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# Diversity of Eusocial Bees in Natural and Anthropized Areas of a Tropical Dry Forest in the Parque da Sapucaia (Montes Claros, Minas Gerais, Brazil)

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**Abstract**

In the present study we inventoried the diversity of eusocial bees (Hymenoptera: Apidae) in preserved and anthropized areas of a tropical dry forest in the Parque da Sapucaia (Montes Claros, Minas Gerais, Brazil). We tested the hypothesis that the diversity of bee species would: 1) be greater in the preserved areas, 2) respond positively to the structure of the vegetation and 3) decrease during the dry season. We sampled eusocial bee species in 18 plots of 10 x 10 m distributed throughout the park, being nine plots in anthropized areas and nine plots in areas with preserved vegetation. In total we recorded 382 individuals and eight species of eusocial bees. The most abundant species was *Oxytrigona tataira* (Smith) (N = 233) and the most common species was *Trigona spinipes* (Fabricius) recorded in 72.2% of the plots. As expected, we found that eusocial bee diversity (Shannon diversity) was higher in preserved plots than in anthropized plots. Tree species richness positively affected bee species richness and abundance, while tree abundance positively influenced the bee abundance and tree height positively affected the bee Shannon diversity, corroborating our expectations. On the other hand, we detected no differences in the diversity of eusocial bees between dry and rainy seasons. Our findings suggest that both natural (vegetation structure) and anthropogenic (habitat modification) factors are important predictors of the diversity of eusocial bee species in tropical dry forests.

## Introduction

The modification of natural habitats is considered the main cause of the current loss of bee diversity (González-Varo et al., 2013; Collado et al., 2019). On a global scale, native bees are threatened mainly due to human disturbances caused by deforestation, intensification of agriculture and introduction of exotic species (review in Winfree et al., 2009). Although some species of bees are able to live and find resources in anthropized areas, such as urban fragments (Martins et al., 2013), environmental anthropization tends to have a deleterious effect on the community of these insects (Zanette et al., 2005). Because of this, a growing number of studies have investigated how anthropic factors influence the diversity of native bees in tropical regions (Liow et al., 2001; Zanette et al., 2005; Martins et al., 2013; Ferreira et al., 2015; Stein et al., 2018).

Fragmentation of natural habitats and environmental changes in the remaining fragments can affect bee pollination processes (Taki et al., 2007; González-Varo et al., 2013). This is worrying because bees are the most important pollinators of several human food crops (Klein et al., 2007; Potts et al., 2010). These losses in pollination occur because the modification of natural habitats impoverishes local bee faunas (Nemésio & Silveira, 2010; Aguiar & Gaglianone, 2012), and also affects species composition (Martins et al., 2013). The negative effects of anthropization on local bee communities tends to occur because the change in habitat characteristics leads to the loss of more sensitive species and also those that need a larger area of foraging (Ferreira et al., 2015). On the other hand, there is also evidence that anthropized habitats (for example, forests in early succession or recently disturbed) may have a high diversity of bee species (Romey et al., 2007; Pengelly & Cartar, 2010; Taki et al., 2013). In these cases, high diversity is generally associated with changes in faunistic composition and dominance of tolerant species in communities of anthropized environments (Rubene et al., 2015). Often these changes in the composition of bee communities occur through the colonization of exotic or super generalist species, which can also compromise the quality of the pollination service (Valido et al., 2019).

Another factor that can affect the distribution of bees is the structure of vegetation (Wu et al., 2018). There is evidence that the richness and abundance of bees is positively related to the richness of plants and the abundance of potential nesting resources (Grundel et al., 2010). Thus, the more heterogeneous and diverse the vegetation, the greater the variety of resources offered, and consequently the greater the diversity of bee species (Tews et al., 2004; Wu et al., 2018). In addition, the type of vegetation is also an important determinant of the composition of the bee community (Sydenham et al., 2016; Wu et al., 2018), because the greater the composition of the plant community, the greater the dissimilarity of the bee community (Alvarenga et al., 2020). Thus, understanding how the structure of the vegetation influences the diversity of bees is an important step for planning the conservation of bees, especially in vegetations that have been little studied, such as the tropical dry forest, one of the least studied forests on the globe (Miles et al., 2016).

Tropical dry forests, also called seasonal deciduous forests, are distributed across the globe and in Brazil they have a wide occurrence in the northern region of Minas Gerais (Dupin et al., 2018). This type of vegetation is under the domain of a strong seasonal climatic regime alternating between rainy and dry periods (Murphy & Lugo, 1986). The pronounced seasonal climate associated with the occurrence of deciduous plant species causes a high deciduousness rate in the tropical dry forests in the dry season, with more than 50% of plants losing their leaves (Sanchez-Azofeifa et al., 2005). The strong deciduousness of the tropical dry forest, in addition to resulting in seasonal changes in the cycling of organic matter and microclimate conditions in the forests, also influences the distribution of animal species that use plant resources (Costa & Araújo, 2019). Insects, such as bees, which feed on plant resources (e.g., nectar or pollen), are likely to be affected by the strong seasonal regime in deciduousness of tropical dry forests.

In the present study we inventoried the diversity of eusocial bees (Hymenoptera: Apidae) in preserved and anthropized areas of a tropical dry forest in the northern region of Minas Gerais, Brazil. Thus, we investigate the following questions: i) Does bee diversity differ between preserved and anthropized areas of tropical dry forest? ii) Is there an effect of the vegetation structure on the diversity of bees? iii) Does the diversity of bee species vary seasonally? Our expectations are that the diversity of bee species will be greater in the preserved areas, respond positively to the structure of the vegetation and decrease during the deciduous period (dry season).

## Materials and Methods

### *Study area*

The study was performed in the Parque da Sapucaia, located in the municipality of Montes Claros, northern region of Minas Gerais State, Brazil (16°44'36.7"S; 43°54'3.49"W). The climate of the region is tropical semi-arid (*as* of Köppen), with hot summers and dry winters and an annual average temperature of 24.1°C (Alvares et al., 2013). The park has an area of 30.2 hectares predominantly composed by tropical dry forest (Santos et al., 2007), where the elevation ranges from 690 to 872 m. Due to the use of the park for visitation and tourism activities, there are parts of the vegetation that have been degraded through undergrowth pruning, tree clearing and canopy opening, for the construction of trails and recreation areas (Costa & Araújo, 2019). However, most of the park area has relatively well-preserved natural vegetation.

### *Sampling*

Sampling was carried out in six bi-monthly collections distributed between April 2017 and February 2018, being three collections in the dry season and three collections in the rainy season. The collections were performed in 18 plots of 10 x 10 m distributed throughout the park, being nine plots in anthropized areas and nine plots in areas with preserved vegetation. The anthropized areas were identified based on signs of human intervention, such as selective vegetation cutting and the presence of buildings (e.g., paved trails, cable car and kiosks) and garbage deposits. On the other hand, the preserved vegetation areas were characterized by pristine vegetation, with no detectable evidence of human intervention.

In each plot, all plants with a circumference equal to or greater than 15 cm (measured 1.5 m above ground) were sampled to measure the vegetation structure (species richness, abundance and height of trees). The eusocial bee sampling was performed using pet bottle traps with mead bait (water, sugar and yeast with 24 hours of fermentation), being used one trap for three hours in each plot. All specimens collected were referred to the Laboratory of Interactions, Ecology and Biodiversity (LIEB) of Universidade Estadual de Montes Claros (UNIMONTES). The sorting and identification of insects was realized according Silveira et al. (2002).

## Data analyses

We used generalized linear models (GLM's) to test the effect of habitat type (anthropized vs. preserved) and vegetation structure variables (tree species richness, tree abundance and tree height) on the eusocial bee diversity. To characterize the diversity of bees we measured the species richness, abundance and Shannon-Wienner diversity index each sampled plot. Additionally, we also used GLM's to compare the species richness, abundance and Shannon diversity between the two seasons (dry vs. rainy seasons). We applied a quasi-Poisson distribution of errors to the models. Finally, we used a multivariate analysis to test the differences in the composition of bee species between anthropized and preserved plots. Firstly, we used Non-metric Multidimensional Scaling (nMDS) to order the samples based on the Bray-Curtis similarity index. Subsequently, a non-parametric permutation procedure (ANOSIM) was applied with 1,000 permutations, also based on the Bray-Curtis index, to test the significance of the groups formed in the nMDS (Hammer et al., 2001). The values of *p* and *r* were obtained and the similarity patterns between the studied plots were determined. All analyses were performed in the *R* statistical software version 3.6.1 (R Development Core Team, 2020).

## Results

In total we recorded 382 individuals and eight species of eusocial bees (Table 1). The most abundant species were *Oxytrigona tataira* (Smith) (N = 233), *Trigona spinipes* (Fabricius) (N = 80) and *Tetragonisca angustula* (Latreille) (N = 32). The most common species were *T. spinipes* recorded in 72.2% of the plots and *T. angustula* recorded in 66.7% of plots. We also detected the exotic species *Apis mellifera* Linnaeus, which was the fourth most abundant species (N = 24) and the third most common (occurring in 61.1% of plots) (Table 1).

Of all collected bees, 202 individuals (mean 20.2 ±43.8) and five species (mean 2.2 ±1.2) were recorded in anthropized plots, whereas in the preserved plots we recorded 180 individuals (mean 18.0 ±30.2) and seven species (mean 2.7 ±1.4) (Table 1). We found no effects of habitat type on bee species richness and abundance, but average Shannon diversity values were higher in preserved plots than in anthropized plots (Table 2; Figure 1). On the other hand, the composition of bee community did not differ between preserved and anthropized plots (ANOSIM: Stress 0.159; r = 0.021, p = 0.359).

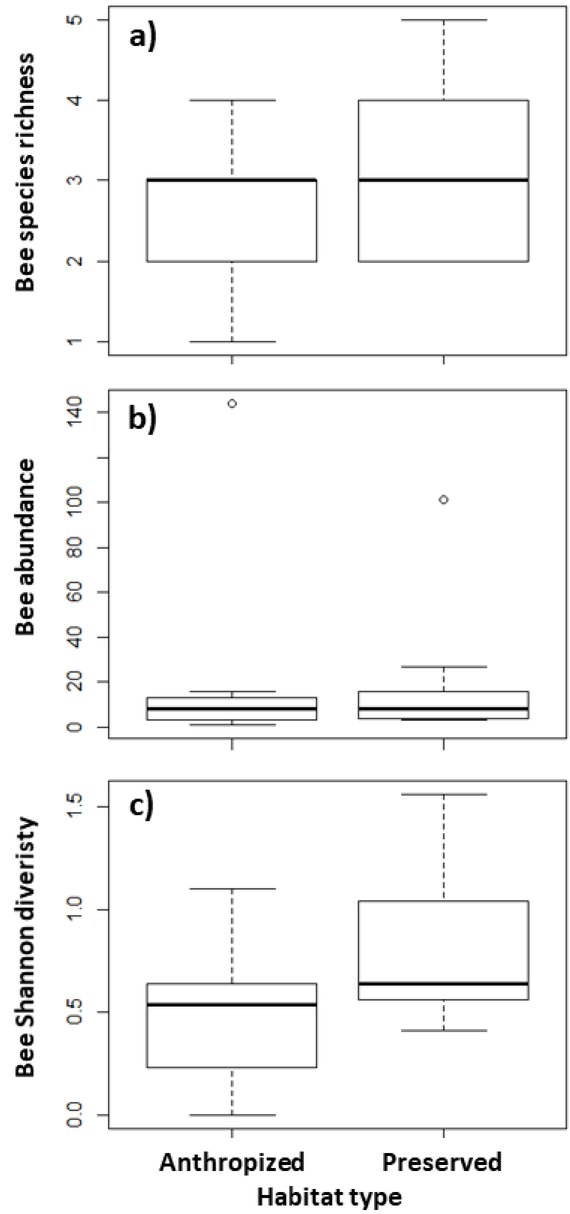


**Fig 1**. Comparison of species richness (a), abundance (b) and Shannon diversity (c) of eusocial bees sampled in anthropized and preserved plots in a tropical dry forest of Parque da Sapucaia (Montes Claros, MG, Brazil).

**Table 1.** Abundance and frequency of occurrence of eusocial bee species in the anthropized and preserved areas of Parque da Sapucaia (Montes Claros, MG, Brazil).

| Species | Anthropized plots | | Preserved plots | | Total | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| *Apis mellifera* Linnaeus | 7 | 27.8 | 17 | 33.3 | 24 | 61.1 |
| *Nannotrigona testaceicornis* (Lepeletier) | 0 | 0.0 | 1 | 5.6 | 1 | 5.6 |
| *Oxytrigona tataira* (Smith) | 144 | 27.8 | 89 | 16.7 | 233 | 44.4 |
| *Plebeia droryana* (Friese) | 4 | 5.6 | 0 | 0.0 | 4 | 5.6 |
| *Plebeia remota* (Holmberg) | 0 | 0.0 | 6 | 5.6 | 6 | 5.6 |
| *Tetragonisca angustula* (Latreille) | 11 | 22.2 | 21 | 44.4 | 32 | 66.7 |
| *Trigona hyalinata* (Lepeletier) | 0 | 0.0 | 2 | 11.1 | 2 | 11.1 |
| *Trigona spinipes* (Fabricius) | 36 | 38.9 | 44 | 33.3 | 80 | 72.2 |
| Total | 202 | - | 180 | - | 382 | - |

**Table 2.** Results of generalized linear models showing the effects of habitat type (anthropized vs. preserved) and vegetation structure (tree species richness, abundance and height) on the species richness, abundance and Shannon diversity of eusocial bees sampled in a tropical dry forest of Parque da Sapucaia (Montes Claros, MG, Brazil).

| Response variable | Explanatory variable | Df | Resid. Dev | F | p |
|---|---|---|---|---|---|
| Bee species richness | Habitat type | 16 | 6.8980 | 2.5358 | 0.1353 |
| | **Tree species richness** | **15** | **3.7784** | **15.4778** | **0.0017** |
| | Tree abundance | 14 | 3.7327 | 0.2269 | 0.6417 |
| | Tree height | 13 | 2.9127 | 4.0687 | 0.0648 |
| Bee abundance | Habitat type | 16 | 689.28 | 0.0683 | 0.7979 |
| | **Tree species richness** | **15** | **461.39** | **12.2787** | **0.0039** |
| | **Tree abundance** | **14** | **290.88** | **9.1866** | **0.0096** |
| | Tree height | 13 | 278.88 | 0.6466 | 0.4358 |
| Bee Shannon diversity | **Habitat type** | **16** | **4.6867** | **4.9306** | **0.0448** |
| | Tree species richness | 15 | 4.3376 | 2.1983 | 0.1620 |
| | Tree abundance | 14 | 3.9204 | 2.6269 | 0.1291 |
| | **Tree height** | **13** | **2.7099** | **7.6216** | **0.0162** |

Vegetation structure variables affected significantly the eusocial bee diversity (Table 2; Figure 2). Tree species richness positively affected the bee species richness (Figure 2a) and abundance (Figure 2b), while tree abundance positively influenced the bee abundance (Figure 2c) and tree height positively affected Shannon diversity (Figure 2d). On the other hand, no differences were detected in the species richness, abundance and Shannon diversity of eusocial bees between dry and rainy seasons (Table 3).

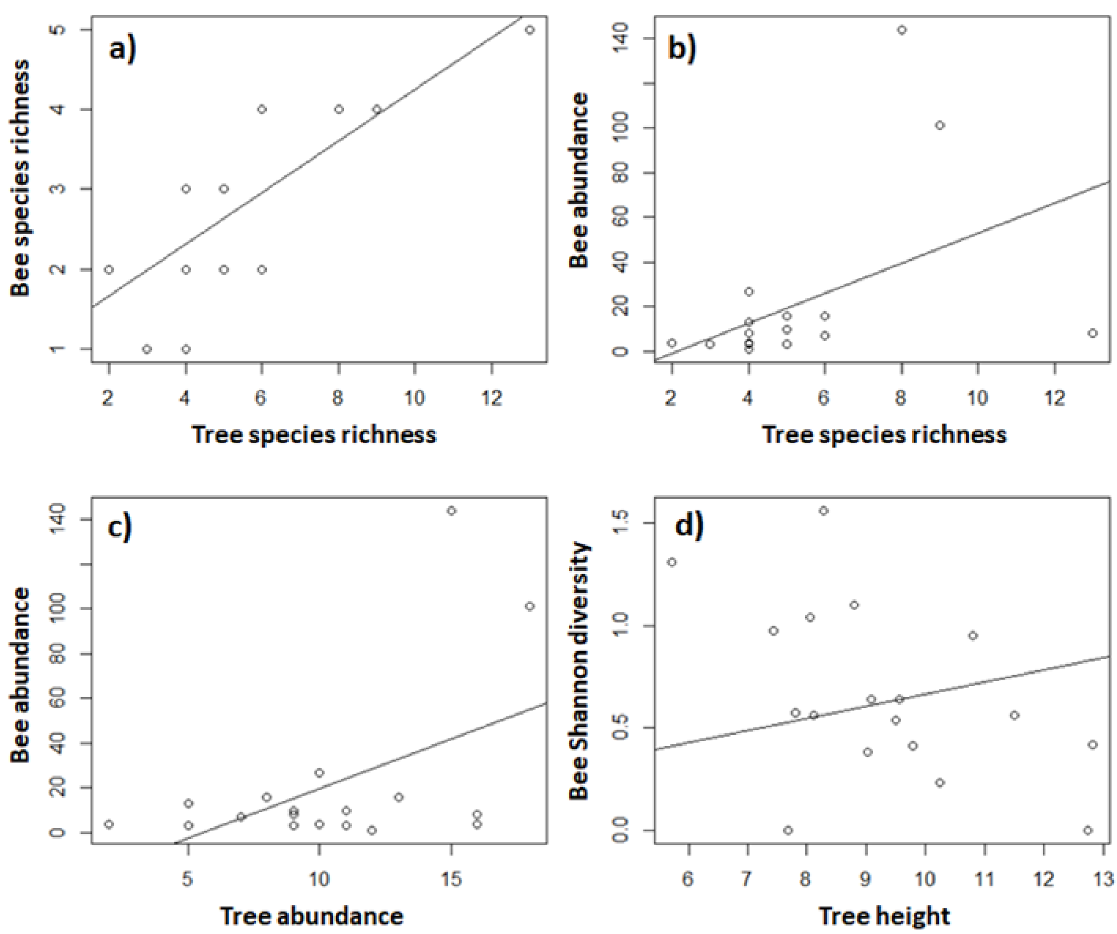


**Fig 2**. Effect of the vegetation structure variables on the eusocial bee diversity variables in a tropical dry forest of Parque da Sapucaia (Montes Claros, MG, Brazil). a) effect of tree species richness on the bee species richness; b) effect of tree species richness on the bee abundance; c) effect of tree abundance on the bee abundance; d) effect of tree height on the bee Shannon diversity.

**Table 3.** Results of generalized linear models showing the effects of sampling season (dry vs. rainy seasons) on the species richness, abundance and Shannon diversity of eusocial bees sampled in a tropical dry forest of Parque da Sapucaia (Montes Claros, MG, Brazil).

| Response variable | Dry season | Rainy season | Df | Resid. Dev | F | p |
|---|---|---|---|---|---|---|
| Bee species richness | 3.7 (±2.1) | 3.0 (±1.0) | 4 | 2.9607 | 0.2644 | 0.6342 |
| Bee abundance | 28.0 (±32.0) | 89.3 (±139.2) | 4 | 501.74 | 0.5238 | 0.5093 |
| Bee Shannon diversity | 0.8 (±0.3) | 0.6 (±0.4) | 4 | 0.83349 | 0.6882 | 0.4534 |

## Discussion

The diversity of species recorded in the Parque do Sapucaia can be considered low when compared to other studies in similar vegetation. For example, Alvarenga et al. (2020) recorded a total of 96 species of bees in areas of tropical dry forest of the Parque Estadual da Mata Seca, Minas Gerais. In other study, Milet-Pinheiro and Schlindwein (2008) recorded 79 species of bees in a transition area between dry and semi-deciduous forests in Pernambuco. A part of these differences in the number of species are probably due to the distinct sampling efforts and methods, which varied between studies. In addition, these studies also sampled not only eusocial bees, and when only this bee group is compared the differences are smaller (22 species recorded by Alvarenga et al., 2020 and only three species recorded by Milet-Pinheiro & Schlindwein, 2008). Thus, considering eusocial bees, our results corroborate the pattern of low diversity in dry forest areas, when compared to other Brazilian vegetation (Zanella, 2000; Milet-Pinheiro & Schlindwein, 2008).

The most abundant and frequent native species in the Parque Sapucaia were *O. tataira, T. spinipes* and *T. angustula.* The species *O. tataira* is considered a generalist species tolerant of anthropized environments (Souza et al., 2015). The species *T. spinipes* is considered one of the most aggressive species of the Meliponini tribe and usually builds its nests in higher tree branches (Souza et al., 2015). The bees of species *T. angustula* are natural pollinators of plants of Neotropical regions, with occurrence in all Brazilian territory (Pedro, 2014). Also noteworthy is the invasive species *A. mellifera* that occurred in both anthropized and preserved areas of the park. This naturalized species of European origin tends to have a low efficiency in the pollination of native plants, due to being a highly generalist species (Hung et al., 2018).

We found that the diversity (Shannon diversity index) of bee species was higher in preserved areas than in anthropized areas, corroborating our expectations. There was also a trend towards greater species richness and abundance in the preserved plots (see Figure 1), although we have not found significant results. We believe that the lower values of Shannon diversity in anthropized areas is a combination of the lowest species richness and the greatest dominance of generalist species in anthropized areas. In the anthropized plots we recorded a lower total number of species and average number of species per plot than in preserved environments. Furthermore, in the anthropized areas there was a much greater dominance of the *O. tataira* species, which represented 71% of the individuals, while in the preserved environments the dominance was 49%. According to Souza et al. (2015) this species is widely distributed in Brazil, being frequent in anthropized habitats, such as urban environments. Our results corroborate previous studies indicating that habitat modification has negative effects on the diversity of native bee communities (Winfree et al., 2009; Ferreira et al., 2015; Stein et al., 2018).

Our findings show that the community of bees also responds positively to the structure of vegetation, corroborating recent studies (e.g. Wu et al., 2018; Alvarenga et al., 2020). As expected, we found a positive effect of tree species richness on the abundance and species richness of bees. These findings support previous evidences that plant species diversity is an important indicator of diversity of floral resources for the exploitation of bees (Ebeling et al., 2008; Plascencia & Philpott, 2017). Our results also showed that the tree abundance and tree height influenced positively the abundance and Shannon diversity of bee communities, respectively. A larger quantity and a larger size of trees in the vegetation may be an indication of greater availability of sites for nesting (Grundel et al., 2010). Corroborating our results, Alvarenga et al. (2020) found a positive effect of tree height on bee diversity in another area of Brazilian tropical dry forest.

Contradicting our expectations, eusocial bee diversity did not vary between the dry and rainy seasons. This result is probably due to the generalist species found in the study being active all year, both in the dry season and in the rainy season. Exemplifying this the bees *T. spinipes* and *T. angustula*, which were the most common bees in the present study, are very generalist social bees (Ricketts et al., 2008; Williams et al., 2010). These species may also use different resources in the environment, such as open or forest environments, because are able to use the resources available in the vicinity of their nests (Garibaldi et al., 2014). These results indicate a constancy of generalist species in different seasons, corroborating previous studies (Oliveira et al., 2010; Gostinski et al., 2016).

In summary, we conclude that both natural (vegetation structure) and anthropogenic (habitat modification) factors affect the diversity of eusocial bee species registered in the Parque da Sapucaia. Our findings reveal that maintaining the state of conservation and the vegetation structure is essential for the conservation of bee fauna in the tropical dry forest. In recent years the tropical dry forests in the northern of Minas Gerais have suffered considerable deforestation due to the increase in urban zones, agriculture and pastures (Dupin et al., 2018). The intensification of land use and the modification of natural landscapes can lead to the extinction of many species of active bees and compromise the quality of ecological pollination services (Potts et al., 2010; Tylianakis, 2013). Little is known about the bee fauna in the tropical dry forests (Alvarenga et al., 2020), which reveals the importance of carrying out further studies, especially in the northern of Minas Gerais. Therefore, future studies can investigate whether these patterns are recurrent in other tropical dry forest areas in the region, as well as compare the diversity of bees between preserved and anthropized environments in other types of vegetation.

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**Authors contribution**

P.S.G.: conceptualization, methodology, investigation, writing & reviewing
W.S.A.: conceptualization, methodology, formal analysis, writing & reviewing

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