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REVIEW

Review of Ants (Hymenoptera: Formicidae) as bioindicators in the Brazilian Savanna

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Abstract

The Brazilian Savanna is threatened mainly by the expansion of agriculture and livestock. Regarding environmental problems, habitat loss in the biome and the need to verify studies on ants as bioindicators, the goal of this paper was to carry out a bibliographic review of the literature about ants as bioindicators in this biome from the last 30 years. We searched papers about ants as bioindicators in the Brazilian Savanna from the last 30 years, refining the search between the years 1986 to 2016 and we analyzed 16 papers about ants as bioindicators. Monitoring studies focusing on ants as bioindicators in the Brazilian Savanna started in 1992 and increased since 2002. The results obtained in the studies presented changes in the species richness and composition in relation to potential bioindication. In general, 167 species are defined as bioindicators of the Brazilian Savanna and are related to specific habitats. We verified that most studies were done Minas Gerais state. We noted that the absence of rigorous analysis damaged the results of the studies, as well as the knowledge of ant fauna biology for correct attribution of indication characteristics of preserved or degraded areas.

Introduction

The majority of environmental problems are related to anthropic action, with habitat loss and fragmentation being a major threat to biodiversity (Bascompte & Sole, 1996; Dirzo & Raven, 2003; Balmford et al., 2005; Oliver et al., 2015). This affects the richness, species abundance, distribution and biodiversity in general. (Lovejoy, 1986; Kattan et al., 1996; Kellman et al., 1996; Turner, 1996; Steffan-Dewenter & Tscharntke, 1997; Kageyama & Gandara, 1998; Golden & Crist, 1999). Fragmentation is more threatening than habitat loss, depending on the existence of ecological effects that can be attributed to changes in the spatial pattern of habitat regardless of their quantity (Fahrig, 2003). The effects of area loss and fragmentation are complex, since both spatial phenomena exhibit a strong correlation (Mortelliti et al., 2010). However, as a result, we always have the change of the configuration, with the replacement of the original vegetation by another type of habitat and, consequently, connectivity becomes disrupted (Smith et al., 2009). Defining the factors and effects of these changes on the remaining environments and their implications for species richness and composition is part of the management practice of degraded areas, which include the effect of size, isolation and vegetation type within the spots to ensure biological viability in this area (Fahrig, 2003).

In this context, the Brazilian Savanna, with about two million km², is the second largest Brazilian biome and is considered a hotspot for the conservation of biodiversity (Myers et al., 2000; Silva & Bates, 2002; Klink & Machado, 2005; Carvalho et al., 2009), which is primarily threatened

by the expansion of agriculture and livestock (Cunha et al., 2008; Carvalho et al., 2009; Strassburg et al., 2007). Between the 1960s and 1980s, 67% of the Brazilian Savanna areas were modified by burning, deforestation, fertilizer and agrochemicals use due to the expansion of agriculture and livestock (Ramos et al., 2003a). In addition, according to Machado et al. (2004), deforestation rates of the biome ranged from 22,000 to 30,000 km² by the end of the 20th century. Such expansion and degradation of the Brazilian Savanna severely threatens the biome and endemic species, making monitoring and policies for future biome prevention necessary (Klink & Machado, 2005; Ferreira et al., 2013; Carranza et al., 2015; Strassburg et al., 2017).

Considering the increasing environmental problems due to habitat loss, methods for environmental monitoring have been developed using biological indicators (Tolmasquim, 2001; Hunter, 2002; Henry et al., 2007), which consider the presence of certain species, or taxa, as an estimate of well-defined environmental conditions (Wilson, 1994; Hughes et al., 2010; Gerlach et al., 2013; Beiroz et al., 2014; Siddig et al., 2016). The presence of certain organisms in a habitat provides information about the environmental situation from reactions when exposed to different types of degradation (Allaby, 1992; Mazzoni-Viveiros & Trufem, 2004). According to McGeoch (1998) bioindicator species are divided into environmental, ecological, and diversity indicators, each one indicating some sensitive and changes in environment or in biodiversity. The most commonly used indicators are environmental quality and integrity (42%), pollution and contamination (18%), and management and restoration of ecosystems (18%). However, syntheses and revisions are infrequent (2%) (Siddig et al., 2016).

In general, invertebrates correspond to approximately 30% of the work on bioindication (Siddig et al., 2016), among them ants, which can be classified as environmental, ecological and diversity bioindicators, since they have a sensitivity to environmental change, great abundance, are present in both intact habitats and disturbed areas, and are taxonomically well known (Majer, 1983a). Secondly, they have high species diversity, behavioral plasticity, besides being of ecological and functional importance in almost all trophic levels of terrestrial ecosystems (Majer, 1983b; Greenslade & Greenslade, 1984; Winston, 1995; Alonso, 2000). Among the studies on ants as bioindicators, Ribas et al. (2012) carried out a bibliographic review that covered a period of 25 years (1987 to 2010) on ants as bioindicators in Brazil, but did not separate studies by Brazilian biomes. One aspect that has been poorly addressed in reviews, theoretical and applied paper in ants is the importance of conducting assessment of ants as biological indicators dealing particurlarly with a biome. Since species or group of species that may be biological indicators of conservation in one biome, may not be in another or may indicate similar and different states (Andersen, 1997; Nordén & Appelqvist, 2001). Such separation is still unclear and the knowledge of ant fauna is important for this statment.

Thus, considering the growing environmental problems and habitat loss in the Brazilian Savanna, and the need to verify studies of ants as bioindicators in the biome, the target of this study was to fulfill a bibliographical review on ants as bioindicators in the Brazilian Savanna within the last 30 years, examining: (I) the development of the theme over the years, (II) the most frequent types of bioindication, (III) the parameters of the myrmecofauna analyzed, (IV) the collection methodologies used, (V) to find out which and if ants are good bioindicator species of preserved and degraded environments and (VI) the most frequent State of research in the area.

Materials and Methods

Considering the work of Ribas et al. (2012a), we analyzed the studies that were executed in the Brazilian Savanna and searched out for other papers about ants as bioindicators in that biome within the last 30 years, refining the search between 1986 and 2016. The search was done from September to November/2016, using the same key words used by Ribas et al. (2012a): "ant", "bioindicator", "indicator", "Brazil", adding the words "Brazilian Savanna" and "Cerrado" to our research. This was made in four databases: Scielo, Google Scholar, Scopus, and Periódicos CAPES. The same key words were used also in Portuguese: "*formiga*", "*bioindicador*", "*indicador*" and "*Brasil*".

For all the papers found, we recorded information about the general idea of the article, objectives (descriptive or hypothetical), perturbation (agriculture, human activity, conservation, fire, restauration or ecological succession), collection methodology (pitfall, attractive baits, winkler extractor, active search, attractive baits or observation), stratum (arboreal, epigeal, hypogea and litter ants), ant fauna parameters (richness and diversity or composition), observed environmental parameters (regeneration areas, baits, anthropic action or land use), results obtained (preservation or degradation) and conclusions reached in the study (Table 1). However, the papers were analyzed by verifying the description of ants as bioindicators in the methodology or objectives, as well as presenting "bioindicators" or "indicators" as key words. In addition, ant collection methodology was analyzed to verify the most commonly used collection methods in the studies.

We used the definitions of McGeoch (1998) to analyze whether the papers examined presented ants as environmental, ecological, or diversity bioindicators. Also, we created a list of bioindicator ant species when the papers displayed their occurrence in specific places or showed descriptions throughout the article. The following tests were used to analyze the data: cubic regression between number of papers and the years of publication, chi-square for the proportions of perturbation types, fauna parameters analyzed, and sampling methodologies used in the work, with an alpha of 0.05 for all analyzes.

Table 1. Description of the information evaluated, categories of analysis and description of disturbances of the papers analyzed.

Information	Category	Description
Objectives	Descriptive	Only description of ants species.
	Hypothetical	Hypothesis test comparing sampled areas.
Perturbation	Agriculture	Studies carried out only on agricultural habitats.
	Human activity	Studies on natural habitats and agricultural habitats.
	Conservation	Studies carried out only on natural habitats.
	Fire	Studies that evaluated the presence of fire, whether natural or by anthropic actions.
	Restoration	Studies that evaluated different techniques for the restoration of degraded habitats.
	Ecological succession	Studies that evaluated the natural succession of the habitat.
Collection methodology	Pitfall	Falling trap for soil or vegetation ants sampling.
	Attractive baits	Sardine bait and / or honey.
	Winkler Extractor	Sampling of litter.
	Active Search	Manual collection of ants.
	Pitfall with attractive baits	Fall trap using attractive baits inside.
	Observation	Observation of nests.
Stratum	Arboreal	Ants collected in trees or shrubs.
	Epigeal	Ants collected above ground.
	Hypogea	Ants collected in soil.
	Litter	Ants collected in leaf-litter.
Parameters of ant fauna	Richness and diversity	Number of species and variety of species in a community.
	Composition	Composition of ant species in the study areas.
	Regeneration of areas	Regeneration of degraded areas by fire, mining. The age of regeneration is also considered.
Environmental Parameters	Baits	Application of formicidal baits.
	Anthropic action	Brazilian Savanna subjected to anthropic impacts.
	Land use	Agriculture and eucalyptus plantation.
Results obtained	Preservation	Presence of bioindicators of preserved areas (Brazilian Savanna).
	Degradation	Presence of bioindicator ants from degraded areas.
Conclusions	-	Conclusions reached in each study.

Results

Sixteen papers on ants as bioindicators in the Brazilian Savanna were analyzed, which covered a period of 30 years (from 1986 to 2016). Of these, seven were obtained through the literature review of Ribas et al. (2012) and nine from the new search. Of all the papers analyzed, only two did not present descriptions about ants as bioindicators either in the introduction or in the objectives. Instead, they presented results with potential for bioindication. The other papers mentioned an intention to use ants as bioindicators, by either utilizing the term "indicator" or using ants to indicate environmental parameters (Table 2).

Monitoring studies about ants as bioindicators in the Brazilian Savanna began in 1992, increasing since 2002. This may be related to the publication of the book "Ants: Standard Methods for Measuring and Monitoring Biodiversity" in 2000, since prior to publication there were no established methodological criteria for ant sampling and, hence, with ants were intensified. There has been an increase in the studies in the last years until 2016 ($R^2 = 0.39$; $p > 0.05$, Figure 1A).

The disturbances of the study areas were also analyzed and we found that there were more studies related to perturbation (75%) than to preservation (25%) ($\chi^2 = 16$, d.f. = 1, $p < 0.05$). From the 16 papers, four were related to agriculture (25%), three to habitat restoration and to human activity (18.75% each theme), and two to fire effect, conservation, and succession (12.5% each theme).

The studies differed between the parameters of ant fauna analyzed ($\chi^2 = 33.33$, df = 1, $p < 0.05$), so, we divided them between those which evaluated only richness (six papers, 37.5%) and those that assessed diversity and/or species composition (ten papers, 62.5%). In relation to studies that analyzed only the species richness of ants, four (25%) had a reduction in species richness in disturbed areas and another two studies (12.5%) showed no reduction in richness.

Regarding the studies that analyzed the diversity and/or composition of species (ten papers, 62.5%), only one (6.25%) showed no change in the diversity and/or composition of ant species in degraded areas.

In relation to the ant collection methodologies, pitfall was the most common one (six studies, 37.5%, $\chi^2 = 59.61$, df = 6, $p < 0.05$), with attractive baits in the interior of pitfalls used in two other studies. We also verified the use of Winkler extractors (five studies, 31.25%), in order to sample the ants present in the litter, attractive baits were used to sample ants in four studies (25%) and active search at the study sites in four studies (25%) to complement other collection methodologies. Moreover, we checked the use of entomological umbrella in one study and observation of nests for another study (6.25% each) (Figure 1B). We emphasize that four of the 16 analyzed papers used multiple (two or three) ant sampling methodologies. With the view to relate the answers obtained in the studies on ant composition and richness with the sampling methodologies used, we observed that the studies using Winkler extractor, multiple sampling techniques, pitfall, and attractive baits showed a change in the composition and richness of the species. However, in three studies, which used pitfall and attractive baits methodologies, there was no change in ant composition and richness (Figure 1C).

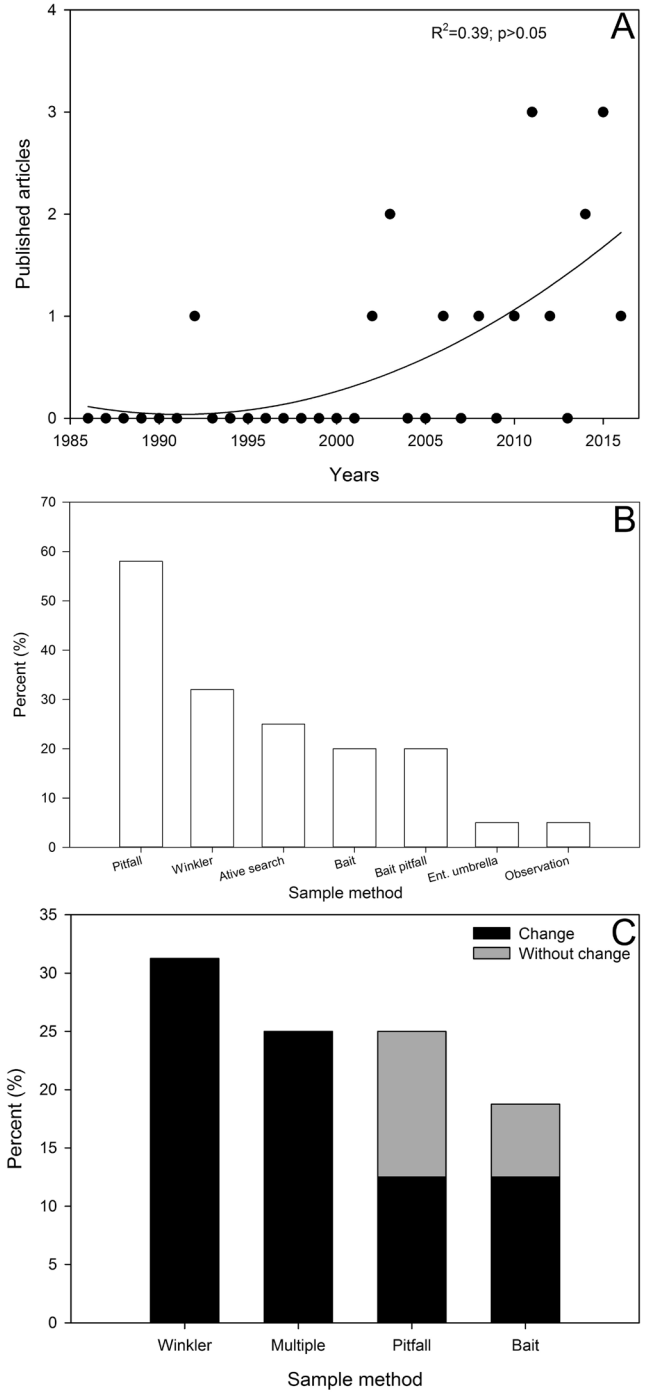

Fig 1. (A) Papers analyzed using ants as bioindicators in the Brazilian Savanna in relation to publication years; (B) Collection methodologies used in the studies analyzed.The papers presenting two or more methods were computed separately, adding up to 100%; (C) Percentage of papers with or without change in richness and composition of species in relation to the sampling methodologies.

Among the analyzed studies, we verified that the ants were sampled in different stratum. Thus, seven papers only collected epigeal ants, followed by litter in four studies. However, in five studies the sampling was carried out in two stratum, three of epigeal and hypogea ants and two of epigeal and arboreal ants. The ants were used as environmental indicators in 14 of the papers, as environmental and diversity indicators in one study, and as ecological indicators in another study. Of the 16 papers, only six did not present lists of species and, therefore, it was possible to make a list of species of Brazilian Savanna bioindicating ants. The parameters used to define the species were presence/absence and frequency of occurrence, both found in five papers each.

In general, 167 species were defined as Brazilian Savanna bioindicators and related to specific habitats according to results found in the articles. These could be Brazilian Savanna sensu stricto (preserved), disturbed Brazilian Savanna, disturbed Brazilian Savanna (post fire), eucalyptus plantation, agriculture, natural and intermediate regeneration of the Brazilian Savanna. The genera with the highest number of indicator species were *Camponotus* (17), *Pachycondyla* (8), *Acromyrmex* (7), *Ectatomma* (7), *Pseudomyrmex* (7), *Cephalotes* (5), *Dolichoderus* (5), *Odontomachus* (5) and *Anochetus* (3) (Table 3).

Following the description of the study areas of the papers that presented a survey of the species collected, we verified that *Linepithema humile*, *Pachycondyla villosa*, *Paratrechina longicornis*, *Pseudomyrmex oculatus* and *Wasmannia rochai* were considered bioindicators of degradation, and were related to eucalyptus plantation and agriculture. The species *Fulakora armigera*, *Camponotus latangulus*, *Cephalotes atratus*, *Cephalotes. Borgmeieri*, *Dolichoderus bispinosus*, *Pachycondyla ferrugínea*, *Pheidole fimbriata*, *Strumigenys zeteki* and *Strumigenys perparva* were considered indicators of preserved areas (Table 3). These criteria for species definition are presented by the authors, however assuming species as bioindicator should be considered some aspects, such as those presented in the discussion just below.

In addition to all the analyzes, we found that 75% of the analyzed papers were carried out in the state of Minas Gerais, followed by Mato Grosso (12.5%), Mato Grosso do Sul (6.25%), and Maranhão (6.25%). This information demonstrates the need for studies in the states such as Bahia, Goiás, Paraná, Piauí, Rondônia, São Paulo and Tocantins (Figure 2).

Discussion

Through a bibliographic review we were able to determine the history of ant research as bioindicators in the Brazilian Savanna in the last 30 years. Between 1986 and 2016, we observed that most of the studies evidenced ants as indicators of environmental quality, diversity, and/or ecology in the introduction and/or objectives. When comparing the number of studies obtained between 1987 and 2010 (seven papers) by Ribas et al. (2012a) with the studies found between the years 2011 and 2016 (nine papers), we verified that there was an increase in the studies on ants as bioindicators in the Brazilian Savanna by more than 128%. This may be related to the increasing environmental problems in the biome caused by habitat loss, and the need to monitor disturbed areas.

Thus, when analyzing the most frequent disturbances we verified that there was a greater amount of studies carried out in degraded areas than in preserved areas, related to agriculture, since there is such great expansion of the agricultural frontier in the Brazilian Savanna. In relation to the studies carried out in preserved areas, we checked that they were related to conservation and succession. This may be related to the need to preserve the areas, since the biome is threatened by agriculture and livestock.

Although most analyzed papers used the terms "bioindicators" and "indicators" in the introduction and/or objectives, not all of them reported results on ants as bioindicators. That because they did not rigorously analyze their results through statistical analysis or because sampling was not fully effective. Among some of the problems we highlight: (i) they did not present control study areas (preserved), (ii) they only sampled one area in different periods or (iii) only compared different plant strata in the same area.

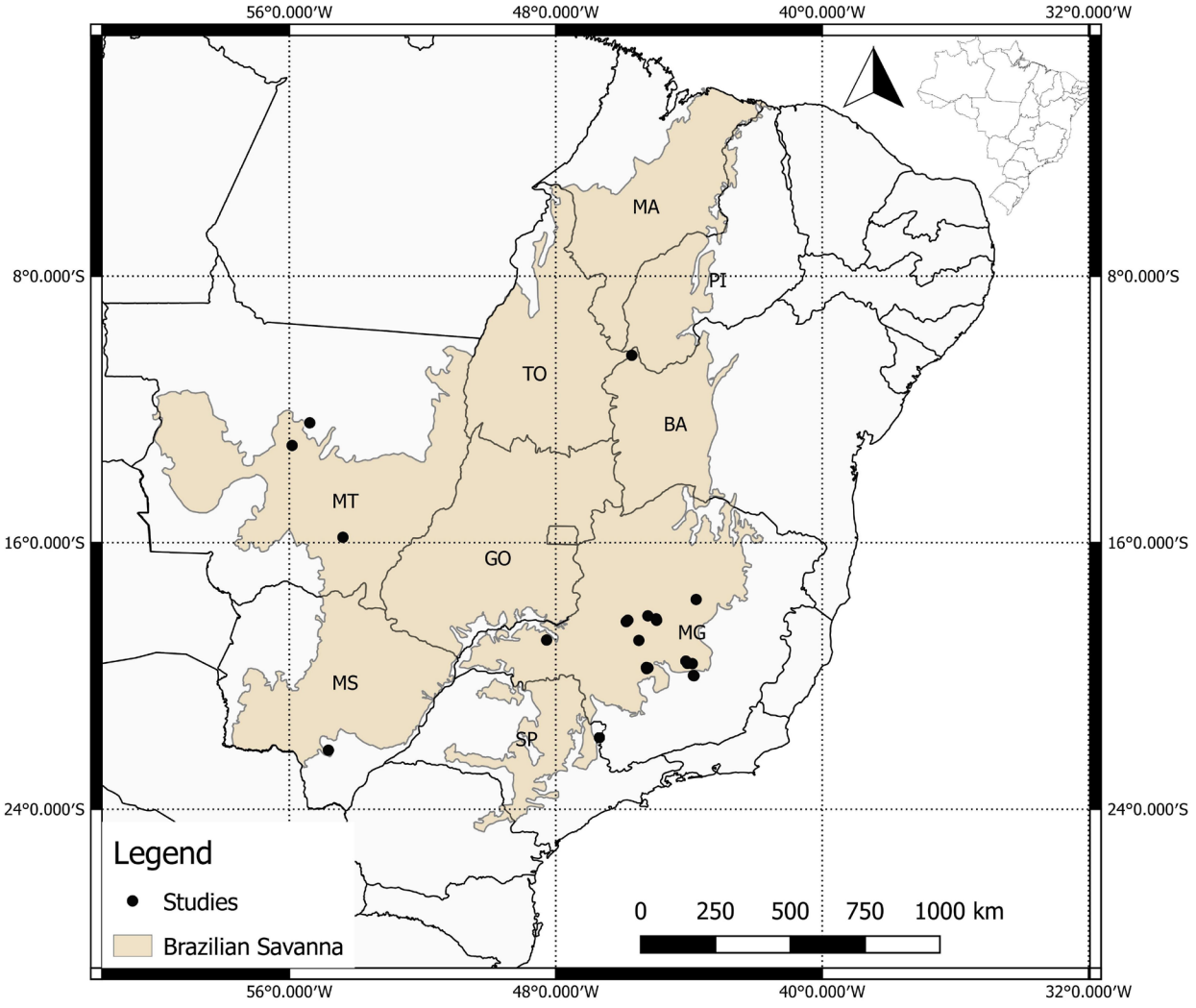

Fig 2. States sampled and studies conducted between 1986 and 2016 in the Brazilian Savanna. Some studies are in transitional areas such as Mato Grosso do Sul (MS) and São Paulo (SP).

We noted that most of the papers were related to ants as environmental indicators, since, according to McGeoch (1998), they are species or group of species that respond to environmental disturbances and are easily observed and quantified. However, we also verified studies on ecological and diversity indicators, which are species that demonstrate the effects of environmental changes and reflect some measures of diversity of other species in a habitat, respectively.

The richness and diversity and/or species composition were the most common parameters of the ant communities analyzed in the papers. We noted that the richness of species is influenced by disturbances, since most of the studies presented a reduction in the richness of ants in disturbed areas. We also verified this in relation to species diversity and/or composition, since most of the analyzed papers also showed a change in the composition of the community in disturbed areas.

Regarding the collection methodology, we verified that most of the studies used only one method. However, considering that ants are present in different stratifications, the use of combined techniques would allow a more complete sampling of the ant community. However, we emphasize that the choice of collection methods is related not only to the sampling of the ants, but also to the financial cost of the study and the time availability for the collection and processing of material. The fact that the most common collection method was the pitfall trap, which is a sampling technique to collect soil and vegetation insects, allows attractive baits to be used in the interior and selects what for the organisms that will be attracted. We emphasize that the use of such methodology can also be related to the low cost to develop it, the duration of the sampling, and the facility to allocate it in the study area.

From the list of species generated and the description in the results of each study the definition of bioindicating species still presents gaps to be filled. Due to the lack of specific analysis of results, these may not be precise. Thus, a more rigorous analysis, such as the Individual Indicator Value, would be required to ensure that species really indicate quality or degradation. This lack of rigor can be verified in the table, since there are various contradictory patterns of occurrence, and species occurring in degraded areas were also present in preserved areas, such as: *Atta laevigata*, *Acromyrmex subterraneus brunneus*, *Acromyrmex rugosus,* among others generic and suprageneric classification (Table 3).

These results on bioindication were obtained from the studies analyzed. Thus, it is important to consider the biology of the species, since the contradictory patterns may be related to possible errors in the delimitation of the study area and sample points. The compilation of species data and bioindications provided by them can be explored in the matter of directing strategies for defining a protocol to take these species as real bioindicators. We see the need to solve the question of the inclusion criteria of the species as a bioindicator. In this way, for example, the area of occurrence of the species and the frequency of records in a particular habitat type (eg the species must always be recorded in perserved environments) should be taken into account. Assume that the timely recording of a given species in a given environment may be detrimental to the exact definition of bioindicator species. It is the suggestion for the creation of a robust database based on previous records of the species and type of habitat where collected. In this way it will be possible to determine the exact definition of the species as bioindicator. Such an adjustment would solve the definition of bioindicators for the various biomes.

The Brazilian Savanna is predominant in 11 Brazilian states, present in Bahia, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, Piauí, Rondônia, São Paulo, and Tocantins. Although, we noted from the bibliographical review that there was higher sampling from the state of Minas Gerais in comparison to the other states and, consequently, a smaller amount or even absence of studies about ants as bioindicators in most of the Brazilian states (Fig 2). This may be related to the reduced number of researchers in each state, the difficulty of sampling areas, the difficulty of access to remaining areas in some states, and even the lack of funding for studies.

Conclusion

Thus, based on the literature review from the last 30 years, we verified that the absence of rigorous analyzes impairs the results of the studies, since the inclusion of statistical analyzes would allow a more precise analysis of the results. As well as knowledge of the ant fauna biology would attribute characteristics of indication of preserved or degraded areas. In addition, the use of a sampling protocol, in which standardization of the sampling method and analyzes to be carried out in future studies, should make the standardization of the work on bioindicators possible, avoiding possible patterns of contradictory occurrence in the inventories.

When using collection protocol aimed at answering questions about bioindicators, it is necessary to create protocol of which parameters are used to define ants as bioindicators. As already shown, species with a double occurrence (+ and - bioindication) should not be bioindicators, or they fit in both categories due to the imprecision of the authors in their categorization. In addition, the use of rare or low-frequency species may mask the patterns, using the most frequent species in each habitat type or desired indication profile, thus generating reliable or generic lists of species for effective monitoring purposes. In addition, a better description of the study areas would allow the inclusion of habitat data, allowing the development of a more robust list of ant species for the Brazilian Savanna. We suggest the creation of a database to solve the definition of bioindicators for the different biomes.

Furthermore, from this review we also verified the need for further studies on bioindicators in the Brazilian Savanna, mainly in the states of Goiás and Tocantins, which contain larger areas of Brazilian Savanna in comparison to the other states and have not presented studies in the past 30 years.

Table 2. Papers analyzed for ants as bioindicators in the Brazilian Savanna, indicating the disturbances investigated, objectives, collection site, indication to be used in bioindicator studies, environmental parameters, ant community response, stratum, type of indicator, and reference of papers.

Perturbation	Objective	Collection site	Indication	Keyword	Environmental Parameters	Effects on the ant community	Stratum	Type of indicator	Reference
Restoration	To investigate which ants have recolonized reclaimed areas and to evaluate the effect of different rehabilitationtechniques, comparing the results with Australia.	Poços de Caldas - MG	Yes	No	Age of regeneration, soil penetration, number of logs, measures of litter and vegetation.	Increased species richness and altered composition (PCoA).	Epigeal	Ecological	Majer (1992)
Human Activity	To inventory the fauna of ants in eucalyptus plantations with different ages of understory.	Bom Despacho - MG	Yes	No	Age of eucalyptus plantation.	Higher density of species in the Brazilian Savanna than in the eucalyptus plantation and similar species richness estimation among the areas.	Litter	Environmental	Marinho et al. (2002)
Agriculture (granulated formicidal baits)	To evaluate the effect of the localized use and the systematic use of granulated baits for the control of leaf-cutting ants on the non-target ant community of the litter in eucalyptus.	Bom Despacho - MG	Yes	No	Forms and timing of application of formicidal baits.	No effect of bait type was found on the richness of ant species. Reduction in species richness observed only in the control method, with systematic application being more damaging.	Epigeal	Environmental	Ramos et al. (2003a)
Conservação	To study the ant community of an area of preserved native Brazilian Savanna and to anthropic impact, evaluating the conservative quality of diversity in the biome.	Bom Despacho - MG	Yes	No	Anthropic action.	Reduction of diversity in impacted sites.	Litter	Environmental	Ramos et al. (2003b)
Conservação	To test the hypothesis that dirt roads are sites favorable to colonization and establishment of nests by founding queens of the *Atta laevigata*.	Uberlândia - MG	Potentially	No	Anthropic action.	The number of attempts to colonize on roads was 5 to 10 times greater than in adjacent vegetation.	Epigeal	Environmental	Vasconcelos et al. (2006)
Human Activity	To evaluate the effect of day and night collection on the faunistic composition of epigeic ants visiting baits in areas planted by eucalyptus and native Brazilian Savanna vegetation.	Paineiras - MG	Potential	No	Land use.	Effect of collection time was more important for ant fauna structure than vegetation effect.	Epigeal	Environmental	Tavares et al. (2008)
Restoration	To evaluate the bioindication of ants in impacted habitats.	Morro do Espinhaço - MG	Yes	Yes	Time since restoration, distance of impact and physical properties of soil.	Greater species richness in the Brazilian Savanna than in the restoration habitats and also greater in the ecotonic and intermediate zones than in the beach and change in abundance and composition.	Epigeal	Environmental	Costa et al. (2010)

Table 2. Papers analyzed for ants as bioindicators in the Brazilian Savanna, indicating the disturbances investigated, objectives, collection site, indication to be used in bioindicator studies, environmental parameters, ant community response, stratum, type of indicator, and reference of papers. (Continuation)

Perturbation	Objective	Collection site	Indication	Keyword	Environmental Parameters	Effects on the ant community	Stratum	Type of indicator	Reference
Succession (soil contamination by arsenic)	To evaluate the potential use of ants communities as bioindicators of the environmental impact caused by arsenic residues in the soil.	Nova Lima-MG	Yes	No	Recovery of areas.	Ant communities were sensitive to changes in the effects of arsenic through changes in habitat condition and availability of environmental resources.	Epigeal and arboreal	Environmental and biodiversity	Ribas et al. (2011)
Agriculture (soybean)	To understand the response of ants' communities on the borders between Brazilian Savanna areas exposed to the use of soybean land.	Chapada das Mangabeiras-MA	Yes	No	Land use (agriculture).	Evidence of edge effects on species composition in ant communities of soil. *Brachymyrmex patagonicus, E. paciventre, C. crassus, L. cerradense* and *W. auropunctata* were classified as species indicating characteristics of the interior of the Brazilian Savanna.	Epigeal	Environmental	Brandão et al. (2011)
Restoration	Evaluate the effectiveness of different rehabilitation efforts after gold mining activities using ants as bioindicators.	Nova Lima-MG	Yes	No	Recovery of areas.	The results of the IndVal test showed a species of Hypoponera as an indicator of area rehabilitation after mining activities being dominated by grasses.	Epigeal and hypogea	Environmental	Ribas et al. (2012b)
Human activity	Examine the assemblage of species of ants in different places of trails.	São Gonçalo do Abaté, Três Marias and Andréquicé-MG	Yes	Yes	Land use (eucalyptus plantation).	Association of ants is characterized by the habitat type and the ant fauna of the Brazilian Savanna is resilient to the surrounding impacts in terms of species richness but not species composition.	Epigeal and hypogea	Environmental	Costa-Milanez et al. (2014)
Agriculture and Livestock	To evaluate the ants community of the soil in an integrated crop-livestock system.	Dourados-MS	Yes	No	Land use (agriculture and eucalyptus plantation).	The morphospecies of *Strumygenys* sp. and *Hypoponera* sp. Were found only in agricultural areas.	Litter	Environmental	Crepaldi et al. (2014)
Fire	To verify the effects of fire in Brazilian Savanna *sensu stricto* trails using ants as tools to evaluate changes in biodiversity and environmental conditions.	São Gonçalo do Abaté and Andréquicé-MG	Yes	Yes	Land use (post fire).	Increased species richness in the Brazilian Savanna after fire.	Epigeal and arboreal	Environmental	Costa-Milanez et al. (2015)
Agriculture	To verify the impacts caused on the biodiversity of the local myrmecofauna, due to the replacement of the native area of Brazilian Savanna.	Lucas do Rio Verde and Vera-MT	Yes	Yes	Land use (agriculture and eucalyptus plantation).	The bioindicator paper of the genus *Pheidole* was verified, being only found in the environment of Brazilian Savanna, which corresponds to its characteristic of colonizing conserved environments.	Litter	Environmental	Corasa et al. (2015)
Succession	To evaluate the species of ants that occur associated to diamond mining, besides identifying the possible species with potential of environmental bioindicators for areas related to this economic activity.	Poxoréu - MT	Yes	Yes	Regeneration of areas (mining).	The species *Forelius brasiliensis* can be considered a bioindicator of environmental degradation in diamond mining and anthropization, while *Camponotus atriceps, Pachycondyla crassinoda* and *Paraponera clavata* can be considered bioindicators of preserved Brazilian Savanna.	Epigeal	Environmental	Rocha et al. (2015)
Fire	To evaluate the impact of the environmental disturbance caused by the anthropic fire on the community of epigeic and hypogical ants	Lagoa Santa, Pedro Leopoldo and Matozinhos - MG	Yes	Yes	Regeneration of areas (post fire).	Ant communities are partially affected by fire occurrences, and epigenetic assemblages are most affected compared to hypoglycemic ants.	Epigeal and hypogea	Environmental	Canedo-Júnior et al. (2016)

Table 3. Species of ants defined as bioindicators for preservation or degradation in the reference studys, indicating the parameter used to relate to the habitat type, and the reference of the papers analyzed.

Subfamily	Species	Parameter	Collection site	Habitat	Bioindicator	References
Amblyoponinae	*Fulakora armigera* (Mayr, 1887)	Presence/ absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
Dolichoderinae	*Azteca alfari* (Emery, 1893)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Dolichoderus bispinosus (Olivier, 1792)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Dolichoderus germaini (Emery, 1894)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna perturbado	Degradation	Costa-Milanez et al. (2015)
	Dolichoderus imitator (Emery, 1894)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Dolichoderus lamellosus (Mayr, 1870)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Dolichoderus lutosus (Smith, 1858)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
	Dorymyrmex brunneus (Forel, 1908)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Dorymyrmex pyramicus (Roger, 1963)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Dorymyrmex spurius (Santschi, 1929)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Dorymyrmex thoracicus (Gallardo, 1916)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Forelius brasiliensis (Forel, 1908)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
		Presence / absence	Poxoréu - MT	Disturbed Brazilian Savanna	Degradation	Rocha et al. (2015)
	Forelius maranhaoensis (Cuezzo, 2000)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Gracilidris pombero (Wild & Cuezzo, 2006)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
	Linepithema anathema (Wild, 2007)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Linepithema cerradense (Wild, 2007)	Presence/ absence	Nova Lima - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2012b)
	Linepithema humile (Forel, 1908)	Presence/ absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
Dorylinae	*Labidus coecus* (Latreille, 1802)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Labidus praedator (Smith, 1858)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna perturbado	Degradation	Ramos et al. (2003b)
		Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)

Table 3. Species of ants defined as bioindicators for preservation or degradation in the reference studys, indicating the parameter used to relate to the habitat type, and the reference of the papers analyzed. (Continuation)

Subfamily	Species	Parameter	Collection site	Habitat	Bioindicator	References
Dorylinae	*Neivamyrmex orthonotus* (Borgmeier, 1933)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
Ectatomminae	*Ectatomma brunneum* (Smith, 1958)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Ectatomma edentatum (Roger, 1863)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
		Presence / absence	Bom Despacho - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2011b)
	Ectatomma lugens (Emery, 1894)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
	Ectatomma muticum (Mayr, 1870)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Ectatomma permagnum (Forel, 1908)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Ectatomma planidens (Borgmeier, 1939)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
	Ectatomma tuberculatum (Olivier, 1792)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Gnamptogenys acuminata (Emery, 1896)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Gnamptogenys striatula (Mayr, 1884)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
Formicinae	*Camponotus atriceps* (Smith, 1858)	Presence / absence	Poxoréu - MT	Brazilian Savanna sensu stricto	Preservation	Rocha et al. (2015)
	Camponotus bidens (Mayr, 1870)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Camponotus blandus (Smith, 1858)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Camponotus bonariensis (Mayr, 1868)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
	Camponotus burtoni (Mann, 1916)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Camponotus cameranoi (Emery, 1894)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and A ndrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
	Camponotus crassus (Mayr, 1862)	Presence / absence	Bom Despacho - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2011b)
	Camponotus fastigatus (Roger, 1863)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
		Presence / absence	Bom Despacho - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2011)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)

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Subfamily	Species	Parameter	Collection site	Habitat	Bioindicator	References
Formicinae	*Camponotus latangulus* (Roger, 1863)	Presence / absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Camponotus melanoticus (Emery, 1894)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Camponotus novogranadensis (Mayr, 1870)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
	Camponotus punctatus minutior (Forel, 1912)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Camponotus renggeri (Emery, 1894)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Camponotus rufipes (Fabricius, 1775)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003)
		Presence / absence	Lagoa Santa, Pedro Leopoldo and Matozinhos - MG	Disturbed Brazilian Savanna	Degradation	Canedo-Júnior et al. (2016)
	Camponotus sericeiventris (Guérin-Méneville, 1838)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Camponotus sexgutattus (Fabricius, 1793)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna perturbado (pós fogo)	Degradation	Costa-Milanez et al. (2015)
	Camponotus trapezoideus (Mayr, 1870)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
		Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Gigantiops destructor (Fabricius, 1804)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Nylanderia fulva (Mayr, 1862)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Paratrechina longicornis (Latreille, 1802)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequência de ocorrência	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
Myrmicinae	*Acromyrmex balzani* (Emery, 1890)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Acromyrmex coronatus (Fabricius, 1804)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Acromyrmex landolti (Forel, 1885)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Acromyrmex niger (Smith, 1858)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Acromyrmex rugosus (Smith, 1858)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)

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Myrmicinae	*Acromyrmex subterraneus brunneus* (Forel, 1912)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Acromyrmex subterraneus subterraneus (Forel, 1893)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Apterostigma pilosum (Mayr, 1865)	Presence / absence	Dourados - MS	Brazilian Savanna sensu stricto	Preservation	Crepaldi et al. (2014)
	Atta laevigata (Smith, 1858)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and A ndrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
	Atta sexdens rubropilosa (Linnaeus, 1758)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
	Blepharidatta conops (Kempf, 1967)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Cardiocondyla emeryi (Forel, 1881)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Carebara urichi (Wheeler, 1922)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Cephalotes atratus (Linnaeus, 1758)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Cephalotes borgmeieri (Kempf, 1951)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
	Cephalotes cristopherseni (Forel, 1912)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
	Cephalotes pavonii (Latreille, 1809)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Cephalotes pusillus (Klug, 1824)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Crematogaster erecta (Mayr, 1866)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Crematogaster tenuicula (Forel, 1904)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Cyphomyrmex peltatus (Kempf, 1966)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
	Cyphomyrmex transversus (Emery, 1894)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Monomorium florícola (Jerdon, 1851)	Presence / absence	Nova Lima - MG	Intermediate Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2012b)
	Mycetagroicus cerradensis (Brandão & Mayhé-Nunes, 2001)	Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
	Mycocepurus goeldii (Forel, 1893)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)

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Myrmicinae	*Mycocepurus smithii* (Forel, 1893)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Myrmicocrypta foreli (Mann, 1916)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Nesomyrmex asper (Mayr, 1887)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Nesomyrmex brasiliensis (Kempf, 1958)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Nesomyrmex spininodis (Mayr, 1887)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
	Ochetomyrmex semipolitus (Mayr, 1878)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Octostruma jheringhi (Emery, 1887)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Pheidole fimbriata (Roger, 1863)	Presence / absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Pheidole gertrudae (Forel, 1886)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Pogonomyrmex abdominalis (Santschi, 1929)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Rogeria scobinata (Kugler, 1994)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Sericomyrmex parvulus (Forel, 1912)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
	Solenopsis saevissima (Smith, 1855)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Solenopsis substituta (Santschi, 1925)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Strumigenys elongata (Roger, 1863)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Strumigenys perparva (Brown, 1958)	Presence / absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Strumigenys subdentata (Mayr, 1887)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Strumigenys zeteki (Brown, 1959)	Presence / absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
	Trachymyrmex bugnioni (Forel, 1912)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Trachymyrmex dichrous (Kempf, 1967)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Trachymyrmex fuscus (Emery, 1834)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
	Wasmannia auropunctata (Roger, 1863)	Presence / absence	Nova Lima - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2012b)

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Subfamily	Species	Parameter	Collection site	Habitat	Bioindicator	References
Myrmicinae	*Wasmannia rochai* (Forel, 1912)	Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
		Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Disturbed Brazilian Savanna (post-fire)	Degradation	Costa-Milanez et al. (2015)
Paraponerinae	*Paraponera clavata* (Fabricius, 1775)	Presence / absence	Poxoréu - MT	Brazilian Savanna sensu stricto	Preservation	Rocha et al. (2015)
Ponerinae	*Anochetus bispinosus* (Smith, 1858)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Anochetus diegensis (Forel, 1912)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003a)
	Anochetus inermis (André, 1889)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Eucalyptus plantation	Degradation	Corasa et al. (2015)
	Dinoponera gigantea (Perty, 1833)	Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
	Ectomomyrmex apicalis (Smith, 1857)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Hypoponera foreli (Mayr, 1887)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003a)
	Odontomachus bauri (Emery, 1892)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Chapada das Mangabeiras - MA	Brazilian Savanna sensu stricto	Preservation	Brandão et al. (2011)
		Presence / absence	Dourados - MS	Agriculture	Degradation	Crepaldi et al. (2014)
	Odontomachus bruneus (Mayr, 1887)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003a)
	Odontomachus chelifer (Latreille, 1802)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003a)
	Odontomachus haematodus (Linnaeus, 1758)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Eucalyptus plantation	Degradation	Corasa et al. (2015)
	Odontomachus meinerti (Forel, 1905)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003a)
		Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2014)
	Pachycondyla crassinoda (Latreille, 1802)	Presence / absence	Poxoréu - MT	Brazilian Savanna sensu stricto	Preservation	Rocha *et al.* (2015)
	Pachycondyla harpax (Fabricius, 1804)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Pachycondyla striata (Smith, 1858)	Presence / absence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Marinho et al. (2002)
		Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003b)
		Presence / absence	Nova Lima - MG	Natural Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2012b)
	Pachycondyla villosa (Fabricius, 1804)	Frequency of occurrence	Bom Despacho - MG	Disturbed Brazilian Savanna	Degradation	Ramos et al. (2003b)
		Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Pseudoponera gilberti (Kempf, 1960)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)

Table 3. Species of ants defined as bioindicators for preservation or degradation in the reference studys, indicating the parameter used to relate to the habitat type, and the reference of the papers analyzed. (Continuation)

Subfamily	Species	Parameter	Collection site	Habitat	Bioindicator	References
Ponerinae	*Pseudoponeraa stigma* (Fabricius, 1804)	Frequency of occurrence	São Gonçalo do Abaté and Andrequicé - MG	Brazilian Savanna sensu stricto	Preservation	Costa-Milanez et al. (2015)
	Rasopone ferrugínea (Smith, 1858)	Presence / absence	Dourados - MS	Brazilian Savanna sensu stricto	Preservation	Crepaldi et al. (2014)
	Thaumatomyrmex mutilatus (Mayr, 1887)	Frequency of occurrence	Bom Despacho - MG	Brazilian Savanna sensu stricto	Preservation	Ramos et al. (2003a)
Pseudomyrmecinae	*Pseudomyrmex flavidulus* (Smith, 1858)	Frequency of occurrence	Chapada das Mangabeiras - MA	Agriculture	Degradation	Brandão et al. (2011)
	Pseudomyrmex gracilis (Fabricius, 1804)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Pseudomyrmex oculatus (Smith, 1855)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Frequency of occurrence	São Gonçalo do Abaté, Três Marias and Andrequicé - MG	Eucalyptus plantation	Degradation	Costa-Milanez et al. (2014)
	Pseudomyrmex pupa (Forel, 1911)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Pseudomyrmex simplex (Smith, 1877)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
	Pseudomyrmex tenuis (Fabricius, 1804)	Frequency of occurrence	Lucas do Rio Verde and Vera - MT	Brazilian Savanna sensu stricto	Preservation	Corasa et al. (2015)
	Pseudomyrmex termitarius (Smith, 1855)	Presence / absence	Bom Despacho - MG	Eucalyptus plantation	Degradation	Marinho et al. (2002)
		Presence / absence	Nova Lima - MG	Intermediate Regeneration of the Brazilian Savanna	Preservation	Ribas et al. (2012b)

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References

Allaby, M. (1992). The Concise Oxford dictionary of Zoology. Oxford University Press, Oxford, p. 442.

Alonso, L.E. (2000). Ants as indicators of diversity. In: Agosti, D., Majer, J. D., Alonso, L. E. & Schultz, T. R. (Ed). Ants – standard methods for measuring and monitoring biodiversity. Washington: Smithsonian Institution Press, 80–88.

Andersen, A.N. (1997). Using Ants as bioindicators: Multiscale Issues in Ant Community Ecology. Conservation Ecology, 1: 1-12.

Balmford, A., Bennun, L., Brink, B.T., Cooper, D., Côté, I.M., Crane, P. Dobson, A. Dudleu, N., Dutton, I., Green, R.E., Gregory, R.D., Harrison, J., Kennedy, E.T., Kremen, C., Leader-Williams, N., Lovejoy, T.E., Mace, G., May, R.,Mayauz, P., Morling, P., Phillips, J., Redford, K., Ricketts, T.H., Rodríguez, J.P., Sanjayan, M., Schei, P.J., Jaarsveld, A.S. and Walther, A. (2005). The convention on biological diversity's 2010 target. Science, 307(5707), 212–213. doi: 10.1126/science.1106281

Bascompte, J. and Sole, R. (1996). Habitat fragmentation and extinction thresholds in spatially explicit models. Journal Animal Ecology, 65: 465-473. doi: 10.2307/5781

Beiroz, W., Audino, L.D., Queiroz, A.C.M., Rabello, A.M., Boratto, I.A., Silva, Z. and Ribas, C.R. (2014). Structure and composition of edaphic arthropod community and its use as bioindicators of environmental disturbance. Applied Ecology Environmental Research. 12: 481-491.

Brandão, C.R.F., Silva, R.R. and Feitosa, R.M. (2011). Brazilian Savanna ground-dwelling ants (Hymenoptera: Formicidae) as indicators of edge effects. Zoologia, 28: 379-387. doi: 10.1590/S1984-46702011000300012

Canedo-Júnior, E., Cuissi, R.G., Curi, N.A., Demetrio, G.R., Lasmar, C., Malves, K. and Ribas, C.R. (2016). Can anthropic fires affect epigaeic and hypogaeic Brazilian Savanna ant

(Hymenoptera: Formicidae) communities in the same way?. Revista de Biología Tropical/International Journal of Tropical Biology and Conservation, 64: 95-104. doi: 10.15517/rbt.v64i1.18239

Carranza, T., Manica, A., Kapos, V., and Balmford, A. (2014). Mismatches between conservation outcomes and management evaluation in protected areas: a case study in the Brazilian Brazilian Savanna. Biological Conservation, 173: 10-16. doi: 10.1016/j.biocon.2014.03.004

Carvalho, F.M.V, Júnior, P.D.M. and Ferreira. L.G. (2009). The Cerrado into-pieces: Habitat fragmentation as a function of landscape use in the savannas of central Brazil. Biological Conservation, 142: 1392-1403. doi: 10.1016/j.biocon.2009.01.031

Corassa, J.D.N., Faixo, J.G., Andrade Neto, V.R. and Santos, I.B. (2015). Biodiversidade da mirmecofauna em diferentes usos do solo no Norte Mato-Grossense. Comunicata Scientiae, 6: 154-163.

Costa, C.B., Ribeiro, S.P. and Castro, P.T.A. (2010). Ants as bioindicators of natural succession in savanna and riparian vegetation impacted by dredging in the Jequitinhonha River Basin, Brazil. Restoration Ecology, 18: 148-157. doi: 10.1111/j.1526-100X.2009.00643.x

Costa-Milanez, C.B., Lourenço-Silva, G., Castro, P.T.A., Majer, J.D. and Ribeiro, S.P. (2014). Are ant assemblages of Brazilian veredas characterised by location or habitat type?. Brazilian Journal of Biology, 74: 89-99. doi: 10.11 11/j.1526-100X.2009.00643.x

Costa-Milanez C.B., Ribeiro F.F., Castro P.T.A., Majer J.D. and Ribeiro S.P. (2015). Effect of fire on ant assemblages in brazilian Brazilian Savanna in areas containing vereda wetlands. Sociobiology, 62: 494-505. doi: 10.13102/sociobiology.v62i4.770

Crepaldi, R.A., Portilho, I.I.R., Silvestre, R. and Mercante, F.M. (2014). Formigas como bioindicadores da qualidade do solo em sistema integrado lavoura-pecuária. Ciência Rural, 44: 781-787. doi: 10.1590/S0103-84782014000500004

Cunha, N.R.S., Lima, J.E., Gomes, M.F.M. and Braga, M.J. (2008). A intensidade da exploração agropecuária como indicador da degradação ambiental na região dos Brazilian Savannas, Brasil. Revista de Economia e Sociologia Rural, 46: 291-323. doi: 10.1590/S0103-20032008000200002

Dirzo, R and Raven, P. H. (2003). Global State of Biodiversity and Loss. Annual Review of Environment and Resources, 28: 137-167. doi: 10.1146/annurev.energy.28.050302.105532

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution and Systematics, 34: 487-515. doi: 10.1146/annurev.ecolsys.34.011802.132419

Ferreira, M.E., Ferreira Jr, L.G., Miziara, F., and Soares-Filho, B.S. (2013). Modeling landscape dynamics in the central Brazilian savanna biome: future scenarios and perspectives for conservation. Journal of Land Use Science, 8: 403-421. doi: 10.1080/1747423X.2012.675363

Gerlach, J., Samways, M. and Pryke, J. (2013). Terrestrial invertebrates as bioindicators: An overview of available taxonomic groups. Journal of Insect Conservation, 17: 831-850.

Golden, D.M. and Crist, T. O. (1999). Experimental effects of habitat fragmentation on old-field canopy insects: Community, guild and species responses. Oecologia, 118: 371-380. doi: 10.1007/s004420050738

Greenslade, P.M.J. and Greenslade, P. (1984). Invertebrates and environmental assessment. Environment and Planning, 3: 13-15.

Henry, M., Cosson, J.F and Pons, J.M. (2007). Abundance may be a misleading indicator of fragmentation-sensitivity: The case of fig-eating bats. Biological Conservation, 139: 462-467. doi: 10.1016/j.biocon.2007.06.024

Hughes, S.J., Santos, J., Ferreira, T. and Mendes, A. (2010). Evaluating the response of biological assemblages as potential indicators for restoration measures in an intermittent Mediterranean river. Environmental Management, 46; 285-301.

Hunter, M. D. (2002). Landscape structure, habitat fragmentation, and the ecology of insects. Agricultural and Forest Entomology, 4: 159-166. doi: 10.1046/j.1461-9563. 2002.00152.x

Kageyama, P.K. and Gandara, F.B. (1998). Indicadores de sustentabilidade de florestas naturais. Série técnica do IPEV, 12: 79-83.

Kattan, G.H. and Alvarez-López, H. (1996). Preservation and management of biodiversity in fragmented landscape in the Colombian Andes. In: Schelhas, J & Greenberg, R. (eds) Forest patches in tropical landscapes. Island Press, Washington, DC, 3–18.

Kellman, M., Tackaberry, R. and Meave, J. (1996). The consequences of prolonged fragmentation: lessons from tropical gallery forests. In: Schellas, J. & Greenberg, R. (Ed.).1996. Forest patches in tropical landscapes. Washington: University Island Press, 37–58.

Klink, C.A. and Machado, R.B. (2005). Conservation of the Brazilian Brazilian Savanna. Conservation Biology. 19: 707-713.

Lovejoy, T.E., Bierregard Jr., R.O., Rylands, A.B., Malcolm J.R., Quintela, C.E., Harper, L.H.; Brown Jr., K.S., Powell, A.H., Powell G.V.N., Schubart, H.O.R. and Hays, M.B. (1986). Edge and Other Effects of Isolation on Amazon Forest Fragments. In: Soulé M. (ed.). Conservation Biology: The science of scarity and diversity. Sinauer Associates Inc., Sunderland, Massachussets. 257-258.

Machado, R.B., Ramos Neto, M.B, Pereira, P., Caldas, E., Gonçalves, D., Santos, N., Tabor, K. and Steininger, M. (2004). Estimativas de perda da área do Brazilian Savanna brasileiro. Conservation International do Brasil, Brasília.

Majer, J.D. (1983a). Ants: bio-indicators of minesite rehabilitation, land-use, and land conservation. Environmental Management 7: 375-386.

Majer, J.D. (1983b). Ant manipulation in agro-and forest-ecosystems. In: Congress of the International Union for the study of social insects. 9; Boulder. They bilogy of social insects: proceeding Boulder: Westview Press, 91–97.

Majer, J.D. (1992). Ant recolonisation of rehabilitated bauxitemines of Poços de Caldas, Brazil. Journal of Tropical Ecology, 8: 97-108.

Marinho, C.G.S., Zanetti, R., Delabie, J.H.C., Schlindwein, M.N. and Ramos, L.D.S. (2002). Ant (hymenoptera: formicidae) diversity in eucalyptus (myrtaceae) plantations and Brazilian Savanna litter in Minas Gerais, Brazil. Neotropical Entomology, 31: 187-195. doi: 10.1590/S1519-566X2002000200004

Mazzoni-Viveiros, S. C., & Trufem, S. F. B. (2004). Efeitos da poluição aérea e edáfica no sistema radicular de Tibouchina pulchra Cogn. (Melastomataceae) em área de mata Atlântica: associações micorrízicas e morfologia. Revista Brasileira de Botânica, 27: 337-348.

McGeoch, M.A. (1998). The selection, testing and application of terrestrial insects as bioindicators. Biological Reviews of the Cambridge Philosophical Society, 73: 181-201. doi: 10.1590/S0100-84042004000200013

Mortelliti, A., Amori, G., Capizzi, D., Cervone, C., Fagiani, S., Pollini, B. and Boitani, L. (2010). Independent effects of habitat loss, habitat fragmentation and structural connectivity on the distribution of two arboreal rodents. Journal of Applied Ecology, 48: 153-162. doi: 10.1111/j.1365-2664. 2010.01918.x

Murphy, S. M., Battocletti, A.H., Tinghitella, R.M, Wimp, G.M. and Ries, L. (2016). Complex community and evolutionary responses to habitat fragmentation and habitat edges: what can we learn from insect science? Current Opinion in Insect Science, 14: 61-65. doi:10.1016/j.cois.2016.01.007

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature 403(333), 853-858. doi: 10.1038/35002501

Nordén, B. and Appelqvist, T. (2001). Conceptual problems of ecological continuity and its bioindicators. Biodiversity and conservation, 10: 779-791. doi: 10.1023/A:101667510

Oliver, T. H., Heard, M.S., Isaac, N.J.B, Roy, D.B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, A.D.L., Petchey, O.L., Proença, V., Raffaelli, D., Suttle, K.B., Mace, G.M., Martín-lópez, B., Woodcock, B.A. and Bullock. J.M. (2015). Biodiversity and resilience of ecosystem functions. Trends in Ecology and Evolution, 30: 673-684. doi: 10. 1016/j.tree.2015.08.009

Ramos, L.S., Marinho, C.G.S., Zanetti, R. Delabie, J.H.C. and Schlindwein, M.N. (2003a). Impact of formicid granulated baits on non-target ants in eucalyptus plantations according to two forms of application. Neotropical Entomology, 32: 231-237. doi: 10.1590/S1519-566X2003000200007

Ramos, L.D., Filho, R.Z.B., Delabie, J.H.C., Lacau, S., Santos, M.F.S., Nascimento, I.C. and Marinho C.G.S. (2003b). Ant communities (Hymenoptera: Formicidae) of the leaf-litter in Brazilian Savanna "stricto sensu" areas in Minas Gerais, Brazil. Lundiana, 4: 95-102.

Ribas, C.R., Solar, R.R.C., Campos, R.B.F., Schmidt, F.A., Valentim, C.L. and Schoereder, J.H. (2012). Can ants be used as indicators of environmental impacts caused by arsenic?. Journal of Insect Conservation, 16: 413-421.

Ribas, C.R., Campos, R B.F., Schmidt, F.A. and Solar, R.R.C. (2012a). Ants as Indicators in Brazil: A Review with Suggestions to Improve the Use of Ants in Environmental Monitoring Programs. Psyche, Article ID 636749, doi: 10.1155/2012/636749. doi: 10.1155/2012/636749

Ribas, C.R., Schmidt, F.A., Solar, R.R.C., Campos, R.B.F., Valentim, C.L. and Schoereder, J.H. (2012b). Ants as Indicators of the Success of Rehabilitation Efforts in Deposits of Gold Mining Tailings. Restoration Ecology, 20: 712-720. doi: 10.1111/j.1526-100X.2011.00831.x

Rocha, W.O., Dorval, A., Peres Filho, O., Vaez, C.A. and Ribeiro, E.S. (2015). Formigas (Hymenoptera: Formicidae) Bioindicadoras de Degradação Ambiental em Poxoréu, Mato Grosso, Brasil. Floresta e Ambiente, 22: 88-98. doi: 10.1590/2179-8087.0049

Siddig, A. A., Ellison, A. M., Ochs, A., Villar-Leeman, C., & Lau, M. K. (2016). How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in Ecological Indicators. Ecological Indicators, 60: 223-230.

Silva, J.M.C. and Bates, J. M. (2002). Biogeographic patterns and conservation in the South American Brazilian Savanna: A tropical savanna hotspot. BioScience, 52: 225-233. doi: 10.1641/0006-3568

Smith, A.C., Koper, N., Francis, C.M and Fahrig, L. (2009). Confronting collinearity: comparing methods for disentangling the effects of habitat loss and fragmentation. Landscape Ecology, 24: 1271. doi: 10.1007/s10980-009-9383-3.

Steffan-Dewenter, I. and Tscharntke, T. (1997). Bee diversity and seed set in fragmented habitats. Acta Horticulturae, 437: 231-234.

Strassburg, B.B., Brooks, T., Feltran-Barbieri, R., Iribarrem,

A., Crouzeilles, R., Loyola, R., and Soares-Filho, B. (2017). Moment of truth for the Brazilian Savanna hotspot. Nature Ecology and Evolution, 1: 0099. doi: 10.1038/s41559-017-0099

Tavares, A.A., Bispo, P.C. and Zanzini, A.C. (2008). Effect of collect time on communities of epigaeic ants (Hymenoptera: Formicidae) in areas of Eucalyptus cloeziana and Brazilian Savanna. Neotropical Entomology, 37: 126-130. doi: 10.1590/S1519-566X2008000200003

Tolmasquim, M.T. (2001). Estrutura conceitual para a elaboração de indicadores de sustentabilidade ambiental para o Brasil. In: Garay, I.E.G., Dias, Braulio F.S. Conservação da Biodiversidade em ecossistemas tropicais: avanços conceituais e revisão de novas metodologias de avaliação e monitoramento. Petrópolis: Editora Vozes, 68-75.

Turner, I.M. (1996). Species loss in fragments of tropical rain forest: a review of the evidence. Journal of Applied Ecology, 33: 200-209. doi: 10.2307/2404743

Vasconcelos, H.L., Vieira-Neto, E.H.M., Mundim, F.M. and Bruna, E.M. (2006). Roads alter the colonization dynamics of a keystone herbivore in neotropical savannas. Biotropica, 38: 661-665. doi: 10.1111/j.1744-7429.2006.00180.x

Wilson, J. (1994). The role of bioindicators in estuarine management. Estuaries and Coasts, 17: 94-101.

Winston, M.R. (1995). Co-occurrence of morphologically similar species of stream fishes. American Naturalist, 145: 527-545.