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Winged Ants in the city of São Paulo, Brazil: analysis of the mating flight

Stefano Cantone
Department of Zoology, São Paulo State University, Avenida 24, 1515, Rio Claro, SP, Brazil

Abstract
In the ants colonies of most species, the mating flight is carried out once or several times during the year, depending on the reproductive strategy and the environmental characteristics. Winged females and males ants, after leaving the nest, are subject to dangers posed by adverse climatic conditions and predators. Therefore, the species of ants have developed, in the course of their evolution, different mating flight strategies to avoid these dangers and synchronize flight with other colonies, so that individuals of the opposite sex have greater opportunity to meet.

The process of urbanization fragment, degrade and isolates natural areas, depending on the density and urban and economic development form, by generating different profiles of urban landscapes. The objective of this study is to understand whether the environmental conditions, generated by different urbanization profiles, influence the mating flight of ants.

Winged ants were captured daily over a two year period at two urban sites in the city of São Paulo, using light traps. Approximately 113,000 individuals were captured and assigned to eight subfamilies and 44 genera. At São Paulo city, in January, I recorded the largest number of ant genera in mating flight, probably associated with the maximum mean temperature values and the rainfall. The periodicity analysis of mating flight at subfamily and genera level shows different patterns between the two urban sites.

I hypothesize that the trophic structure of ant communities reflects the dynamics of the trophic availability in different urban microhabitats showing, as a result, plasticity in the mating flight periodicity.

Keywords: ants phenology, urban ecology

Introduction

The ants perform multifarious ecological functions at all trophic levels, contributing to the aeration and fertilization of soil, dispersing seed and undertaking important trophobiotic and mutualistic interactions with phytophagous insects and predating a wide variety of invertebrates (Wheeler, 1910; Hölldobler and Wilson, 1990, 2009) [42]. Ants are present in all terrestrial ecosystems and are sensitive to habitat changes, showing variations in community structure, and are, therefore useful as bio-indicators (Folgarait, 1998; Andersen *et al*. 2002; Ribas *et al*. 2012; Xavier *et al*. 2014) [14, 4, 34, 43]. The great diversity of ant species and their ecological niches creates difficulties in monitoring studies of species diversity in any environment. Ants occupy subterranean and arboreal environments and the workers, who are seen walking on the ground, represent approximately 50-60% of the real species diversity of a given environment (Agosti *et al*. 2000) [1]. The capture of individuals belonging to the winged caste offers the possibility to record the presence of upper arboreal and subterranean species and other species that are rare or secretive, which are otherwise difficult to detect.

The process of urbanization, fragments, degrades and isolates natural areas, generating different profiles of urban landscapes (Alberti, 2010) [2]. Human activities in the cities creates air, light and sound pollution that, together with the waterproofing of large surfaces and high building density, generates different urban microhabitats (Collier, 2006; Grimm *et al*. 2008; Clown and Grant, 2015) [9, 16, 8]. Although such changes to ecosystems generally have a negative impact on biodiversity, it must be emphasized that the urban landscape can also offer some opportunities for the conservation of native biodiversity (Alvey, 2006; Menke *et al*. 2010) [31]. Indeed, urban ecosystems are characterized by great spatial heterogeneity and can offer ecological niches for many native species (McKinney, 2008; Silverman, 2010; Guénard *et al*. 2015) [30, 31, 17].

The function of ant mating flights is to colonize surrounding environments and facilitate gene flow, a task that males are solely responsible in wingless queen species (Hölldobler and Wilson, 1990, 2009) [25, 26]. Two mating flight strategies predominate: a) the males are attracted to the pheromone produced by females, known behavior as female calling syndrome; b) males and females meet in a Lek mating where they mate, a known behavior as male aggregation syndrome (Hölldobler and Wilson, 1990, 2009; Heinze and Kazuki, 1995) [25, 26, 22].

In the temperate regions of the Northern Hemisphere, mating flight occurs mainly in the warmer months, especially between the months of June and October, showing high synchrony among populations of the same species (Kannowski, 1961; Hölldobler, 1976; Gomez and Abril, 2012; Cantone, 2017, 2018) [18, 15, 5]. In tropical regions, mating flight can occur all year round or during certain months, depending on the species (Kusnezov, 1962; Pfeiffer and Linsenmair 1997; Torres *et al*. 2000; Kaspari *et al*., 2001; Cantone, 2017, 2018) [20, 33, 40, 44].

Mating flight may occur at different hours of the day or night and is species-specific. Its adaptive features include: a) intraspecific sexual stimulation, b) exclusion of other species from the copulatory activity, c) synchronization and coordination of flight movements within the species and d) regulation of the dispersal rate (Wilson, 1957). The periodicity of mating flight is also related to climatic (Dunn *et al*. 2007) and trophic environmental variables that influence, in many species, the production and behavior of the winged caste (Ruppel and Heinze, 1999; Helms and Kaspari, 2014) [23].

Based on the hypothesis that temporal gradients of diversity arise from the intervals superposition of reproductive phenology in the species, we can understand the temporal diversity patterns by studying the factors that control the intervals of the reproductive phenology (Martin *et al*. 2009) [29]. Variations in and alteration to the urban environment may therefore affect the mating flight periodicity and reproductive phenology. The aim of the current study is to explore the spatial and temporal variation in ant diversity and mating flight at two sites with different urbanization profiles in the city of São Paulo. It will provide an important insight into the role of urbanisation on reproductive phenology in ants in the region.

Methods

Study site

São Paulo city is a metropolis of nearly 12 million people, with an area of 1,521 km^2 and an average demographic density of approximately 7400 inhabitants/ km^2. The city is located on the Tropic of Capricorn (23°33'S, 46°38'W) at an average altitude of 770 meters sea level and about 60 km from the Atlantic Ocean coastline. The local climate is considered subtropical wet with dry winters (June to August) and wet summers (October to January) (IBGE, 2014) [27].

Pollution, high concentration of buildings and the presence of urban parks in São Paulo create a variety of climatic microregions. The city represents an urban ecosystem with a mosaic of landscapes: urban forests, urban parks, squares and green areas, small family farming areas, regions with vertical (buildings with many floors) and horizontal (houses) urbanization, and areas for industrial activities, food markets and logistical purposes. Such urban complexity generates a diverse range of microhabitats with different biotic and abiotic characteristics, which are associated with variation in ant composition and richness (Savage *et al*. 2014, Slipiski *et al*. 2012) [37].

Collection were made at two sites, herein denoted I and H. These sites were located in different micro-climatic regions and approximately 14 km apart (Fig. 1). The place I (23°35'17''S, 46°38'58''W, 800 meters sea level) is located in a small urban park of about one hectare at the headquarters of the Instituto Biologico, in a central district of the city. This neighborhood is dominated by vertical urbanization, with buildings of 20-30 floors, and has an average population density of approximately 15,000 inhabitants / km^2. It is also adjacent to an urban park (Ibirapuera park) of about 120 hectares. The place H (23°27'33''S, 46°38'17''W, 900 meters sea level) is located in an urban park (Albert Löfgren park) of about 187 hectares, located in the northern region of the city in a district that is dominated by horizontal urbanization (houses), has an average population density of approximately 7,800 inhabitants / km^2 and is adjacent to a protected area of Tropical Rainforests (Cantareira State Park) of approximately 7,900 hectares (IBGE, 2014) [27].

Catching technique

Specimens were captured using light traps equipped with 15 watts "black blue" ultraviolet lamps. Two traps were employed at each site and hung from the branches of trees at height of three to seven meters. Traps were activated each night from 01/08/2012 to 01/09/2014 using a photocell.

Since the presence of winged individuals of ants in entomological collections is poor, a part of the captured species was deposited in the Zoological Museum of University of São Paulo, SP, Brazil and all species are in my personal collection available to the entire scientific community.

Meteorological data

Climatic data, namely average temperature and rainfall, were obtained from the Mirante Santana Meteorological Station, Institute of Meteorology, Ministry of Agriculture. This station (Site M) is located between the two places of capture and indicated in the Figure 1.

Trophic categories

The ants community was split into three categories, based on trophic function, defined as: Predators, comprised of genera from the subfamilies Dorylinae, Ectatomminae, Heteroponerinae, Ponerinae and Pseudomyrmecinae; Generalists, comprised of genera from the subfamily Myrmicinae; and Generalists/Opportunists, comprised of genera from the subfamilies Dolichoderinae and Formicinae, where various species are known to present a trophic behavior that varies according to food availability (Wheeler, 1910; Hölldobler and Wilson, 1990, 2009; Brandão *et al*. 2012) [25, 26, 5].

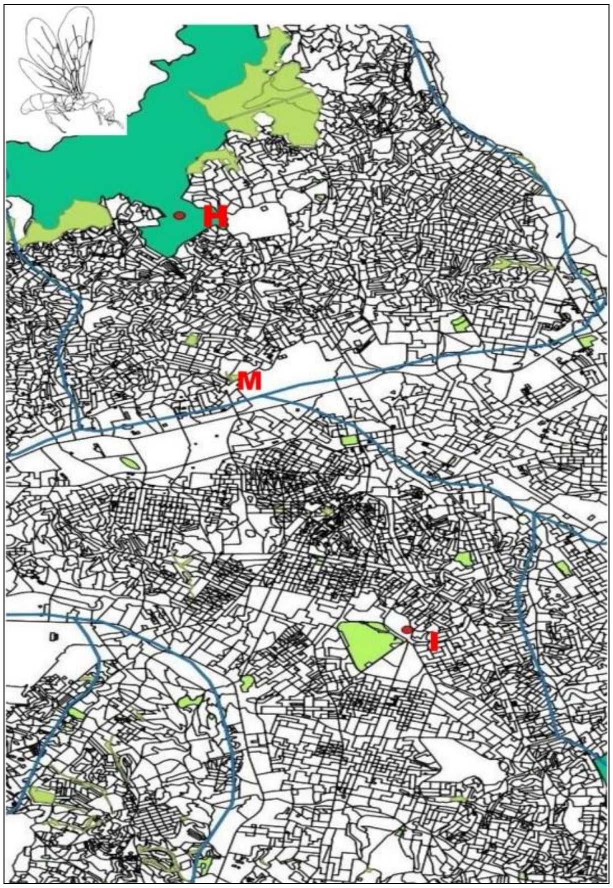

Fig 1: São Paulo city, Brazil. Places of capture: I and H, weather station: M

Result and Discussion

Approximately 113,000 individuals were captured, belonging to eight subfamilies, 44 genera and 288 morphospecies (Table 1; Figure 2). Twenty eight genera were identified from site I and thirty nine genera from site H.

This level of generic diversity is high, given that the trans-South America diversity along the tropic of Capricorn has been estimated at about 60 genera (Dunn *et al*. 2010) [31].

The highest generic diversity in mating flight occurred in the months of December, January and February, probably associated with the maximum mean temperature values and the rainfall. The maximum mean temperature and the rainfall are the abiotic variables that appear to be associated with the mating flight and for this reasons, winged ants in mating flight may therefore be useful as bio-indicators of climate change (Figure 3)

Analysis of mating flight periodicity found important differences in subfamilies between sites. In particular, many genera from the Dolichoderinae and Formicinae subfamilies are only found at site I in the driest months with the lowest average maximum temperature (Figure 4).

Much of the variation in diversity, observed in this study, cannot be explained by simple comparisons with temperature and rainfall, showing that mating flight behavior is more complex and subject to other variables.

Trophic community structure shows differences between sites, with Predators dominant (41%) at site H, and Generalist Myrmicinae dominant (40%) at site I (Fig. 5).

This difference may be related to the availability of trophic resources between the two study sites. Site I has a higher human population density, with greater quantities of human food and waste., thus favouring Generalist and Generalist/Opportunistic genera at site I versus site H.

The hypothesis is that the trophic structure of ant communities reflects the dynamics of the trophic availability in different urban microhabitats showing (Penik *et al*. 2015), as a result, a change in the mating flight strategy. The availability of trophic resources is an important variable in the study of mating flight intervals in tropical ants because of the high energy costs of colony in breeding of the winged caste and in its capacity of dispersing (Helms and Kaspari, 2014) [23].

Site I is considerably more urbanized than Site H. It has almost double the human population density of Site H, large number of restaurants and is adjacent to a city park that is visited by approximately 13 million people annually. The availability of food resources is therefore abundant, continues throughout the year and probably influences the mating flight periodicity of the Generalist/Opportunist trophic category, which one recorded winged ants, all year long, only in place I, showing high plasticity of mating flight. This high mating flight plasticity is absent from most of the genera Generalist Myrmicinae and Predators categories (Figure 6).

Table 1: The diversity of genera of the ants for subfamily at São Paulo city.

Subfamily	Genera
Dolichoderinae	5
Dolyrinae	4
Ectatomminae	3
Formicinae	5
Heteroponerinae	2
Myrmicinae	18
Ponerinae	6
Pseudomyrmecinae	1
8	44

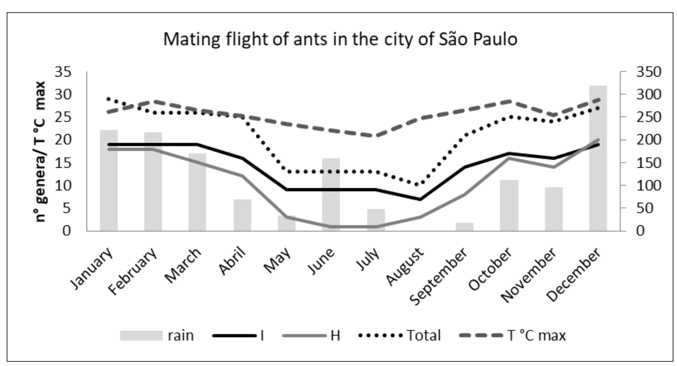

Fig 3: Comparison between the genera presence in mating flight, the maximum temperature and the rainfall of the year São Paulo city, Brazil in the places of capture I and H.

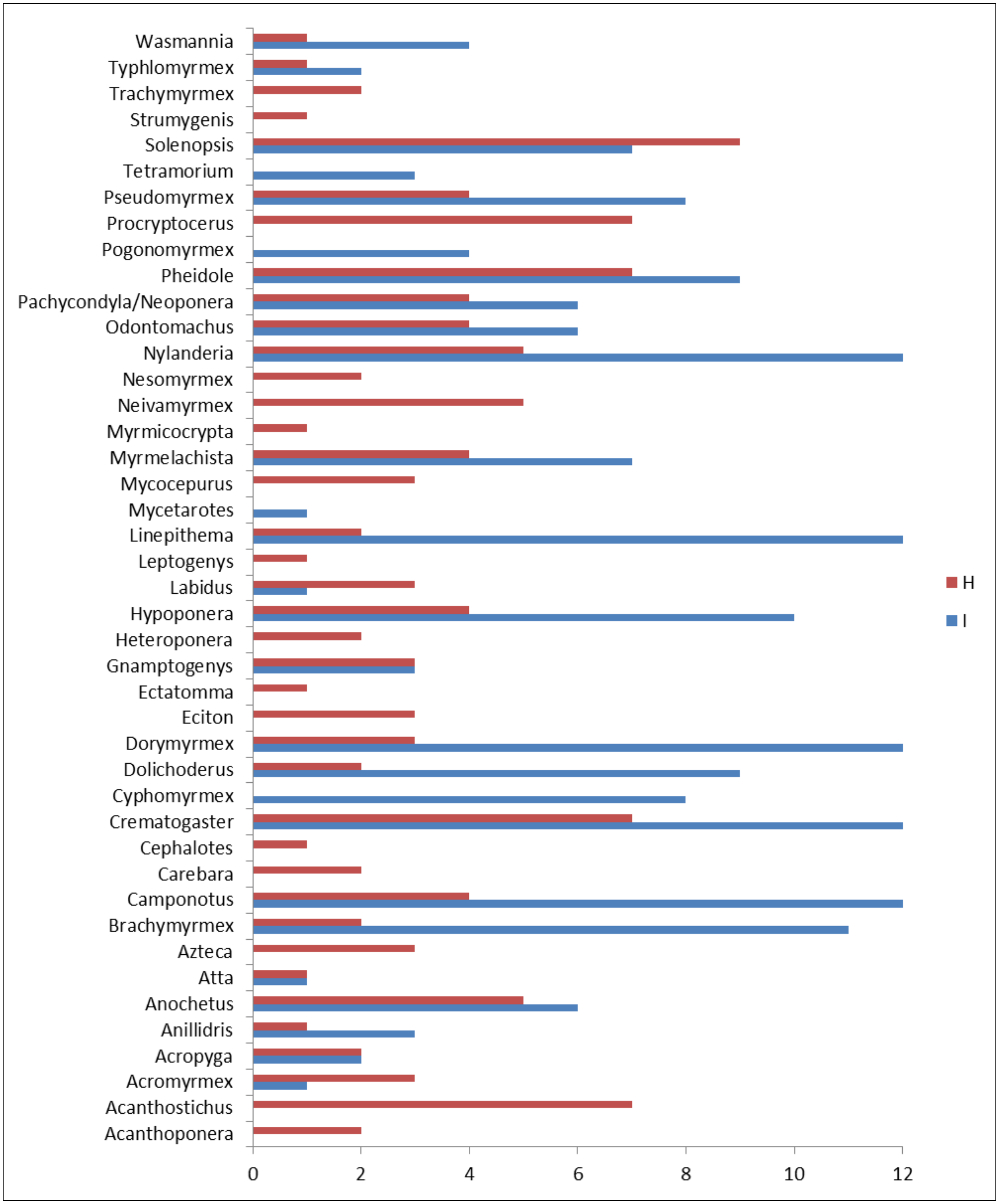

Fig 2: The diversity of genera and the respective number of months of mating flight during the year at the places of capture I and H at São Paulo city, Brazil.

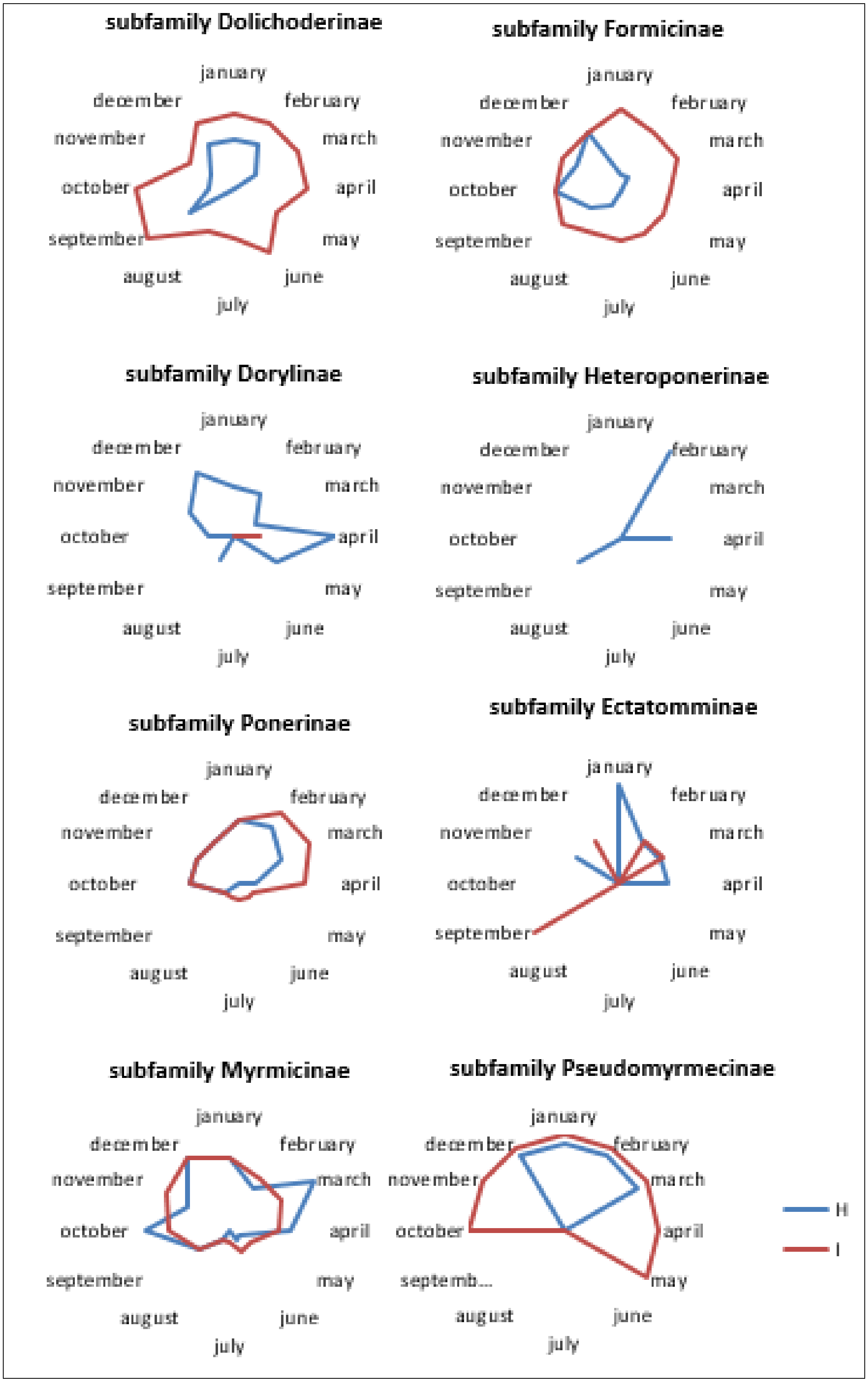

Fig 4: The mating flight analysis at the family and subfamily level of ants at São Paulo city, Brazil. Each graph has a different proportion depending on the number of genera in each subfamily. Places of capture I and H.

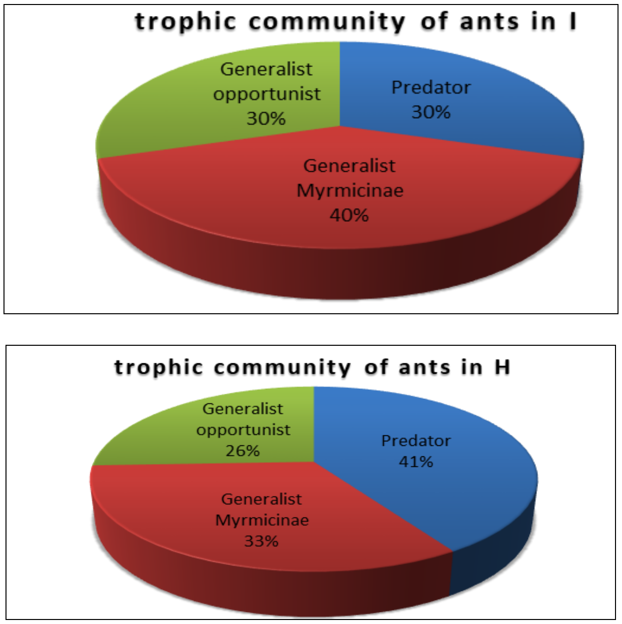

Fig 5: The trophic community of ants, in two places of capture, shows a different composition of genera in percentage.

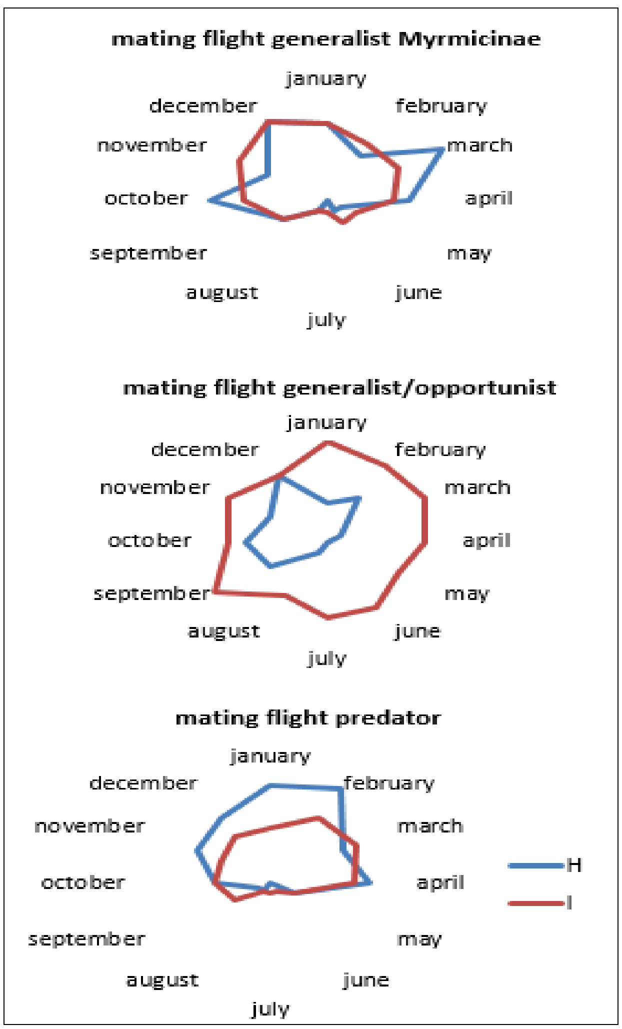

Fig 6: Mating flight in trophic community of ants in São Paulo city. Each graph has different proportions depending on the number of genera. Place of capture I and H

Conclusions

The findings of this study support raising an hypothesis that the plasticity of mating flight behavior in Tropical urban ecosystem, of the Generalist/Opportunist trophic category is influenced by the availability of food due to the human activities (Sanford *et al*. 2009) [36]. This relationship amends the composition of ant communities and represents an adaptive response to the urban ecosystem (Donihue and Lambert, 2014) [11].

The capture technique with light trap used for the winged ants in urban ecosystem showed a high efficiency in the diversity register.

This study represents an important baseline for winged ant diversity in urban ecosystems, offers further opportunities to use winged ant diversity and mating flight periodicity to measure to ecological impact of habitat and climate change in urban environments.

This research is the first study of mating flight in a community of ants in urban ecosystem, and there is no other research to make a comparison!

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