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Fire effects on the ant community in areas of native and exotic vegetation

JM Arcusa

Universidad Nacional de Mar del Plata, Instituto de Investigaciones en Biodiversidad y Biotecnología (INBIOTEC), Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, Mar del Plata, Argentina

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Corresponding author
Juan Manuel Arcusa
Universidad Nacional de Mar del Plata
Instituto de Investigaciones en
Biodiversidad y Biotecnología (INBIOTEC)
Comisión de Investigaciones Científicas de
la Provincia de Buenos Aires
Mar del Plata, Argentina.
E-Mail: Juan.arcusa@gmail.com

Abstract

Acacia melanoxylon is an invasive species of the mountain grassland of the southeastern part of the Buenos Aires province, Argentina. Fires are a natural disturbance, characteristic of the area, and favor the germination of this invasive plant. However, they are used as the first step in management systems for the Acacia species. Moreover, the use of ants in monitoring programs is very scarce for Argentina. The objectives of this work are: 1) to analyze the response and resilience capacity of native and invaded sites by *A. melanoxylon* after a fire for controlling this invasive species; 2) to detect groups of ants considered to be indicators of the recovery phase subsequent to the burning; and 3) to apply the concept of groups of disturbances, proposed by Roig and Espadaler, as an effective tool for monitoring. The sampling design consisted of three replicates of 10 pitfall traps for each environment, native and invaded. Ant species were grouped into functional groups, trophic guilds, and disturbance groups. The fire did not generate significant changes in the richness and abundance of ants in the mountain grassland. However, it generated a positive effect on the sites invaded by Acacia during the first year after the fire. The groups of minimum specialists of vegetation and the dominant Dolichoderinae are considered good bioindicators. Finally, the disturbance indicators can be considered reliable management tools if the biology of the species that compose it is known beforehand.

Introduction

Invertebrates have been used for years as indicators of the ecological conditions of an ecosystem. That is why they are highly diverse, functionally important, sensitive to variations in the environment and easy to sample (Greenslade & Greenslade, 1984; Rosenberg et al., 1986; Andersen, 1999; Brown, 1997; McGeoch, 1998). Ants have all these characteristics and many authors consider them as better bioindicators than other groups of arthropods (Andersen, 1991; Peck et al., 1998; Alonso, 2000; Kaspari & Majer, 2000). However, their use in monitoring programs in Argentina is scarce.

Ants have been used as a tool to monitor sites under restoration or impacted by the functional groups scheme (Andersen, 1995, 1997). This model has been widely used to analyze biogeographic patterns in community composition and changes caused by disturbances (King et al., 1998). The success of this methodology is based on the large number of papers that describe the response of the ant community to the disturbances. They have been able to identify groups of species whose responses are consistent, decreasing or increasing, in relation to the disturbance (Andersen & Majer, 2004).

Buenos Aires province has important areas for conservation. However, several factors, influence the dynamics of the environment in those areas, such as floods caused by strong storms (Rossel & García Martínez, 2008), strong winds causing soil blasting (Gaspari, 2007), fires (anthropic or natural) and the presence of invasive plants (Arcusa, 2016). Fire affects the soil fauna directly and indirectly, changing the microclimatic conditions of the ground (Guazzelli, 1999). On the other hand, biological invasions usually accompany the processes of environmental deterioration resulting in the elimination of the invaded ecosystems resilience (Bilenca & Miñarro, 2004). For this reason, it is important to monitor areas under conservation to preserve them.

The aim of this work was to evaluate the effects of fire and invasive plants on a natural environment using ants as bioindicators. We monitored a burned area for a 3-year period. The fire is expected to produce positives effects in the invaded sectors, increasing the richness and abundance of ant species. Moreover, it is expected to produce changes in the species composition and functional groups of ants. Finally, we used for the first time the concept of disturbance groups proposed by Roig and Espadaler (2010) in a long monitoring program.

Materials and Methods

Study area

The Paititi Private Nature Reserve (Fig 1) is located in the Mar del Plata-Balcarce mountain range. It is part of one of the Sierra de Difuntos outcrops, which in turn is part of La Peregrina of the Sierras de Mar del Plata (Guazzelli, 1999). Its access point is at kilometer 22.5 of route 226.

The vegetation is characteristic of the pampas grassland where *Paspalum quadrifarium* (Lambert) and *P. exaltatum* (Presl) (Poaceae) are dominant. Shrubs conformed by *Baccharis articulata* (Persoon), *B. cordifolia* (Candolle), *B. dracunculifolia* (DC) (Asteraceae), *Buddleja thyrsoides* (Lamarck) (Scrophulariaceae), *Dodonaea viscosa* (Boissier) (Sapindaceae), and *Colletia paradoxa* (Sprengel) (Rhamnaceae) predominate in the mountains.

However, large areas of the Reserve are invaded by the species *Acacia melanoxylon* (R.br) (Fabaceae). This forms a layer of leaf litter that results in a highly homogeneous environment.

In March 2015, a fire was unleashed and burned 1000 hectares of the mountain environment. As a result, practically the entire Sierra de Difuntos was affected by fire, completely losing its vegetation (Fig 1).

Sampling

The sampling design consisted of three replicates, separated by 200 m., of 10 *pitfall* traps for each environment, native and invaded (60). Data from the summer prior to the fire were obtained from a sector that was already being studied. After the fire, the sample was continued until 2016, so that the data for the next two summers could be obtained.

The traps used are the classic *pitfalls*, consisting of plastic pots measuring 850 cm³ for determining the density-activity of different edaphic arthropods (Agosti et al., 2000). A 30% alcohol solution and detergent were used as a preservative. Pitfalls were placed at a minimum distance of 10 m from each other. The data corresponded to the summer months (January to March) of 2014, 2015, and 2016. The traps were active for one week per month.

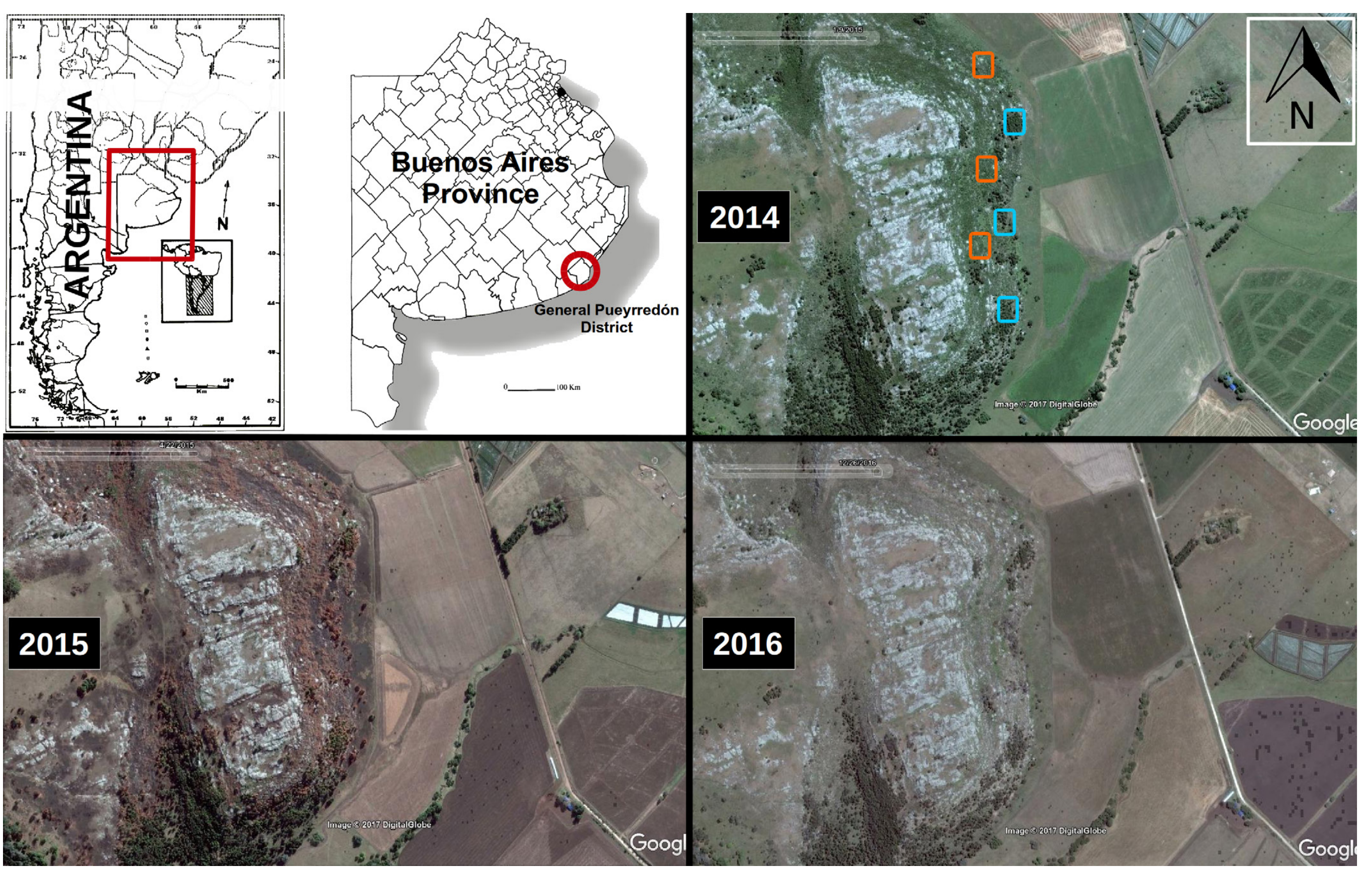

Fig 1. Location and condition of the study area for the sampling years. The orange rectangles indicate the sites with native vegetation, the sky blue ones the sectors invaded by *A.melanoxylon*.

We studied the difference in richness, abundance, composition, functional groups, trophic guilds, and disturbance groups between native and invaded sites before and after a fire (1 and 2 years after the fire).

Ant species were grouped into functional groups. These were conformed according to the criterion proposed by Andersen (1997) based on differences in habitat use, foraging mode, activity, and dominance. Then, the species were grouped into trophic guilds, using those proposed by Silvestre et al. (2003). Finally, the ants were grouped into three groups taken from Roig and Espadaler (2010) according to three criteria: indicators of disturbance and indicators of maturity and cryptic species. To assemble the ants into groups, biological and ecological data of each species were taken from bibliography.

It was determined possible differences between the three years for richness and abundance, functional groups, trophic guilds and disturbance groups using the two-way ANOVA test and Man-Whitney test. In order to determine the difference in the structure composition, the ANOSIM analyses was applied. These analyses were carried out by the programs Past 3 and Statcato 1.0.2.

Species abundances in individual traps were transformed to a five-point scale (1= 1 ant, 2= 2± 5 ants, 3= 6± 20 ants, 4= 21± 50 ants, 5= <50 ants) to avoid misleadingly high abundances due to sampling near foraging paths or nest entrances (King et al., 1998).

Results

In the Paititi Natural Reserve, 26 species were identified as belonging to 15 genera and 8 subfamilies. These were grouped into 7 functional groups and 13 trophic guilds (Table 1).

After the fire, the richness and abundance of both habitats were significantly incremented (Fig 2). Nevertheless, in 2016, both variables had decreased their value regarding 2015. On the one hand, for the native environment, these variables reached the initial values. On the other hand, for the invaded environment, both variables decreased their values in relation to 2015. However, this amount kept on being significantly higher than the initial state. Finally, there were no differences in 2016 comparing both sites.

Table 1. Classification of the ants in the different groups proposed.

Species	Functional group	Trophic guilt	Disturbance group
Acromyrmex lundi	Attini	Leaf-cutting ants	Disturbance
Acromyrmex ambiguus	Attini	Leaf-cutting ants	Disturbance
Apterostigma bruchi	Attini	Cryptic-cutting ants	Cryptic
Mycetophylax sp.	Attini	Cryptic-cutting ants	Cryptic
Crematogaster quadriformis	Generalized Myrmicinae	Omnivorous dominant of ground	Maturity
Pheidole sp.1	Generalized Myrmicinae	Omnivorous dominant of ground	Disturbance
Pheidole sp. 2	Generalized Myrmicinae	Omnivorous dominant of ground	Disturbance
Pheidole sp.3	Generalized Myrmicinae	Minimum specialist of ground	Cryptic
Solenopsis richteri	Climate specialist	Omnivorous dominant of ground	Disturbance
Solenopsis minutissima	Climate specialist	Minimum specialist of vegetation	Maturity
Oxyepoecus sp.	Cryptic species	Predator cryptic Myrmicinae	Cryptic
Linepithema humile	Dominant Dolichoderinae	Omnivorous dominant of ground	Disturbance
Linepithema micans	Dominant Dolichoderinae	Arboreal of massive recruitment	Cryptic
Camponotus puntctulatus	Subordinate Camponotini	Generalist Camponotini	Maturity
Camponotus bonariensis	Subordinate Camponotini	Generalist Camponotini	Maturity
Camponotus rufipes	Subordinate Camponotini	Generalist Camponotini	Maturity
Camponotus sp.1	Subordinate Camponotini	Generalist Camponotini	Maturity
Camponotus sp.2	Subordinate Camponotini	Generalist Camponotini	Maturity
Nylanderia silvestrii	Opportunist	Omnivorous dominant of ground	Maturity
Brachymyrmex brevicornis	Cryptic species	Vegetation and soil omnivorous	Maturity
Ponera opaciceps	Cryptic species	Cryptic Ponerinae	Cryptic
Discothyrea neotropica	Cryptic species	Minimum specialist of ground	Cryptic
Pseudomyrmex phyllophillus	Climate specialist	Agile Pseudomyrmecinae	Maturity
Neivamyrmex sp.1	Climate specialist	Nomadic species	Maturity
Neivamyrmex sp.2	Climate specialist	Nomadic species	Maturity
Gnamptogenys striatula	Opportunist	Large epigean predator	Maturity

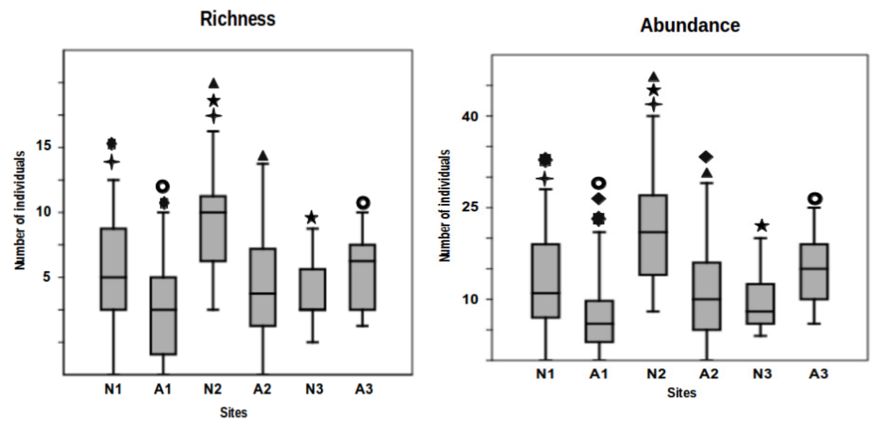

Fig 2. N= native site; A= invaded site. Numbers correspond to the sample year: 1 for 2014, 2 for 2015 and 3 for 2016. Same symbols indicates differences between sites.

From the seven functional groups, only the subordinate camponotini (CS) was not present in the sectors invaded by Acacia. Furthermore, the opportunists (O) and climate specialists showed differences only in 2014 regarding their abundance between native and invaded environments, with the former being more abundant before the fire than the latter. Finally, the dominant Dolichoderinae group (DD), which was completely absent before the fire, increased in number significantly in 2016 (Fig 3).

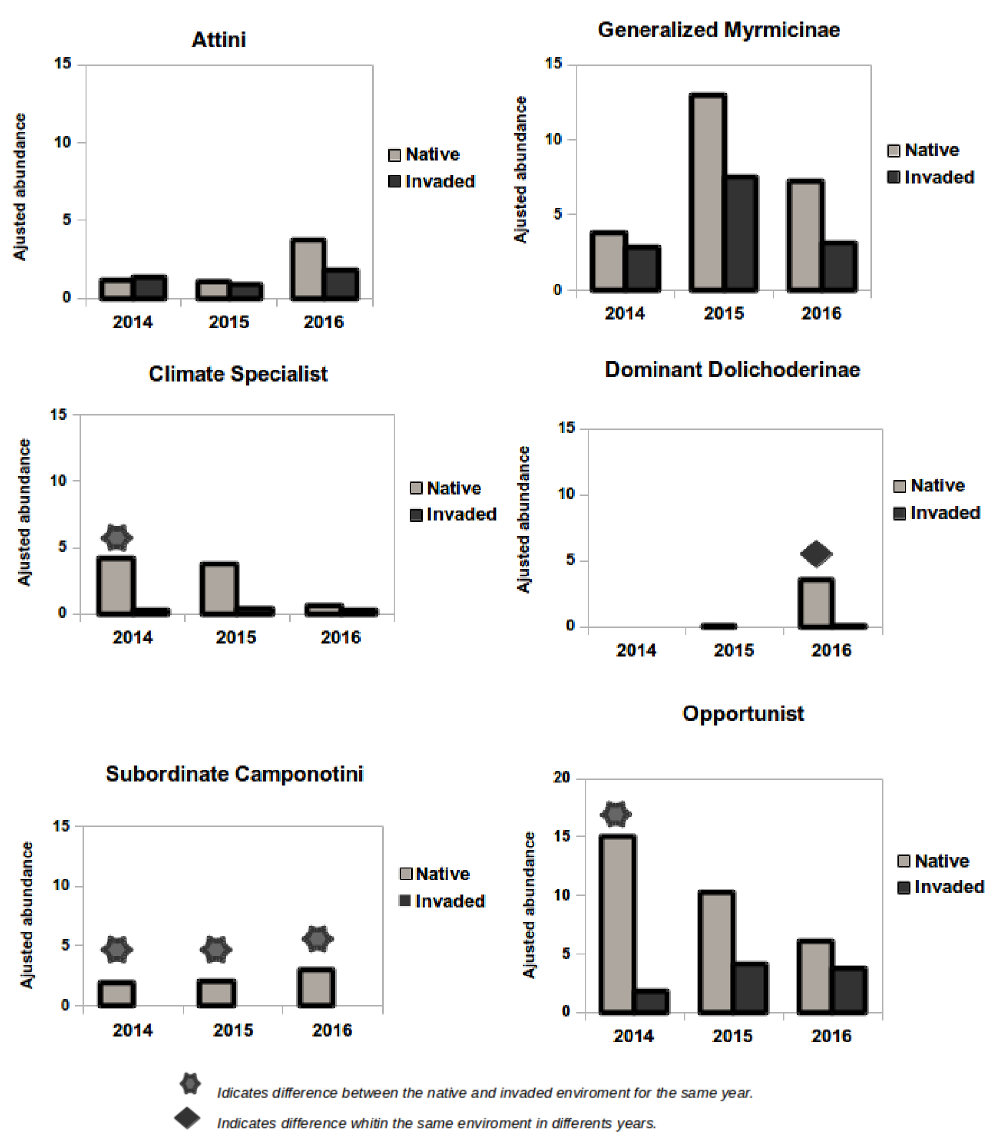

Fig 3. Functional groups of ants. Only groups with a representative number of individuals were plotted.

In relation to the trophic guilds, only three of them show a difference between sectors or years. The group of Omnivorous dominants of ground showed a difference between the native and invaded environment for the postfire years. Minimum specialists of vegetation, a group composed only of *Solenopsis minutissima*, presented differences between environments and was more abundant before the fire. In subsequent years, it was not present, or its abundance turned out to be very low. Finally, the guild of the generalist camponotini repeated the obtained results for the functional group of the subordinate camponotini, because these groups are identical (Fig 4).

When analyzing the disturbance groups, a considerable increase of the species of disturbance indicators was observed in 2015. For the following year, they diminished in abundance, reaching a situation similar to the one before the fire episode. The maturity indicator species varied significantly during the 3 years, increasing after the fire and subsequently decreasing in abundance (Fig 5).

Changes in functional groups and trophic guilds are reflected in differences in structure assemblage. The native environment in 2014 was different regarding the same in 2015 (p = 0,001; R = 0,12) but it returned to the basal state in 2016 (p = 0,1; R = 0,1). The same occurred in the invaded site. There was a difference between 2014 and 2015 (p = 0,04; R = 0,3) but not considering 2016 (p = 0,8; R = -0,07). However, the R values were relatively low in all comparisons.

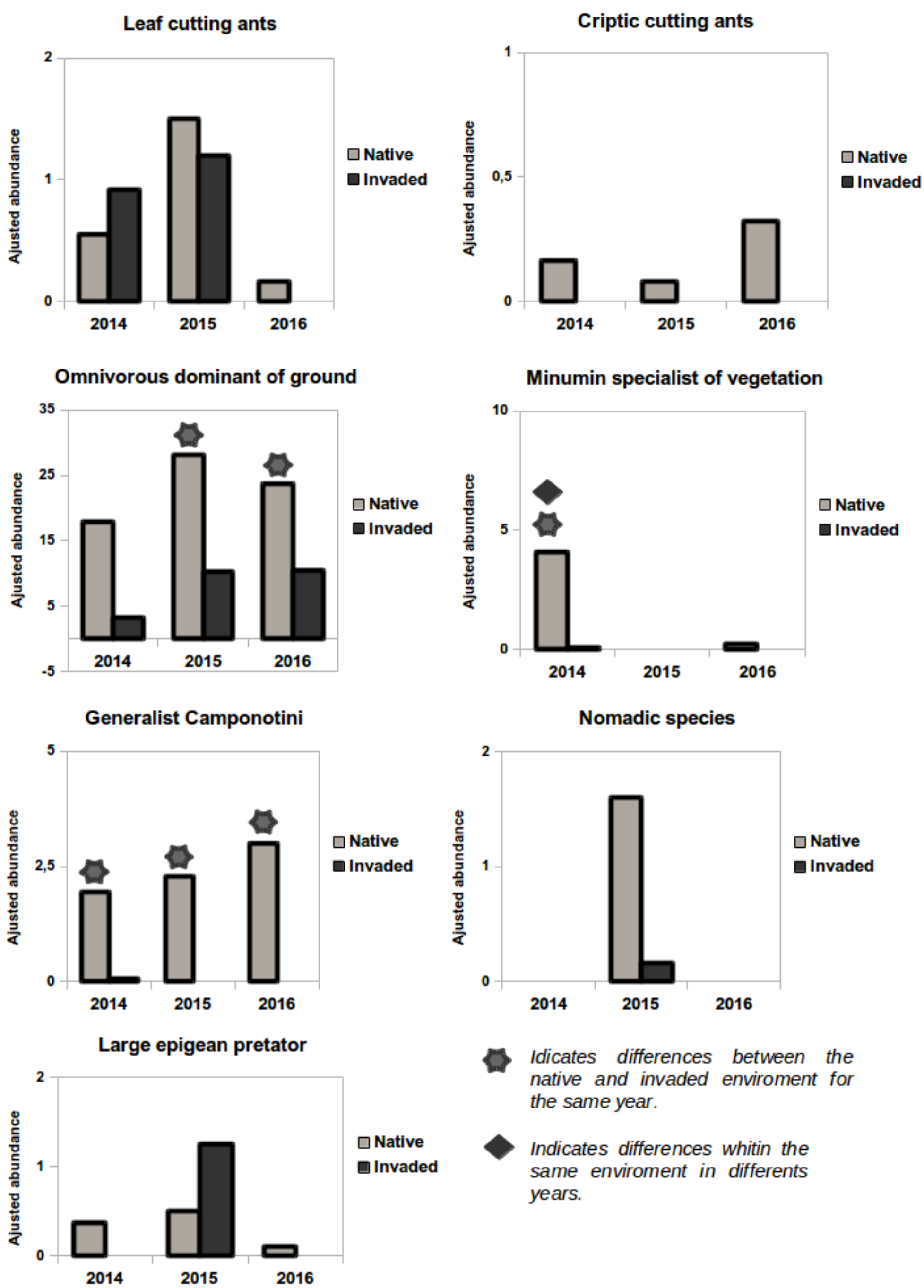

Fig 4. Trophic guilt of ants. Only groups with a representative number of individuals were plotted.

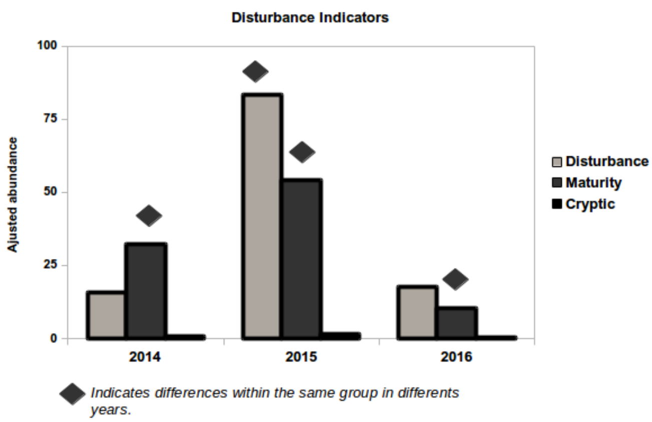

Fig 5. Disturbance indicators.

Discussion

Differences between both environments in their initial sate were mainly attributed to changes in the resource availability by *A. melanoxylon* (Le Maitre et al., 2011; Arcusa, 2016). Meanwhile, the slight variation among the variables belonging to the native sites was mainly due to the geological history of the place. Certain species that inhabit areas where fire is a part of the system are expected to be resistant and resilient to conflagration such as those that happen in the Brazilian savanna and Rupestrian grassland (Anjos et al., 2017). In addition, areas with low vegetation, such as grasslands, are dominated mainly by ground ants. The soil temperature does not change significantly below 5cm. underground in the savannas (Anjos et al., 2017), which would explain why the ants are protected from the fire. Moreover, the fire completely eliminated the leaf litter produced by the Acacia. This produced a significant increase in available resources such as seeds, tender shoots, and nesting sites. This increase attracted species from the surrounding areas by increasing the richness. Finally, as a result of the rapid recovery rate of Acacia (Gibson et al., 2011), by 2016, all the invaded systems had recovered their initial state, leading to a negative impact on the species richness.

Regarding the functional group of the climate specialists, it was equivalent to the minimum specialists of vegetation guild as the former consisted mainly of *Solenopsis minutissima* and the latter exclusively of them. Both groups were considerably affected by the fire, decreasing their density-activity. This occurred because this species is frequently found nesting inside the floral poles of the plants belonging to the genus *Eryngium*, the dry stems of *Carduus* and *Cortadeira* (pers. obs.). After the fire, the rods and dry stems were reduced to ashes as they are very flammable. The detection of this ant after two summers is possible due to the recolonization of the new floral poles. For species that nest on branches, leaves, and trunks, nesting sites are a limiting factor after a fire (Fagundes et al., 2015). Likewise, *S. minutissima* was not found in invaded sites where only *A. melanoxylon* predominated and, therefore, the conditions for its nesting were not satisfied. The guild of the minimum specialist of vegetation was previously considered an indicator of recovery environments (Silvestre et al., 2003), for this reason, I consider it an important group for the monitoring of affected systems.

The increase of dominant Dolichoderinae after the fire reflects what is already known about this group. It usually increases its abundance after a disturbance and remains low or absent at undisturbed sites (King et al., 1998, Andersen et al., 2003; Andersen & Majer, 2004; Villalba et al., 2014). This group has an omnivorous diet and forages preferentially in open sites with bare soil (Silvestre et al., 2003), which is why it is not found in the invaded areas (Arcusa, 2016). This functional group is included within the guild of the omnivorous dominant of ground. *Solenopsis richteri* is included among the species that define this guild, a disturbance indicator species (Folgarait, 1998), that increased its abundance after the fire in the native environment. Being a heterogeneous group consisting of five species, it is affected by the responses of each one of them, making its interpretation difficult. However, as a whole, it proved to be a beneficial and valuable group for monitoring because it was made up of two species of known roles as indicators of disturbance. In this regard, this work reinforces the observations made by Silvestre et al. (2003) for this group.

Ants of the genus *Camponotus* are characterized by being opportunistic and generalist in terms of diet and nesting (Silvestre et al., 2003). Both reasons may explain why this group was less affected by the fire. Other studies indicate that these species can become more abundant after a fire episode (Fagundes et al., 2015). *Camponotus punctulatus*, the most abundant species, does not feed on leaves or seeds (Gonzalez-Polo et al., 2004), the main resources within the Acacia forest. *Camponotus bonariensis* is a species associated with stems of plants such as *Eryngium spp.*, *Cicuta sp.*, *Cortadeira sp.,* and *Cardurs sp.* (Kusnezov, 1951). These plants were not detected in the invaded sectors.

The opportunist group, wich consist of *Nylanderia silvestrii* and *Gnaptogenys striatula*, were reduced in abundance after the fire. This could be probably related to the increase of Dominant Dolichoderinae, the occurrence of *S. richteri*, and the fact that this group is noncompetitive (Fuster, 2014).

The disturbance indicator group could be considered a good management tool if the biology of the species that composes it was widely known. In this work, the group was made by grouping species or genera whose response to disturbances is documented (Folgarait, 1998; Tizón et al., 2010; Fuster, 2014; Villalba et al., 2014; Arcusa, 2016). In this way, it was possible to monitor the increase of these species and estimate the time of resilience. This is not the case for indicative of maturity species. This group turned out to be very heterogeneous in its composition. With a high number of species and scarce information of a biological and ecological nature, it was difficult to analyze the changes in abundance. The first application of these groups as a monitoring tool was for olive groves in Portugal (Patanita et al., 2012), and, as in this work, the importance of disturbance indicators as a management and monitoring tool was emphasized.

Changes produced in the different groups (functional groups, trophic guilds, and disturbance groups) reflect changes in the assemblages of ants. This is in accordance with other works where it is indicated that the fire produces changes in the structure of the communities (Neves et al., 2016; Anjos et al., 2017; Maravalhas & Vasconcelos, 2014; Costa et al., 2010).

Conclusion

The fire did not generate significant changes in the richness and abundance of ants in the mountain grassland of Paititi's Nature Reserve. However, it generated a positive effect on the sites invaded by Acacia during the first year after the fire. It increased the values of richness compared to those found in the native environment. These values were reduced again after two yars.

The Minimum specialist of vegetation, mainly *Solenopsis minutissima*, and the dominant Dolichoderinae stands out at as bioindicator groups. The former are indicators of recovery of nesting sites and, therefore, an improvement in the conditions of the system. The latter, as has already been shown in previous works, are indicators of disturbance.

Within the disturbance groups, the disturbance indicators can be considered reliable management tools if the biology of the species that compose them is known beforehand.

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