	0.094

4. Discussion

The results of this study demonstrated that the study area is in a high level of urbanization with percentages of paving above 50% [26] and urban densification, despite being a medium-sized city. At this stage the natural areas have already been replaced by large paved areas, where only low flower covers and potential nesting places for bees remain. Making this areas harmful to the pollinator community [4].

Results indicated that the different guilds of bees diverged in responses to the conditions found in urban green areas and their surroundings. The structure of the bee community showed a composition mainly of eusocial and generalist bees, common in open and highly modified environments. Other studies carried out in Brazil have shown the tendency for eusocial bees to be more abundant in urban areas [42–45]. These results can be explained by the fact that the colonies of eusocial species have thousands of individuals and are active throughout the year, which allows to take advantage of resources from plant species with different phenological cycles [7]. In addition, eusocial bees recruit and are able to collect a large amount of resources quickly. In places with little diversity of resources, these eusocial bees are usually benefited when compared to solitary bees.

The greater plasticity of *A. mellifera* favors the increase of its abundance in urban areas and the competitive pressure on native species, which can lead to the homogenization of the structure of the bee community in these areas [31] through the replacement of native bee species by this exotic one [32]. Although several human activities promote biotic homogenization. Urbanization is the one that most favors this process [33,34]. The city is made to atend human needs and therefore has a uniform nature, which is repeated throughout the world with buildings, roads and houses. The construction of cities destroys the habitat of native species. But on the other hand creates habitat for other exotic species such as *A. mellifera*. As a consequence. More vulnerable species tend to disappear. Decreasing the community species richness [33,34].

Among the guilds that demonstrate greater vulnerability to the urban environment are the specialist bees, In this study, specialists represented only 20% of the community, similar to described by other studies that recorded low abundance of specialist bees in the urban area [26]. One of the reasons why specialists bees are less recorded is the substitution of native vegetation by exotic plants. This is a pattern of anthropized environments. Limiting the availability of resources [15,35]. The decline of specialist bees is directly related to the loss of the host plant, as described in study that found the decline of specialist bees associated with the decline of Fabaceae plants caused by the management of agricultural areas and removal of native vegetation [36]. Other studies showed that the dominance of generalist bee species increases competition over resources, contributing to the change in the behavior of specialist bees in the face of resource scarcity [37]. This change in behavior explains the influence of the variable "flower coverage" on the richness and abundance of specialist bees found in this study; greater flower coverage decreases competition and increases the possibility of foraging. The best predictor model for the abundance of specialist bees also showed a negative relationship with DBH. Whereas trees with a higher DBH are also trees with a higher canopy, which increase the shading and limit the growth of other plants that could serve as a resource for specialist bees. A similar result was described by [38] when observing a correlation between the decrease in species of oligolytic bees and the increase in canopy coverage.

Analyzing the abundance of bees that nest in the soil we found a sensitivity related to the "surroundings percentage paving". Of the 41 species of bees sampled in this study. Only 18% are from the guild that nests in the soil. As the paving of the surroundings increases. There is less abundance of bees from this guild in the UGAs. The negative influence of paving on this bee guild is due to the limited nesting site consequence of replacement of exposed soil areas by paved areas in UGAs and surroundings, as well as the removal of small bushes or spontaneous vegetation that provide food resources [27]. However. For bees that nest in the soil. The availability of nest building sites may be more important in the establishment and growth of their populations than the availability of food resources [10,13].

A lower abundance of solitary bees was found overall. Only 13% of the captured bees belonged to solitary species. The statistical analysis showed the influence of the variable "percentage paving" on solitary bees abundance and the variable "number of buildings with more than three floors" on richness. The urban environment is composed of mosaics of vegetation and buildings [39] that probably prevent or hinder the circulation of bees with a small flight radius like many solitary bees [40]. Few individuals in this group reach long flight ranges. Which increases the dependence of solitary bees on the resources available near the nests. The distance from the resource determines the ability to maintain the species as verified by [39]. According to the authors. The number of descendants generated by the species *Osmia lignaria* was greater when the nest was close to areas with greater supply of resources. We can expected similar situation for solitary bees in studied areas. Considering the cost of foraging trips is critical for solitary bee guild conservation programs including the management in urban areas.

5. Conclusions

We suggest that decisions about management of urban green areas must be a transdisciplinary decision making and planning. The management of urban green areas is complex and needs to take into account many factors, such as acclimatization and adaptation of species to urban devices. However, it is also necessary to pay attention to factors that contributes to minimize the negative effects of urbanization on the bee community to find nesting places, foraging and feeding needs. Bee conservation programs in urban areas should include the management of plants that provide resources for bees and other pollinators. The increase of impervious surfaces must be avoided, because in addition to not being beneficial to bees, which do not find resources and place to make their nests, it causes local heating. The creation and maintenance of urban parks with more vegetation

cover is important to maintain the milder climate and increase the diversity of important animals, such as pollinators and seed dispersers in the urban area. This vision is pursued within two of the UN Sustainable Development Goals (SDGs), item 15, which deals with terrestrial Life and aims to protect, recover and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, stop and reverse the degradation of the Earth and stop the loss of biodiversity. And item 11 that deals with Cities and sustainable communities with the objective of making cities and human settlements inclusive, safe, resilient and sustainable. This work considers that the planned urban policies, considering other organisms besides humam beings, can lessen the negative impacts of rapid urbanization. A new way of looking at the city, one that considers man as part of the ecosystem and that by conserving other species will be conserving its quality of life in the urban environment.

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