THE ROLE OF COMPETITION IN STRUCTURING ANT COMMUNITIES: A REVIEW

Stela de Almeida Soares [1]

[1] Universidade Federal do Paraná, Setor de Ciências Biológicas, Departamento de Zoologia, Programa de Pós-graduação em Entomologia Caixa Postal 19020, 81531-980 Curitiba, Paraná.
Email: stelasoares@ufpr.br

ABSTRACT

Understanding the mechanisms that determine local patterns of diversity is among the primary goals of ecology. Among these mechanisms, competition is mentioned as the regulatory factor structuring biological communities, despite the fact that the concept is controversial in ecology. Myrmecologists, however, for the most part, view competition as one of the main factors structuring ant communities. Two hypotheses on the mechanisms underlining species coexistence have received support from empirical studies. The first predicts a balance between competition and colonization, which form a continuum along which species are distributed. Species at one extreme are good at competing and bad at colonizing, whereas species on the opposite end are bad competitors and good colonizers. The interactions among various species over time are in a state of constant flux along this continuum. The second hypothesis predicts spatial clustering. According to it, ecologically dominant species have an aggregated spatial distribution, which would increase competition among individuals and the species' coexistence with subordinate species. Beyond these two, there are the trade-off and the mosaic theories, which involve competition and promote coexistence, and also the null models, which are used to determine if competition is responsible for ant community structures. In the Myrmecology, the competition is par excellence as one of the main factors structuring ant communities. Some hypotheses have been supported in empirical studies of natural communities as mechanisms for species coexistence. The first is the balance competition/colonization, species were distributed along a continuum between good and bad contestants competing colonizing up bad and good colonizers, and their interactions over time would allow a state of constant flux along this continuum. The second hypothesis is the spatial clustering, in which ecologically dominant species have an aggregated spatial distribution, which would increase competition among individuals and species coexistence with subordinates. Besides these there are the trade-off theory and the mosaics, which involve competition and promote coexistence, and also the null models, which are used to determine if competition structures communities of ants. However, the objective is to demonstrate the main mechanisms that involve competition in structuring ant communities

Keywords: coexistence; mosaics; null models; trade-off.

INTRODUCTION

One of the main goals of ecological studies is to explain biodiversity and its distribution in time and space. Generally speaking, ecologists can be divided into two groups according to what they believe to be the primary force structuring communities: biotic interactions and individual responses of species to environmental conditions (Ribas & Schoereder 2002).

Although competition is considered an essential force in the distribution of communities, its role is one of the most controversial issues in ecology. There is broad consensus among *myrmecologists* that competition has a role in regulating the structure and diversity of ant communities (Wilson 1971, Cole 1983,

Hölldobler & Wilson 1990). Studies on different issues such as dominance hierarchy (Savoläinen & Vepsäläinen 1988, Davidson 1988), mosaics (Dejean *et al.* 1994) and resource partitioning (Albrecht & Gotelli 2001) illustrate this. Despite their great importance, however, only a few and isolated studies have been published about the mechanisms that promote coexistence among species.

In general, ant colonies are sessile, and have similar requirements, including those associated with nesting site and food supplies. This generates aggressive interactions between species, as well as agonistic interactions among individuals of the same species (Fellers 1987; Savoläinen & Vepsäläinen 1988). Hence, ant communities are highly interactive

and displaying both inter and intraspecific competition (Oliveira & Della Lucia 1992, Oliveira *et al*. 2002, Rico-Gray & Oliveira 2007). Although several studies have pointed out the inter and intraspecific competition as a factor structuring ants communities (Levings & Franks 1982, Fellers 1987, Savoläinen & Vepsäläinen 1988, Andersen & Patel 1994), only a few have looked for patterns of competition, and the nature of biological interactions in determining species diversity (Soares *et al*. 2001, Arnan *et al*. 2011). Still, studies in the tropical savannas (Yamamoto & Del-Claro 2008) have shown that ant activity is correlated with environmental factors and that there is an overlap in the foraging area between neighboring colonies without evidence of agonistic interactions.

There is intriguing evidence showing the role of competition in structuring ant communities, for instance the importance of it in the formation of ant mosaics (Majer 1976b) and the influence of stochastic factors in structuring communities (Ribas & Shoereder 2002). Even though Ribas & Shoereder (2002) accept Majer's ideas (1976b), they also offer alternatives to the hypothesis that competition plays a role in the structure of mosaics. In addition, other studies (Hölldobler & Wilson 1990, Laster *et al*. 2009) have discussed how difficult it is to test for competition in the field or under laboratory conditions, pointing out that co-existence between two species does not necessarily represent evidence that they are competing (Ribas & Schoereder 2002). There are studies involving competition in ants that are limited to determine the importance of the dominant species over the remaining ant communities (Vasconcelos *et al* 2008), and which not touch on the importance of competition in general (Andersen 1992, Andersen & Patel 1994, Brandão *et al*. 2000, Parr *et al*. 2005, Vasconcelos *et al*. 2008). Therefore, a review of the major tested hypotheses on ant competition is needed.

The aim of this review is to demonstrate the main mechanisms whereby competition plays a role structuring ant communities. To accomplish this we analyze the main aspects and the history of competition in the family Formicidae. We also discuss the importance of defining the concepts of intra/ interspecific competition, point out some mechanisms that promote coexistence through competition, and finally present a brief report on the null models used to explain the co-occurrence of species.

HISTORY OF COMPETITION IN FORMICIDAE

Back in the nineteenth century, with the publication of "On the Origin of Species ", Charles Darwin questioned the coexistence of species and used the following metaphor to explain his ideas about why they are distributed the way they are. *"The face of Nature may be compared to a yielding surface with ten thousand sharp "wedges packed close together and driven inwards with incessant blows, sometimes one wedge being struck, and then another with greater force."* (Darwin 1859 p. 631). This metaphor represents nothing more than a scenario promoted by competition.

During the 1960s and 1970s, field investigations about competition in insects consisted of observations on resource sharing. The reason for such studies seems to be the classical theory of competition, which predicted that two species could not occupy the same niche or coexist unless there were some differences in the way they used resources (Schoener 1982). During this period, many entomologists reported on how the niches and habitats of insects differed, and argued that competition was the cause for such differences (Denno *et al*. 1995).

There is evidence, such as described by Haldane (1953), that growing populations will stabilize on a certain density and that intraspecific competition limits the distribution of individuals. Therefore, competition among individuals affects density or reduces reproduction, limiting the area of distribution of populations.

Since its first definition by Elton (1932), the concept of competition has not been sufficient to elaborate ecological models. Despite of that, competition in ant communities needs further investigation because it affects their distribution, abundance, structure and complexity. Furthermore, several authors have shown that competition is the main factor determining the distribution patterns of different species of ants in tropical environments (Torres 1984, Tobin 1994, Tschinkel 2006), and that interspecific competition is one of the most influential factors structuring ant communities (Hölldobler & Wilson 2009).

A revision by Traniello (1989) on the foraging strategies of ants reported that a determining factor for foraging ants is competition, to the extent that the

choice of quantity, quality and distribution of resources, time and sites of foraging is made in order to minimize it. Sanders & Gordon (2002) argued that there are several issues at the interface of competition, especially the behavior of the foragers and the use of resources. However, issues related to competition, individual behavior and resource use, as described above, are not well established.

Few are the studies on ants that test the effects of interspecific competition, the behavior of the foragers and their use of resources (Christianini *et al*. 2012). Moreover, even those few studies have arrived to different conclusions. For example, Ryti & Case (1988), in experiments with ants that carry seeds in the desert, showed that removal of the neighboring colonies did not influence the types and quantities of resources collected by *Veromessor pergandei* (Mayr, 1886) or colonies of *Pogonomyrmex californicus* (Buckley 1867). By contrast, the influence of neighboring species was clear in experiments conducted in the Taiga biome , where subordinate species adjusted their diets to less preferred food items under the influence of dominant species, (Vepsäläinen & Pisarski 1982). In addition, Parr (2008) demonstrated by means of null models that among three different types of vegetation of the African savannah, the congregation of ants is significantly structured by competition in only one. On the other hand, Brandão *et al*. (2000) argued that dominant ant species do not influence the pattern of co-occurrence of subordinate species in heterogeneous environments, and Arnan *et al*. (2011) suggested that some dominant species actually can promote it by neutralizing the effects of the others dominant species. In their data, a positive relationship between the abundance of the dominant species and the richness of subordinate species was found. The protection exerted by the dominant ants on subordinate species can help explain the paradoxical, positive relationship between ant dominance and species richness. Moreover, in the leaf-litter ant communities, the dominant and subordinate species can gather into different guilds, but this depends on the criterion for the establishment of ecological variables. In this manner, co-occurrence is enabled and competition is minimized or ceased, due to the utilization of different resources, or the use of the same resource in different ways by each guild in question (Silvestre *et al*. 2003). Therefore, the competition is not determinant factor in the organization structure of in

the leaf-litter ant communities in the form the guild. Thus, the tropical competition does not follow the same logic as in the environments of Nearctic, Palearctic and Australian. In this sense, Schoereder *et al*. (2004) suggest that apart from the competition, the conditions of the habitat factors, stochastic colonization and extinction must also be considered to explain the competition in ants.

Historically, competition has been implied as the culprit of ant community structure (Schoereder *et al*. 2004), and has been described as the hallmark of ant ecology (Hölldobler & Wilson 1990). However, other factors that act on different spatial scales may obscure the prevalence of competition (Ribas & Schoereder 2007) and despite the fact that studies on the role of it in ant communities have advanced considerably over the history of ecology, few researchers have attempted to find patterns. Finally, there are still many unresolved issues surrounding competition that need experimental studies and revisions.

COMPETITION CONCEPTS

Competition can be broadly defined as a negative interaction between two individuals sharing a limited resource. It may be symmetrical or asymmetrical. The result of competition between two species is that the species that best exploits the resources available will fare better than the other, less competent species (Andersen 1992).

Competition among ants should be common, because of are greatly diverse, widely distributed and have generalist habits (Wilson 1987a, 1987b). Competition is supposedly more intense when the resource is limited in time and space (Wiens 1989). Therefore, competition, which can be intra or interspecific (Hölldobler & Wilson 2009), can be defined as the struggle of individuals to find the best conditions for survival and reproduction (food, territory, lighting, nests, female, male, etc.)

In ants, workers major / minor and the colony is considered together as "an individual" with respect to competition, because ant colonies are considered as a "Superorganism" (Hölldobler & Wilson 2009) whose success depends on both workers and queen. Since Darwin's time, through observations of the sociability of the ants, it has been argued that competition acts on the colony, which is the unit of selection.

One difference between intraspecific and

interspecific competition is that individuals of different species do not require exactly the same resource or use it in the same way. Interspecific competition, by contrast, can be more intense and asymmetric (Hölldobler & Wilson 1990). There are three main general mechanisms through which ants can engage in competition either intra or interspecific: 1) *Interference competition* - (direct action) the physical effects of foraging when resources are limited, such as aggressive encounters among individuals, can reduce the number of individuals in the colony and cause the colony to collapse. 2) *Exploitation competition* - (indirect action) comes from the English expression "scramble competition". It usually occurs when a resource is limited and one ant colony depletes it leaving nothing for the others, for example large-scale recruitment colonies driving other smaller colonies away. 3) *Natural Competition* and/or *Pseudocompetition* - it occurs when two species do not compete directly for the same food resource but share the same natural enemy. The presence of two populations of prey species allows the predator to increase its population to levels which may exclude one of the prey species (Lach *et al.* 2010).

INTRASPECIFIC COMPETITION

Intraspecific competition occurs when two or more individuals of the same species compete for the same resources, i.e., nesting sites, food access, or any resource needed for survival and reproduction (Hölldobler & Wilson 2009). Because each ant colony is a superorganism, intraspecific competition in ants is always between different colonies of the same species. This type of competition has an important role in the structure of ant communities and influences the abundance, fertility, survival, growth and density of ant populations in the area occupied by these communities (Lach *et al.* 2010).

Intraspecific competition may become apparent after the death or displacement of an ant colony in the presence of another colony of the same species. In this example, the most often cited in the literature, mature colonies are broadly and uniformly distributed in space, which is accompanied by an overdispersion of nesting sites (Hölldobler & Wilson 1990). However, spatial uniformity in and on itself is not enough evidence that competition is happening (Ribas & Schoereder 2007). The first records of overdispersion of an ant colony were conducted by the pioneer ecologists Elton

(1932) and Brian (1956). Since then, few experiments on intraspecific competition and overdispersion of ant colonies have been conducted. However, polidomic nests of ant colonies are often overdispersioned and common, especially in nests on the edge of streams and estuaries, such as those of *Solenopsis* sp. (Traniello & Levings 1986). Polygenic colonies are often associated with multiple nesting (Walin *et al.* 2001). However, in monogenic species, a polidomic tingle may be composed by a central nest containing the queen and the brood, and peripheral nests containing mainly forager workers (Pfeiffer & Linsenmair 2001). Polidomic nests do not reflect an intraspecific competition, but polidomy reduces the costs of foraging, because all nests belong to the same colony. Intraspecific competition, by contrast leads to overdistribution in large scales, a colony strategy (Ryti & Case 1986).

The importance of density of individuals in populations was first mentioned by Haldane (1953). If only intraspecific competition is in place, a population could achieve stability through its density. In such cases, the term density-dependency, very common among ecologists, applies. In density-dependent situations, the interactions and behavior of a population are controlled by the density of individuals in it. Observations on the territoriality of *Lassius flavus* (Fabricius 1782) performed by Wiernasz & Cole (2003), showed that the distribution of this ant nest is density-dependent, supporting the hypotheses of Haldane (1953) and Wallof & Blackith (1962).

Competition can occur at any stage of the life cycle of the colony, but has more impact on the foundation stage, when the colony is not already established and the ants are not able to defend it. Competition decreases the availability of food and nesting sites for colonies that are not yet stabilized and for solitary individuals. Cloistered species, however, can avoid competition at this stage because the first workers are hidden until they become foragers (Peeters & Molet 2010). In a study by Gordon & Kulig (1996) on queens of *Pogonomyrmex,* only 1% of the queens succeeded in founding a colony. Intraspecific competition between colonies can reduce the ability of a colony to become established by changing the territorial foraging area and by reducing the size of the colony and the production of winged ants (Gordon & Wagner 1997). The parameters and experimental evidence on intraspecific competition focusing on the

distribution of nests, colony cycle and behavioral interactions are well discussed by Andersen (2008).

INTERSPECIFIC COMPETITION

Interspecific competition in ant communities is intriguing when we consider that the classical ecological theory suggests that such situations would lead to a high frequency of competitive exclusion. The essence of interspecific competition is that individuals of one species have lower survival and reproduction rates when they share the same resource with another species. This competition affects the dynamics of populations, which in turn affects the distribution of species and therefore their evolution (Brown & Davidson 1977, Aho *et al.* 1999).

While competition between different species of ants has been widely documented, competition among them and other groups of organisms has received little attention from researchers (Hölldobler & Wilson 1990), despite the fact that it might represent a key factor in structuring communities (Orrock & Danielson 2004). Brown & Davidson (1977) examined competition between ants and rats. They showed that desert ants compete with rodents and have the potential to compete and influence the community dynamics of many other taxa. Another recent contribution on the subject was provided by Orrock & Danielson (2004), who observed that the foraging behavior of a rodent, *Peromyscus polionotus* (Osgood 1907) is affected by the presence of the ant *S. invicta*. Their results show that in the presence of *S. invicta* the foraging behavior of the rodent was reduced because *S. invicta*, even in the presence of the rodent's urine, potentially reduced the quality of the habitat for *P. polionotus* and the distribution of the seeds consumed by the rodent.

Competition within a dominance hierarchy is also considered a result of ant community structuring. The term dominance, however, can be interpreted in three ways: behaviorally, numerically and or ecologically, as follows: a. *Behavioral dominance*: attributed to species that exhibit aggressive behavior and cause another species to avoid a given resource, usually food, or to migrate. Hölldobler and Wilson (1990) demonstrated dominance hierarchy in queens of *Camponotus ferrugineus* (Fabricius 1798), dominated by the *Myrmica rubra* (Latreille 1804) queen.

Numerical dominance: is attributed to species that have a large biomass, massive recruitment and make intense use of a givenresource (LeBrun 2005).

Ecological dominance: is one that combines behavioral dominance with a superior ability to exploit a resource. It is exemplified by ants that first discover a resource and defend it from others which have higher foraging rates (Davidson 1997).

The types of dominance in interspecific interactions can be easily observed with the use of baits such as sardines, honey or carbohydrates (Davidson 1997). The numerically and/or behaviorally dominant ant species will invariably monopolize the resource, except in extreme temperatures (Bestelmeyer 2000). The subordinate and submissive species, in response, may engage in three different strategies:

1 - Find the resource quickly and remove it before the arrival of the dominant species (Davidson 1997);

2 - Change its the period of activity (Bestelmeyer 2000) and / or

3 - Choose another item to consume (Kaspari *et al.* 2008).

The degree of incidence of the dominant species may affect species richness in communities, intensifying competition among ants (Andersen 1992). In addition, historical and ecological factors can be cited as possible causes of the increased importance of interspecific competition (Parr *et al.* 2005).

The importance of historical factors can be exemplified by the Australian and Brazilian ant fauna. While 40% of the ant fauna of the Australian savanna is primarily from arid areas (Andersen 2000), most genera inhabiting the Brazilian savanna are most likely from the forest, having their biodiversity centers of origin in tropical forests (Kempf 1972). This influences ant abundance directly, resulting in competitive interactions. The species of *Pheidole* that occur in Brazil, for example, have smaller nests and are less active than the Australian *Pheidole* species (Wilson 2003).

With respect to ecological factors, while in the Australian savanna the vegetation is often dominated by tree species distributed in only two strata (Mott *et al.* 1985), the Brazilian savannah has a high diversity of plants in three well-defined strata (Oliveira-Filho & Ratter 2002). This greater heterogeneity of the vegetation of the Brazilian savanna can increase the availability of food and shelter for ants, thus increasing the richness and species turnover and consequently decreasing competition.

ECOLOGICAL MODELS OF COEXISTENCE OF ANT COMMUNITIES

Competition has been studied for over two centuries (Darwin 1859). However, there are still questions about its role: are there patterns promoting the coexistence of species? Are there regularities associated with this process? The factors determining the coexistence of species in extremely diverse habitats can also be considered as one of the most debated subjects in theoretical ecology (Diamond 1975, Stone & Roberts 1990, Blüthgen & Fiedler 2004a, 2004b, Parr 2008). The numbers of ant species that can co-exist in communities structured by competition are determined by four main factors (Schoener 1982): (i) habitat specialization may significantly influence community structure (Lynch *et al.*1980, Vasconcelos *et al.* 2000, Yanoviak *et al.* 2008); (ii) differences in food preference may reduce niche overlap, acting as a positive factor increasing species richness (Kaspari *et al.* 2008); (iii) temporal niche differentiation, mainly determined by different species being active at different times (Albrecht & Gotelli 2001); and (iv) foraging behavior , essentially characterized by dominance hierarchies, allows species to forage in the same location, for the same resource and at the same time, thereby increasing local richness (Savoläinen &Vepsäläinen 1988).

Several authors have undertaken efforts to understand the maintenance of ecological diversity (Chesson 2000). In addition to the Lotka-Voltera model, which addresses competitive exclusion as the precursor of coexistence (Begon *et al.* 2006), other models have been proposed to explain coexistence of species. Kneitel & Chase (2004) explained the dynamic process of colonization and extinction as a trade-off between competitiveness and ability to colonize. Species possess traits that allow them to effectively exploit a resource in certain ways, while limiting its utilization by others. This trait differentiation may result in a distinct and deterministic allocation of resources among competitors (Tilman 1982). The neutral theory has put into question the importance of such niche-based processes, by asserting that species assemblages are mediated by stochasticity (Clark *et al.* 2007). However, recent evidence demonstrates that both stochastic and niche-based processes contribute to community structure (Wiescher *et al.* 2011). Also, spatial aggregation may allow species to coexist

(Belchior *et al.* 2012), especially those that use ephemeral resources and patches (Hartley & Shorrocks 2002). The Mosaics theory describes a spatial partitioning through dominance that permits non-overlapping of species territories (Majer 1972, Lach *et al.* 2010). Furthermore, stochastic processes emphasize the importance of chance of colonization, which is driven by random extinction and ecological drift (Chase & Myers, 2011). Finally, more recently, HilleRislambers (2012) argued that coexistence of species depends on *the stabilization of niche differences*, relative fitness differences and environmental conditions such as biotic and abiotic interactions. Because stabilizing niche differences and relative fitness differences both depend on the environmental conditions and biotic interactions unique to a given community, stable coexistence is vulnerable to any environmental perturbation and changes in species composition. Therefore, for coexistence to be maintained in natural systems, the niche differences should include not only differences in niche resource partitioning , but also differences in the responses to changes in the environment, both at the local and regional levels.

Although competition has been one of the most discussed concepts in studies of species coexistence (Voltera 1926, MacArthur & Wilson 1967, Schoener 1983), other interactions have also been described (Chesson 2000). These interactions often include some degree of antagonism among species (Giaconmini, 2007). In general, the spatial and temporal variation of species, as well as their responses to environmental fluctuations, result in a structural complexity that cannot be explained by the models mentioned above. For example, stochastic processes may determine species occurrence within a community while competitive trade-offs affect species persistence (Wiescher *et al.* 2011). Thus, knowledge of the importance of these processes in different communities, region and environments may lead to a better understanding of the factors that determine the assembly of communities and their maintenance.

CONCLUSION

It is unquestionable that some biological communities are structured by competition. Within this context, there is an agreement among *myrmecologists* that ants' communities are structured by competition.

Because evidence is scant, however, two questions remain to be answered: if there are patterns in the occurrence of competition and what is the role of competition in determining the diversity and distribution of ants.

Competition will occur when different species or individuals exploit the same limited resource, which can only be demonstrated experimentally. Competition can be intraspecific or interspecific For example, future queens within a colony claim the right to reproduction and queens from different populations compete for a specific site. Thus, studying both inter and intraspecific competition is important in determining the relationship between spatial distribution associated with habitat heterogeneity and resource use. This approach is also useful to better understand how these patterns vary in different scales.

Studies such as the ones developed by Haldane (1953) and Pointin (1961) show that the strength of competition is density–dependent, and also pointed to the need to understand the impact that this and other factors (e.g. vegetation complexity and viability of resources) have on the strength of competition. Biotic and abiotic interactions should also be investigated as playing a role in regulating competition. Yet, one question remains answered: does the degree of competitive structuring decrease with habitat complexity, and heterogeneity, of with resource limitation ? In order to answer this question, we need field experiments that investigate and/or manipulate habitat complexity, heterogeneity and the resource limitations. Furthermore, most of the research involving competition has not focused on the interactions of invasive species or exotic species that become invasive or those that disrupt communities. Such research would be relevant to prevent the homogenization of the ant fauna, which is as important as understanding the role of competition in natural communities. Moreover, the homogenization of the ant fauna can cause serious damage to gene flow in these communities and endanger biodiversity. Thus, it is important to give greater attention to the role of competition in invasive ant communities and how it differs from natural communities.

Ants are eusocial insects, and and a consequence of this is the structured hierarchy of their communities. However,. Investigations can be carried out using approaches that consider the entire ant assemblages. These approaches remove a number of species from the system while controlling for different factorsand make it possible to determine the degree to which these communities are structured, helping us understand the real importance of each member across the assembly.

Understanding ant dominance will also be important in describing other phenomena that involve competition, such as evolutionary trade-offs. This is a very relevant topic for studies that try to comprehend the relationships between dominance and resource discovery . These studies often include investigations on the impact that biotic and abiotic conditions have on these trade-off mechanisms. Trade-offs are most likely to occur in systems where non-native or invasive ecological dominance occurs. This leaves open the question: which are the characteristics that can influence trade-offs? Is competition ability a result of interference by specialized morphological, behavioral and/or physiological traits? Does discovering dominance abilities reduce the capacity of other species to compete? To clearly answer these questions and contribute to the understanding of trade-off operations in ant communities, data on morphology, physiology and behavior is needed.

Regarding the use of null models to assess the co-occurrence of species and their possible interactions, the arguments constructed by Gotelli & Entsminger (2007) are plausible. The combination of null models of co-occurrence and behavioral observation methods with baits may increase our ability to generalize findings on the importance of competition for the ant fauna. Hence, it is not possible to determine whether competition is an important factor based only on null models.

The central idea of the aggregation model is that aggregated species may limit the growth of their own populations, keeping population density low and consequently keeping resources available. In other words, ecologically dominant species with aggregated distribution might increase intraspecific competition and promote coexistence with subordinated species. Patterns of aggregation create a conflict between evolutionary theories, essentially the ecological concept of species coexistence and ephemeral resources.

In the context of competition, colonization and extinction theory provide insights into the potential effects that these demographic processes might have on species richness. However, extra care is needed when studying these phenomena in forest remnants.

Fragmentation causes changes in ant species composition and these changes are likely to be more pronounced in small fragments, due to the edge effect being more pronounced. Furthermore, substitution of species is also evident, causing a change in community composition. Research addressing the dynamics of colonization and extinction is essential for the management and conservation of biodiversity.

Finally, the theory of mosaics, extensively studied, is also heavily criticized (Majer 1976a, Ribas & Schoereder 2007). Major criticisms on it were made by Blüthgen & Stork (2007), who presented an excellent review of the concept of ant mosaics. The necessity to establish and understand the term dominance as it applies to ants and its relationship with colony size, habitat preference and local abundance have also been argued. This would favor the establishment of an accurate prediction of patterns influencing community structure. To this end, it would be ideal to propose techniques that could be used together to detect, and to provide conclusive evidence for competition. With this established, the importance of other biological, historical and ecological processes and factors could be better assessed. The distribution patterns of species and the setting of mosaics need to be better understood, together with the relative contributions that habitat preference, habitat heterogeneity and stochastic events of extinction and colonization have on these phenomena.

It can be therefore concluded that, although competition has been studied since Elton (1932) and Darwin (1859) and by others scientist of the last century (Savoläinen & Vepsäläinen 1988, Davidson 1988, Albrecht & Gotelli 2001, Ribas & Schoereder 2002), it is yet often difficult to demonstrate it. There are still many issues to be resolved which will favor science and biodiversity conservation. Nevertheless, competition is an important factor shaping ants' ecology and attributes, being decisive for the structure and regulation of ant communities in a number of levels.

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