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A bromeliad species reveals invasive ant presence in urban areas of French Guiana

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ABSTRACT

Tank bromeliads, frequently associated with ants, are considered 'biodiversity amplifiers' for both aquatic and terrestrial organisms, and thus have a high ecological value. The focal species of this study, *Aechmea aquilega*, sheltered the colonies of 12 ant species in a Guianese rural habitat where *Odontomachus haematodus*, associated with 60% of these plants, was the most frequent. Unexpectedly, the ant species richness was higher in a compared urban habitat with 21 species, but two synanthropic and four invasive ants were noted among them. Consequently, we conducted baiting surveys (on the ground, on trees and on trees bearing *A. aquilega*) as well as complementary surveys using different sampling modes in urban areas to test if *A. aquilega* is a surrogate revealing the presence of certain invasive ants. During the baiting survey, we recorded four Neotropical and eight introduced invasive ants out of a total of 69 species. Of these 12 invasive species, five were noted by baiting *A. aquilega* (including two only noted in this way). A bootstrap simulation permitted us to conclude that *A. aquilega* significantly concentrates certain species of invasive ants. This was confirmed by complementary surveys, where we did not record further species. We conclude that baiting on trees bearing large epiphytes in human-modified, Neotropical areas is a relevant complement to the early detection of invasive ants.

1. Introduction

Global trade has greatly contributed to the dispersal of plants and animals whose introduction into new habitats generally results in their death or a low rate of survival as they are unable to adapt. Still, some of them have become invasive, constituting an important threat to biodiversity in their introduced range because they can eliminate native species through resource pre-emption and/or direct competition, and, so, disrupt ecosystem functions. This has economic repercussions due to the costs of control measures (Clavero and Garcia-Berthou, 2005; Shogren and Tschirhart, 2005).

Ants are among the most widespread and harmful invasive taxa because they occupy a central place in the functioning of ecosystems. This is due to their abundance as they constitute one of the largest fractions of the animal biomass and play different roles in food webs since they can be herbivores, generalists, scavengers or predators. In natural conditions, ants coexist in well-organized communities regulated by competition and predation at both the intra- and inter-specific level. Yet, among invasive ants, so-called 'unicolonial species' form spatially vast and competitively dominant supercolonies over large geographical distances (Holway et al., 2002; Moffett, 2012). Thanks to their huge colonies, they lower the species richness and abundance of native ants through exploitation and interference competition so that they can disrupt the arthropod community structure with subsequent repercussions on the entire ecosystem (Holway et al., 2002).

Therefore, a major challenge is to develop predictive management strategies based on understanding the processes behind these invasions. The period just following the introduction of a potentially invasive species is central to that understanding. This is particularly true for insects which, due to their small size, are

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difficult to detect, so that their presence is generally discovered once the invasive process is already well underway or completed. Because most invasive taxa, including ants, are first introduced into urban areas through maritime harbors or airports and along roads (Holway et al., 2002; Laurance et al., 2009), the early detection of ants in cities is a critical component of environmental management. Yet, the ecological requirements of some potentially invasive ants means that their occurrence can be missed when researchers use a conventional sampling technique, especially when these ants first congregate in certain habitats where, in fact, they can be likened to the 'Trojan Horse'.

Because epiphytes abound in the trees that grow in some Neotropical cities and because epiphytes favor the installation of numerous ant species (Davidson and Epstein, 1989; Dejean et al., 1995; Blüthgen et al., 2000), we hypothesized that large epiphytic plants which commonly form habitats for insects can be "surrogates" for the occurrence of invasive ants prior to their spread. "Surrogacy", or how easily recorded taxa predict the presence of other taxa, can constitute a useful tool in conservation planning (Warman et al., 2004) and could also be used to detect the recent introduction of potentially invasive ants (see also Addison and Samways, 2006, for artificial surrogate habitats).

Tank bromeliads (Bromeliaceae) are flowering plants comprised of 59 genera and some 3140 species native mainly to the Neotropics (Givnish et al., 2011). The interlocking leaves of tank bromeliads form wells that collect rainwater (from a few milliliters to a few liters), leaf litter and other organic detritus. The rosettes of these plants permit numerous opportunistic ant species to profit from the moist habitat. Most ant-bromeliad associations are not species-specific (Blüthgen et al., 2000), but specialized associations do exist (Dejean et al., 1995). In this context, the aim of this study was to evaluate whether tank bromeliads can reveal ant invasions in Neotropical cities. Tank bromeliads are frequently found in human-modified, Neotropical areas, particularly when those areas are close to the seaside, rivers, or lakes, or situated at high, humid altitudes (Richardson et al., 2000; Serramo Lopez et al., 2009; Cach-Pérez et al., 2013; here *Aechmea aquilega*). So, we first sought to assess whether they point to the presence of synanthropic and invasive ants in urbanized areas of French Guiana, all situated along the coast. Second, we determined if these ant species are outcompeted by native species in a surrounding rural area. Third, we looked for new approaches permitting us to improve the conventional baiting sampling technique so as to detect as effectively as possible the presence of invasive ants by extending the survey to include trees, particularly those bearing an *A. aquilega* cluster. Further surveys using different sampling techniques rounded out this approach.

2. Materials and methods

2.1. The focal taxa

A. aquilega, found from Costa Rica to Brazil, usually forms massive clumps of epiphytes on old trees, but can also grow as a geophyte. This large species (60–120-cm in height; Mori et al., 1997) has tightly interlocking leaves that form a highly compartmented rosette creating a tank (or phytotelm) that collects water and organic detritus and provides a habitat for aquatic micro- and macro-organisms (Carrias et al., 2014).

2.2. Study areas and field surveys

2.2.1. Ants associated with A. aquilega

Between 2011 and 2013, we studied the ants associated with 45 mature *A. aquilega* in an urban area (each randomly selected in a city block of Sinnamary, French Guiana; 05°22′39″N 52°57′35″W), and 26 others in a rural habitat situated 5 km away, along 6 km of a dirt road (*route de l'Anse*) lined with 10–30 m-tall trees. In both areas, *A. aquilega* abound as epiphytes, with most individuals growing at a height of 3–6 m on different tree species. The sampling area in each environment extended over a surface of *ca.* 45 ha.

We used a ladder to reach the selected *A. aquilega* individuals and removed them from their substrates using a hack saw and then placed each of them into a plastic bag which was sealed to avoid contamination during transport to the laboratory. There, each individual was carefully inspected and taken apart; each leaf was torn from the base starting from the outermost leaf and working inward, allowing us to collect entire ant colonies installed between the leaves among the detritus accumulated by the plant.

2.2.2. Baiting survey to test if A. aquilega is a surrogate helpful in detecting invasive ants

To detect as effectively as possible the presence of invasive ants, we used a conventional sampling technique consisting of baiting ants with, each time, a series of two 2-ml Eppendorf colorless microtubes (one containing pieces of cotton imbibed with diluted honey and the other containing pieces of canned sardines in oil). Each time, after 30 and then 60 min, the ants occupying the baits and those patrolling all around were collected using an aspirator.

The survey was conducted in Cayenne (4°55′59″N; 52°19′59″W), Kourou (05°09′30″N; 52°38′34″W) and Sinnamary, three cities in the littoral zone of French Guiana (white sand deposits) and situated along a river. Less than 95 km (as the crow flies) separate Cayenne from Sinnamary, with Kourou located almost midway. First, we placed 30 pairs of baits on the ground separated by an interval of more than 20 m in Cayenne (the airport; the heliport; the tarmac of the harbor; the marina; and at the base of the building of the Customs Office in the harbor), in different city blocks of the *Vieux Bourg* of Kourou (areas not far from the marina) and Sinnamary (in different city blocks; more than 100 m from each other). Second, in Kourou and Sinnamary, we used the same type of sampling technique, placing the baits at more than 2 m in height on the trunks of 30 tall trees (>15 m), mostly mango (*Mangifera indica*) and mombin (*Spondias mombin*), both Anacardiaceae, and *Inga* spp. (Mimosoideae). These trees were chosen haphazardly in different city blocks. Third, to verify the ability of *A. aquilega* to concentrate invasive ant species, the same survey was conducted in Sinnamary on 30 other large trees bearing an *A. aquilega* cluster (almost all were mango trees) and situated in different city blocks than the previous trees or in different distant parcels of the same block (with a distance of more than 75 m between two trees). A complementary survey was conducted in the three cities. We firstly prospected by sight along the grassy roadsides of different city blocks, totalizing in each city more than 5 km. Only the workers of infrequent species were gathered (using an aspirator) for further identification. Second, we sampled ants from 20 plots (6 m × 3 m; 18 m^2) situated in grassy areas in different city blocks. Sampling was standardized by spending one man-hour per plot carefully searching for ants in all suitable microhabitats: the leaf litter including all hollow, rotten twigs; dead wood; humus and the bare ground. Third, we conducted a baiting survey on trees smaller than in the previous survey (*i.e.*, 5–12 m in height). Also, in the *Vieux Bourg* in Kourou, we baited the only nine reachable mango trees bearing an *A. aquilega* cluster.

Voucher specimens of the ants were identified and deposited in the *Laboratório de Mirmecologia* collection (acronym: CPDC), Cocoa Research Centre (Ilhéus, Bahia, Brazil).

2.3. Statistical comparisons

We compared the ant diversity in the two habitats using Shannon's diversity *t*-test (PaST software; diversity statistics), and the