

ANTS AS FLAGSHIP SPECIES: WHICH ONES AND WHY? A STUDY CASE WITH BRAZILIAN ANTS

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ABSTRACT

The fragmentation and loss of habitats, pollution, and climatic change are the main drivers leading to an unprecedented decline in insect populations. A strategy to generate public engagement and funding for conservation action is using flagship species. Large mammals and top predators are often used as flagship species, but this does not ensure that insects also might benefit from this strategy. A solution to this bias is to select insects as flagship species directly. Three categories of flagship insects are proposed: ecosystem service providers, threatened species, and charismatic species. Unfortunately, ants are popularly known as pests or unbeloved species making it difficult to discuss conservation strategies for them. Hence, selecting ants as flagship species would require direct attention and conservation efforts straight to them. Our aim is to select ants as flagship species, considering the species' ecological importance and charismatic appeal using species occurring in Brazil as a study case. Using the list of officially threatened species in Brazil and the non-human charisma concept, we selected two species as potential flagship species with ecological relevance and charisma: *Dinoponera lucida* for the Atlantic Forest and *Atta robusta* for restinga. In addition, we discuss the use of species with cultural relevance as flagship species and *Eciton burchellii* as an umbrella species used as flagship species too. We hope this study stimulates ant researchers to work with conservation biologists, social studies researchers, politicians, grassroots organizations, and other stakeholders in projects using ants as flagship species for conservation.

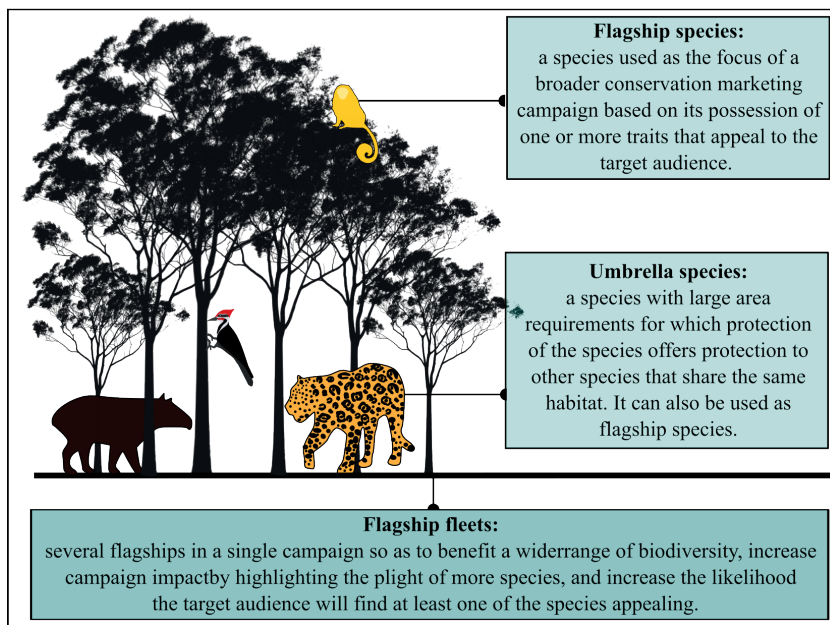
Keywords: Formicidae; conservation; charismatic species; endangered species; umbrella species.

INTRODUCTION

Recent analyses have highlighted a worrying global decline in insect populations (SÁNCHEZ-BAYO and WYCKHUYS, 2019. SEIBOLD *et al.*, 2020). Despite their vast diversity and importance for ecosystems and human societies, insects are seen by most people as pests that need to be managed. Consequently, they are seldom considered when conservation decisions are made (KIM, 1993). They are important ecosystem service providers acting in processes like pollination, seed dispersal, or even soil fertilization (ELIZALDE *et al.*, 2020). This means that, beyond their intrinsic importance, insects are essential to human society and therefore must be preserved.

The scientific community has paid less attention to insects compared to the greater number of extinction studies on large animals or vascular plants (DUNN, 2005). Given high insect diversity, species monitoring and managing is a laborious and difficult task. Data deficiency is one of the main limitations against biodiversity loss, thus monitoring neglected fauna is required to fill these gaps (HOCHKIRCH *et al.*, 2020). According to Hochkirch *et al.* (2020), a key goal for the next decades is to provide funding mechanisms for these monitoring programs. A conservation strategy to address this biodiversity issue is the use of focal species, also referred as surrogate species (DUCARME; LUQUE; COUR-CHAMP, 2013). Among surrogate species, flagship species are specifically used as symbols for conservation efforts in fundraising campaigns (DIETZ J.; DIETZ L.; NAGAGATA 1994; CARO and O'DOHERTY, 1999; Figure 1).

Figure 1 - Definitions of different surrogate species with conservation appeal. The scheme illustrates the Atlantic Rain Forest and some different species. Animal illustrations do not correspond to the original scale. Flagship species definition from Verissimo, MacMillan and Smith (2011). Umbrella species definition from Ozaki *et al.* (2006). Flagship fleets definition from Verissimo *et al.* (2014).



The conservation appeal exerted by flagship species is exploited using very charismatic species like large mammals or top predators as umbrella species (ALBERT; LUQUE; and COURCHAMP, 2018. Figure 1). However, this strategy does not ensure the conservation of insects and other invertebrates (DIETZ J.; DIETZ L.; NAGAGATA 1994; GUINEY and OBERHAUSER, 2008). This can be explained by two reasons: conservation efforts are concentrated in a single flagship species; and biased conservation campaigns or policies by the teams or individuals who work with these species (VERISSIMO; MACMILLAN; SMITH, 2011). Verissimo *et al.* (2014) also point out that choosing charismatic or umbrella species as flagship species causes saturation of flagship species, weakening the effectiveness of this approach to attract efforts or funding for conservation. In other words, if large mammals compete with each other for funding of their respective campaigns, this competition reduces their effectiveness in attracting funding for their organizations. A suggested solution is focusing

on uncommon species for conservation because they do not suffer from this saturation. This strategy can be reinforced by using species never considered charismatic historically and culturally (DUCARME; LUQUE; COURCHAMP, 2013).

In general, insects suffer from a “charisma challenge” due to stereotyping as pests and disease vectors, leading them to be neglected when discussing conservation strategies (BERENBAUM, 2008). For this reason, insects are unusual options as flagship species and therefore have better chances of standing out from the more typical ones and attracting attention. Attempting to solve this problem, Guiney and Oberhauser (2008) proposed yet to use insects directly as flagship species. Three categories for potential flagship species were proposed: ecosystem service providers, endangered species, and charismatic species. This strategy can be used for direct insect conservation and more broadly to attract attention to general conservation issues. Some insects have already been used as flagship species: butterflies, because of their aesthetical charisma, (BARUA; AHMED; TAMULY, 2012) and bees due to their services as pollinators and honey producers (SUMNER; LAW; CINI, 2018).

Among insects, ants stand out due to their diversity, abundance, huge biomass and eusocial organization (HÖLLDOBLER and WILSON, 1990). Ants are also globally noteworthy as ecosystem service providers and essential to terrestrial ecosystems (DEL TORO; RIBBONS; PELINI, 2012; ELIZALDE *et al.*, 2020). Ants can be a food resource in some cultures or provide substances with potential medical or biotechnology applications. They also act directly as biological controllers of other organisms. Lastly, ants can inspire or be personified in movies, literature, or sacred symbols for some New World indigenous cultures (SLEIGH, 2003). They also have already been used as surrogate species with ecological relevance, like keystone species (Sanders and Van Veen 2011) and bioindicators of ecological restoration (CASIMIRO; SANSEVERO; QUEIROZ, 2019). However, their use as surrogate species with conservation appeal is uncommon (VAN ITTERBEECK *et al.*, 2014).

Brazil has the highest ant species diversity in the Neotropics with thousands of possible new species (BACCARO *et al.*, 2015). There are officially 11 endangered ant species on the Brazilian Red List, threatened mainly by habitat loss, and all of them are endemic to the Atlantic Rainforest (BRASIL, 2022, Table 1). Because of the scarcity of studies monitoring ant populations in Brazil and the

growing rates of deforestation, more species are probably at risk. Considering these factors, the conservation of ants is necessary to ensure their existence, and consequently, the ecosystem services provided by them. There are currently no ants used as flagship species in the Neotropics. Beyond the Neotropics, *Formica rufa* has been proposed as an effective flagship species in Europe (BALZANI *et al.*, 2022). Considering the rich diversity of ants, the extensive habitat loss (BRASIL, 2022), the scarcity of population monitoring studies, and their importance to human societies and terrestrial ecosystems, conservation strategies focused on ants are needed (ALONSO, 2010). Our aim with this study is to select ants as flagship species *per se* in Brazil and for the conservation of their ecosystems, considering the species' ecological importance and charismatic appeal.

METHODS

From the three insect flagship species categories, namely *ecosystem service providers*, *endangered*, and *charismatic species* (GUINEY and OBERHAUSER, 2008), we focus on threatened species due to the urgency of conservation actions. In addition, we filtered the charismatic ones according to the non-human charisma concept proposed by Lorimer (2007) (Figure 2). This way, we combine conservation priorities (threatened status) and charismatic features that can be used with the flagship species selected. We performed bibliographic research about studies published in Brazil from 1945 to 2019 with ants with cultural importance using SCIELO (All Databases) and SCOPUS (Elsevier). Given the traditional practice of consuming *Atta* queens by human populations in Brazil, the following keywords were individually paired with "Formicidae" during the literature search: *entomophagy*, *Atta*; *biotechnology*; *biological control*; *ethnobiology/ethnoentomology*. The species with cultural importance were not filtered through the non-human charisma concept because they were already considered charismatic to the cultures in which they are used (BOWEN-JONES and ENTWISTLE, 2002, Table 2).

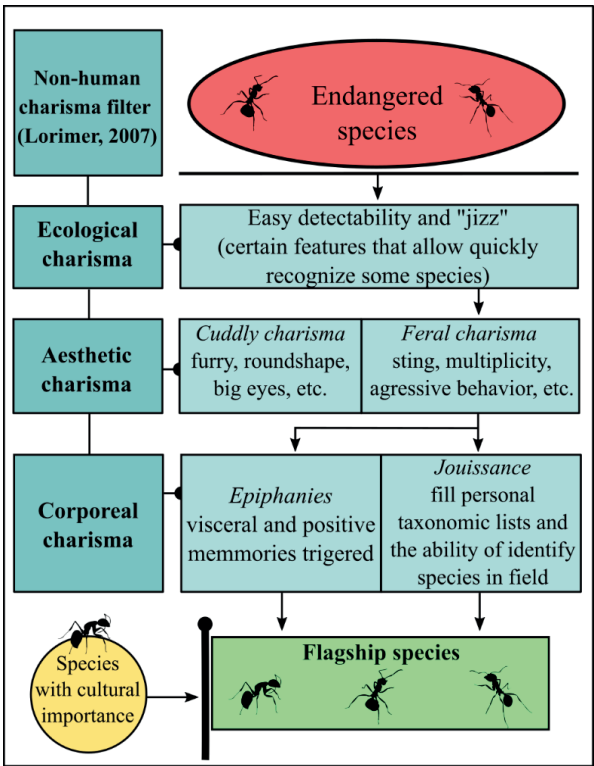
Table 1 - List of endangered ant species in Brazil (Brasil, 2022). All the threat categories follow the IUCN Red List pattern. VU=Vulnerable; EN=Endangered; Critically Endangered (CR); Protected areas: PE=Parque Estadual; APA=Área de Proteção Ambiental; PARNA: Parque Nacional; RPPN: Reserva Particular do Patrimônio Natural; REBIO: Reserva Biológica; FLONA: Floresta Nacional.

Ant species	Threat category	Habitat	Occurrence at protected areas
<i>Atta robusta</i> (Borgmeier, 1939)	VU	Restinga on the coast of Rio de Janeiro (RJ) and Espírito Santo (ES) states.	PE de Itaúnas, REBIO de Comboios, PE de Setibas, APA Costa das Algas (ES); Parque Natural Municipal do Grumari, PM Ecológico de Marapendi (RJ)
<i>Brachymyrmex micromegas</i> Santschi, 1923	VU	City of Agudos, Anhembí, Mogi das Cruzes and São Paulo, in São Paulo (SP) State.	APA Estadual Várzea do Rio Tietê (SP)
<i>Diaphoromyrma sofiae</i> Fernández, Delabie & Nascimento, 2009	EN	Natural reserves between eucalyptus plantations in the south of Bahia (BA) state in the cities of Porto Seguro and Santa Cruz Cabrália.	PARNA do Pau-Brasil, RPPN Estação Veracel (BA)
<i>Dinoponera lucida</i> Emery, 1901	EN	Atlantic Forest from southern Bahia (BA) to Espírito Santo (ES) states and in small isolated forest areas in the east of Minas Gerais state.	PARNA e Histórico do Monte Pascoal, PARNA do Pau Brasil (BA); REBIO de Sooretama, FLONA de Goytacazes, PE de Fonte Grande, REBIO de Duas Bocas (ES).
<i>Fulakora cleae</i> (Lacau & Delabie, 2002)	CR	Known only by type locality in a fragment of semi-deciduous forest on top of a hill in Itororó city, southern of Bahia (BA) state.	Unknown
<i>Gnamptogenys wilsoni</i> Lattke, 2007	EN	Known by a few registers in Ilhéus city, Bahia (BA).	Unknown
<i>Monomorium delabiei</i> Fernández, 2007	VU	Known only by three registers at seasonal deciduous forest in Barra do Chiça, Guaratinga and Boa Nova cities in Bahia (BA) state.	PARNA de Boa Nova (BA)
<i>Mycetagroicus urbanus</i> Brandão & Mayhé-Nunes, 2001	CR	Known only by type locality in the Ibirapuera Park in São Paulo (SP) state.	Does not occur at conservation units
<i>Mycetomoellerius atlanticus</i> (Mayhé-Nunes & Brandão, 2007)	VU	Restinga areas in the coasts of Rio de Janeiro (RJ), Espírito Santo (ES) and Bahia (BA) states.	RPPN São João Farm, RPPN Arte Verde Farm, RPPN Salto Apequique (BA); APA Municipal da Orla Marítima da Baía de Sepetiba, REBIO Estadual de Guaratiba (RJ)
<i>Mycetophylax simplex</i> (Emery, 1888)	VU	Restinga areas in the coast of Santa Catarina (SC) and Rio Grande do Sul (RS) states.	Unknown
<i>Rhopalothrix plaumanni</i> Brown & Kempf, 1960	EN	Known only by type locality in Araucária forest in Seara city, west of Santa Catarina (SC) state.	Unknown

SELECTING ANTS AS FLAGSHIP SPECIES

According to Lorimer (2007) "Nonhuman charisma can be best defined as the distinguishing properties of a non-human entity or process that determine its perception by humans and its subsequent evaluation". The author defines three types of non-human charisma: *ecological*, *aesthetic* and *corporeal* (Figure 2). Ecological charisma is related to ethological resemblance to humans, like diurnal lifestyle, social behaviour, or parental care. These features also need to be easily recognizable, which means, the ecological charismatic species must be recognizable. The facility to find and recognize the flagship species is also mentioned by Dietz *et al.* (1994) as a relevant trait for them. In the case of ants, this implies that rare or even too small or cryptic species are not good choices. Considering this, large-sized species are the best candidates.

Figure 2 - Diagram representing the selection of ants as flagship species through the non-human charisma. Squares represent non-human charisma categories.



The second non-human charisma proposed by Lorimer (2007) is aesthetic charisma, subdivided into “feral charisma” and “cuddly charisma”. The first one best applies to insects: organisms and places that have wild or chaotic features that are considered admirable. This kind of ecological charisma is possessed by the 20 most charismatic species for conservation and the authors pointed out that being terrifying is an important trait to be considered charismatic (ALBERT; LUQUE; COURCHAMP, 2018). Another characteristic that is common between these feral species is their large size. When it comes to insects the size scale is completely different from the vertebrates, so relatively large insects would be considered feral charismatics. Even though ants are much smaller than the typical charismatic mammals, among ants some species are relatively larger. Cuddly is a mostly mammalian-associated feature that is not readily applicable to ants or insects in a general way. Due to this, all the ant species were filtered only through the feral charisma (Figure 2), which means that species with a sting, aggressive behaviour, and/or multiplicity are good choices.

Corporeal charisma is more related to individual experiences and abilities than species features. The term “epiphanies”, coined by Lorimer (2007), is related to visceral memories of positive experiences with some species. For example, the sound of birds and crickets during a vacation trip, a colourful butterfly in our garden or even the smell of some plants or the taste of its fruits. In this case, ant species that can be related to some specific places or positive situations are good options, like those with cultural relevance. The satisfaction feeling related to the desire of some people to complete personal taxonomic lists or the ability to identify them in the field was called by Lorimer (2007) as “jouissance”. It is common among bird- and butterfly-watchers. In this case, endangered species are good examples considering their vulnerable status or rarity.

Brazilian ants with cultural importance

The search for papers regarding the cultural importance of ants in Brazil points to *Atta* Fabricius, 1804 species used as food by indigenous people (Table 2). Another culturally important species is *Paraponera clavata* (Fabricius, 1775), also known as the bullet ant or locally as *Tocandira* or *Tucandeira*.

Table 2 - Ant species used in Brazilian indigenous traditions.

Ant species	Indigenous community	How ants are used	References
<i>Atta cephalotes</i> (Linnaeus, 1758)	Several Amazonian tribes	Winged queens are consumed with a kind of manioc cake and the eggs are considered delicacies.	Posey (1978)
<i>Atta sexdens</i> (Linnaeus, 1758)	Mave and Arapium	Winged queens' gasters are roasted, grinded and added to manioc flour	
	Tukano	Workers are used as flavoring because of their lemon odor.	Dufour (1987)
<i>Atta laevigata</i> (Smith, 1858)	Tukano	Major workers and winged queens are consumed as food resources.	
<i>Paraponera clavata</i> (Fabricius, 1775)	Sateré-Mawé	Essential element at Waumat's rite of passage	Alvarez (2005)

For New World indigenous people, ants are ecosystem service providers in two different ways: as a food resource or as an important cultural ritualistic element (SILVESTRE and NETO, 2020). The custom of eating winged queens, captured during nuptial flights is widespread in Latin America (COSTA-NETO, 2015), and in Brazil, generally, some populations consume queens of *Atta* as delicacies. The consumption of winged queens of *Atta*, popularly called *Tanajura* or *Içá*, and of workers collected from nests or ground have been described since the nineteenth century by explorer-naturalists in Brazil (DUFUR, 1987). Additionally, indigenous people can use them for medicinal purposes (SILVESTRE and NETO, 2020). Besides this importance as a food resource, curiously, people do not associate the *Tanajuras*, with their workers, popularly called *Saúvas*, also known as leaf-cutter ants. This can be perceived in the contrast between considering the reproductive caste as a delicacy and the sterile caste as a crop pest. Similarly, some people do not associate caterpillars with butterflies, considering the larval and adult stages as different species with different conservation views associated with them (BARUA; AHMED; TAMULY, 2012). Even though leaf-cutter ants are highly social, easy to recognize in the field, and relatively big, choosing a leaf-cutter ant as a flagship species initially seems a bad strategy due to their image as farm pests. However, thanks to the cultural importance of these ants, they could become good options in regional projects that include local people. Leaf-cutter ants consumed as a food resource

have considerable nutritional value (DUFOR, 1987) suggesting they may also be exploited for ecotourism in Brazil's northern states as unique gastronomic delicacies. Entomophagy is widely recommended by FAO (Van Huis 2013) and, if adopted, may change the image of leaf-cutter ants as farm pests by converting them into a food resource worthy of being conserved. An example of this approach is the use of *Atta sexdens* (Linnaeus, 1778) workers, as a flavouring in artisanal chocolate (CASA LASEVICIUS©, 2020).

Species used by traditional populations and with popular names are good choices for flagship species on the local or regional scale (BOWEN-JONES and ENTWISTLE, 2002). Charisma depends on cultural factors (DUCARME; LUQUE; COURCHAMP, 2013), and the fact that some ant species are already used by indigenous people shows their acceptance. Even though leaf-cutter ants are considered farm pests, they can trigger memories of observing, collecting, or even eating the *Tanajuras*, responsible for a corporeal charisma called "epiphanic affections" (LORIMER, 2007). The visual appeal of *Atta* nuptial flights is a feature that can be considered charismatic and used to captivate public attention. Leaf-cutter ants also inspired the name of a group of indigenous women called Yarang, which means "leaf-cutter ants" in their language (IKPENG, 2019). The Yarang women collect seeds from the forest floor in the Indigenous Territory of Xingu in Brazil to reforest it. The name Yarang was chosen because the ants work collectively, walking in line, each with a piece of leaf or a seed. This example shows how different cultures and target audiences can offer several interpretations of the same species. This is also a good example of how an ant species can be used as a flagship species that inspires the local community in ecosystem restoration.

Paraponera clavata (Fabricius, 1755) has one of the most painful stings (SCHMIDT, 2016) and can be considered an ecosystem service provider of cultural importance. This species is a relevant ritualistic symbol for the *Waumat* coming-of-age ceremony among members of the Sateré-Mawé people, attracting fascination because of its mysticism (ALVAREZ, 2005) and association with sexual arousal. Some cultures use this painful sting, compared to a gunshot, as a treatment for sexual impotence (SILVESTRE and NETO, 2020). This species can be easily recognized in the field. These factors can trigger jouissance in tourists and the relatively large size and painful sting make this species ecological

and feral charismatic. These peculiarities can be highlighted with marketing strategies to attract attention to indigenous people and their cultures, needing attention and more effective protection too. Beyond their cultural importance, the *Tocandiras* are also capable of triggering epiphanic affections in the indigenous men who have experienced their sting. That means, local people also interpret them as charismatic and can be included in conservation actions without interest conflicts (VAN ITTERBEECK *et al.*, 2014). Approaches that use this species to attract attention to the conservation of Amazonia associated with the conservation and protection of indigenous people are promissory because they can reach more people and act like a flagship fleet (VERISSIMO; MACMILLAN; SMITH, 2011; Figure 1).

Endangered Brazilian ant species

Although species officially listed as endangered tend to be more successful as flagship species (DIETZ J.; DIETZ L.; NAGAGATA 1994 *apud* GUINEY and OBERHAUSER, 2008), few threatened insect species have been suggested as flagship in comparison to vertebrates (BARUA; AHMED; TAMULY, 2012). The reasons are mainly explained by the difficulty of observing insects due to their generally small size, the relative rarity of threatened species, and lack of visual appeal. Regarding endangered Brazilian ants, most of them are small and rare (Table 1), however, advertising campaigns can make them more known and attractive for use as flagship species (VERISSIMO; MACMILLAN; SMITH, 2011). Therefore, these ants could be used to promote the protection of areas where they occur (Table 1). This proposal can be used to inform the public about threats to biodiversity and how protected areas can act as a refuge for threatened species, or even engage people in volunteer work. Curiously, *Mycetagroicus urbanus* Brandão & Mayhé-Nunes, 2001 besides its small size, has a peculiar fact regarding its discovery: its type-locality is the Ibirapuera Park, located in São Paulo city, the largest city in Brazil. *Mycetagroicus urbanus* could become a symbol of the importance of urban green areas for insect conservation (SANTOS, DELABIE; QUEIROZ, 2019). The critical threaten status can be a warning of how urbanization can negatively affect biodiversity.

Finding and recognizing endangered ant species can provoke *jouissance* (Figure 1), but the rarity and small size do not make most of these species ecological and aesthetically charismatic. However, two endangered Brazilian ants have great potential as flagship species: *Atta robusta* (Borgmeier, 1939) and *Dinoponera lucida* Emery, 1901. Thanks to their relatively large size they are easy to observe, thus ecological and feral charisma can be evoked. The restricted distribution of both species helps to recognize them in the field with certainty and this is a good trait for flagship species (BOWEN-JONES and ENTWISTLE, 2002; GUINEY and OBERHAUSER, 2008). Easy observation is one trait of ecological charisma (LORIMER, 2007) and is important since the people who donate or act in conservation programs expect to observe these species when visiting their habitats (DIETZ J.; DIETZ L.; NAGAGATA 1994).

Atta robusta has traits that evoke some empathy through ecological charisma (LORIMER, 2007). The complex social organization with task labour division (HÖLLDOBLER and WILSON, 1990) can be compared to professions in human society, including agriculture. Leaf-cutter ants can process impressive amounts of vegetable mass to feed the fungus that they cultivate (LEAL; WIRTH; TABARELLI, 2014), an agricultural activity exercised long before humans (HÖLLDOBLER and WILSON, 2010). The easily identifiable trails formed due to foraging activity can be compared to streets or avenues and so be of interest to people. These characteristics associated with the endangered status enhance the conservational appeal. Meetings with *A. robusta* provoke epiphanic affections among people who frequent the beaches due to their distribution along littoral areas and their nests established in sandy soil (GONÇALVES, 1945; TEIXEIRA; SCHOEREDER; MAYHÉ-NUNES, 2003; QUEIROZ 2018). All the forms of charisma that *A. robusta* has can be used to engage people to keep beaches clean or even in citizen science programs monitoring nuptial flights since the population trend of this species is unknown (QUEIROZ, 2018). *Atta robusta* occurs in urban areas in Rio de Janeiro city (GOMES; ELIZALDE; QUEIROZ, 2013), which has a high flux of tourists, as well as in the areas of the state of Espírito Santo, it would be interesting to use it as flagship species in touristic campaigns.

Dinoponera lucida belongs one of the genera with the largest ants in the world, with the workers of some species longer than three centimetres long (DIAS and LATTKE, 2022). This species occurs in the Atlantic Rain Forest, a

conservation hotspot biome decimated by historic and ongoing deforestation (DIAS and LATTKE, 2022; Table 1). The restricted distribution of *D. lucida*, its large size, and its smooth and shining integument make it easy to recognize and evoke both ecological and feral charisma (LORIMER, 2007). This ant could become a symbol for the areas where it occurs and engage people in Atlantic Forest conservation. People encountering this species probably will have some *jouissance* upon recognizing it. Hence, its ecological, feral and corporeal charisma makes this species a great candidate as a flagship species.

Ants as umbrella species

Flagship species with ecological relevance (i.e., umbrella species), are frequent as well as charismatic species (DIETZ J.; DIETZ L.; NAGAGATA 1994; VERISSIMO; MACMILLAN; SMITH, 2011; DUCARME; LUQUE; COURCHAMP, 2013). There is a keystone species that is proposed as an umbrella, and in this case also as a flagship species: *Eciton burchellii* (Westwood, 1842) (PÉREZ-ESPONA, 2021). It needs large areas to live (BOSWELL *et al.* 1998; BRADY 2003) and is affected by habitat fragmentation (KUMAR and O'DONNELL, 2007). Further being a key species, *E. burchellii* is the animal with more known associations with other species (RETTENMEYER *et al.* 2011). A total of 557 species were counted, mostly arthropods, associated with *E. burchellii*, with up to 300 depending on it. These associations occur in three ways: in the swarm raids, on the ant's refuse deposits, and inquilines that live in the bivouacs and columns. Some birds are very or even totally dependent on the swarm raids, which makes this species even more relevant as an umbrella species (PÉREZ-ESPONA, 2021). This is an important trait because of the importance that birds have for conservation through people interested in bird-watching (Steven and Morrison 2016). *Eciton burchellii*, and birds associated with it, can act together as flagship fleets (Figure 1; VERISSIMO; MACMILLAN; SMITH, 2011).

Beyond a keystone and umbrella species, *E. burchelli* can be considered charismatic too. It is easy to recognize it in the field due to its epigeic raids. The large mandibles of major workers and painful sting evoke feral charisma. The magnitude of their raids can trigger epiphanies in bird-watchers. For this reason, this species has great potential as a charismatic flagship species with

an ecological appeal. Taking into account that insects as flagship species can be used in campaigns beyond their own (GUINEY and OBERHAUSER, 2008), *E. burchelli* could be used for projects that stimulate the conservation and restoration of the Atlantic Forest. This way, it is possible to raise funds and encourage commitment to reforestation or even monitoring programs that benefit many other invertebrate species under its conservation umbrella.

Why ants as flagship-species

How to select a flagship species is an issue that has been discussed often (BOWEN-JONES and ENTWISTLE, 2002; VERISSIMO; MACMILLAN; SMITH, 2011; BARUA; AHMED; TAMULY, 2012; DUCARME; LUQUE; COURCHAMP, 2013; JEPSON and BARUA, 2015). Two factors are essential for the choice to be successful: how the species are already seen by society and how they can be promoted in marketing campaigns. Verissimo *et al.* (2011) propose that any species could become a flagship species with marketing campaigns. Jepson and Barua (2015) warn that the complexity of pre-existing cultural frames should be considered for the species chosen to be efficient and lasting. Similarly, Bowen-Jones and Entwistle (2002) make clear the importance of cultural factors over the choice of a flagship species. The approach proposed by Guiney and Oberhauser (2008) uses ecological relevance criteria (i.e. ecosystem services and endangered status) as well as marketing aspects (i.e. aesthetical charisma). This approach was made thinking specifically of insects, different from the other authors. Hence, combining the ecological relevance and charismatic features, the ant species chosen in this study are promising candidates (Figure 2). Together, both criteria can be used in marketing campaigns for conservation programs calling attention via ecological appeal and charisma.

Figure 3 - Ant species selected as flagship species with ecological relevance and charisma. *Atta robusta* in frontal view (A) and lateral view (B), imaged by Eder França. *Dinoponera lucida* in frontal view (C) and lateral view (D), imaged by Amanda Nunes (DZUP549807, Source: AntWeb.org/); *Eciton burchellii* in frontal view (E) and lateral view (F), imaged by April Nobile (CASENT0009218, Source AntWeb.org/).



Insects may have some characteristics that can cause phobia in humans such as multiplicity, monstrosity, autonomy, and parasitism (LORIMER, 2007). Specifically, the fact that ants are eusocial insects (HÖLLDOBLER and WILSON, 1990), contradicts the concept of subjectiveness that, for humans, is something important (LORIMER, 2007). However, species with social behaviours are also interesting options to become flagship species, because they share this feature with human societies (DIETZ J.; DIETZ L.; NAGAGATA 1994). Eusocialism when approached in ways that do not neglect the importance of individuality, can be a

powerful tool to positively enhance the image of ants, as shown in the movies "A Bug's Life" and "AntZ". Cultural factors are trivial for how these traits would be perceived among different people in different cultural frameworks (DUCARME; LUQUE; COURCHAMP, 2013). *Oecophylla smaragdina* (Fabricius, 1775) is an example of it that would not be accepted by local people as a flagship species because it is seen as a food resource that does not need to be protected (VAN ITTERBEECK *et al.*, 2014).

An example of ants as a Flagship fleet is the book "Formigas do Alto Tietê" (SUGUITURU *et al.*, 2015), which aims to attract people's attention to the biodiversity in remnants of the Atlantic Forest in the Tietê river basin. The charismatic challenge faced by insects is an important issue when it comes to conservation (KIM, 1993). Macroscopic photos associated with natural history are an efficient strategy against their image as disgusting or worthy of hate (BERENBAUM, 2008). In the case of "Formigas do Alto Tietê", the ants can raise awareness in the readers of the importance that place has on the maintenance of biodiversity and ecosystem service provision. Recently, Brazilian myrmecologists have worked on new books about ant biology available for the general public and scientific divulgation actions (FRANÇA and QUEIROZ, 2021). These efforts are good starting points for overcoming the charismatic challenge and attracting people to the ants' natural history. With society sensitized the acceptance of ants as flagship species can be easier.

Considering that all of the species selected here (Figure 2) have ecological and charismatic appeal, they stand out from the other categories of insects proposed by Guiney and Oberhauser (2008). All of these species are attached to other contexts of conservation and can be used as flagship fleets in their own biomes (VERISSIMO; MACMILLAN; SMITH, 2011) warranting that different people can be reached and engaged in the conservation of their habitats.

First steps about ants as flagship species

Ants are among the insects neglected in monitoring surveys (SÁNCHEZ-BAYO and WYCKHUYS, 2019). This factor is alarming considering that they are great ecosystem service providers (ELIZALDE *et al.*, 2020) and diverse (HÖLLDOBLER and WILSON, 1990), especially in tropical regions. Fundings are

necessary to fill these gaps (HOCHKIRCH *et al.*, 2020), and flagship species can promote the image of themselves and their habitats. Most of the hotspots for conservation are in tropical regions, where ants are diverse with some species threatened by extinction (MYERS, 2000). A massive amount of ant species is associated with these priority areas and their ecosystem service provisioning. It would be interesting if other regions could choose their flagship ants. The methodology proposed here ensures that these species have ecological and charismatic traits to be exploited in marketing campaigns for conservation. However, to select a flagship species is just the first step in a long way to solid conservation campaigns and it requires interdisciplinarity (VERÍSSIMO *et al.*, 2011).

Media streaming associated with extension projects has a fundamental role in the way people look ecosystem services (SUMNER; LAW; CINI, 2018). Bringing it to the flagship species means that scientists need to be closer to people who work with social communication. It needs to be done in ways that do not create misconceptions about the roles of each species (MELERO, 2017) and make clear the benefits that human society receives from ecosystem services. This way, people can create affection or respect for the importance of each ant species because they can disperse seeds, prey on pests, display wildness or even be endangered due to deforestation. Even though ecosystem service valuation of eusocial insects needs more advances (ELIZALDE *et al.*, 2020), some simple strategies can be applied. For example, when someone questions a myrmecologist about reasons for studying ants, instead of quickly answering about ecosystem services, a good alternative is to simply respond "Why not?". This makes it possible to identify factors that cause displeasure or estrangement so the arguments in favour of ants can be given objectively and misunderstandings corrected assertively.

Using ant species as flagships will depend on local factors, the target audience, and the short and long-term goals (BOWEN-JONES and ENTWISTLE, 2002; VERISSIMO; MACMILLAN; SMITH, 2011; BARUA; AHMED; TAMULY, 2012). As leaf-cutter ants inspired Yarang indigenous women (IKPENG, 2019), we hope that the species chosen in this study can inspire conservation projects in Brazil that mitigate or reduce their respective habitat loss. Beyond their benefit, insects as flagship species act to inspire people to take more sustainable attitudes, or even create future naturalists (NEW, 2011 *apud* BARUA; AHMED;

TAMULY, 2012). Social media are good alternatives to stimulate engagement from audiences previously sensitized. Groups interested in ant breeding could be the target audiences for which campaigns about ant conservation could start. Even so, it is necessary to be careful with charismatic appeals because the attention raised by flagship species does not outshine the other sympatric species that need to be conserved too (DUCARME; LUQUE; COURCHAMP, 2013).

Even though we can find charismatic and ecological ants that can be used as flagship species, it is still necessary to address how it could be applied. Studies about people's perceptions regarding ants are also necessary. Using their results, the flagship species strategy might be refined and applied on different scales, with specific goals and target audiences. Sumner *et al.* (2018) already asked, "Why do we love bees and hate wasps", and what about ants? Maybe the answer would be positive if we could measure the benefits of their ecosystem services like their disservices. Data deficiency also can reinforce the negative perception of hymenopterans by society (SUMNER; LAW; CINI, 2018). This gap and the farm pest stereotype also reinforce the neglect of ants in conservation projects. Two strategies suggested by Hochkirk *et al.* (2020) to address data deficiency in neglected biodiversity are to create monitoring programs for lesser-known taxa, and funding mechanisms. The flagship species strategy can act in both strategies with any species chosen. The data and funding gathered by them also could be applied to projects involving local people and the conservation of their habitats. Once again, marketing strategies and interdisciplinary efforts are necessary to achieve short and long-term goals.

CONCLUSION

Selecting flagship species is a hard task and it is necessary to take into consideration ecological, cultural, and marketing aspects. Species with cultural importance can be used at a local scale with specific target audiences. *Dinoponera lucida*, *A. robusta* and *E. burchellii* have ecological and charismatic appeal, being good options as flagship species for their respective habitats.

We hope this study stimulates myrmecologists to work with conservation biologists, social studies researchers, politicians, grassroots organizations, and other stakeholders on ant conservation projects. Our qualitative approach can

be applied to other places with their ant fauna or other insect groups. Ecological and charismatic species can boost the flagship strategy making them even more appealing. Based on the criteria of insects as flagship species and non-human charisma, we advise selecting species that are ecosystem service providers (in this case species with cultural relevance), that are relatively large, easily recognizable in the field, with feral features, and species that can evoke epiphanies or jouissance.

ACKNOWLEDGMENTS

Thanks to Dr. John Lattke for helping the authors with valuable suggestions to the text and with English too; to Sindia Lima for helping with English writing and translation. This study was financed in part by the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) - Grant #130862/2020-7 (EF; scholarship) and the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* - Brasil (CAPES) - Financing Code 001 (CB; PhD scholarship). JMQ acknowledges support from the MBZ Species Conservation Fund.

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