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Six new non-native ants (Formicidae) in the Canary Islands and their possible impacts

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Abstract

Biological invasions are one of the main causes of biodiversity loss, especially on oceanic islands. Ants are among the most damaging pests in the world. After systematic sampling of more than 1,000 localities in the Canary Islands, six new exotic ant species are reported for the first time: *Pheidole bilimeki* (Myrmicinae), *Pheidole navigans* (Myrmicinae), *Strumigenys membranifera* (Myrmicinae), *Brachymyrmex cordemoyi* (Formicinae), *Tapinoma darioi* (Dolichoderinae) and *Technomyrmex pallipes* (Dolichoderinae). Moreover, another two recently reported species have been genetically confirmed. Morphological and genetic data were analysed to confirm the identity of the new records. For each species, information regarding identification, distribution, global invasive records and possible impacts is given. The arrival of these species may endanger local biodiversity.

KEYWORDS
barcoding, exotic ants, introduced species, Macaronesia, New record, oceanic islands

1 | INTRODUCTION

Exotic species, by definition, are those that are outside their natural distribution, introduced intentionally or unintentionally by human action (IUCN, 2000). The expansion of these species around the world is directly related to transport by humans (Hulme, Pyšek, Nentwig, & Vilà, 2009; Kairo, Cock, & Quinlan, 2003). The greatest number of introductions has occurred in the last few decades, mainly due to the growth of more frequent means of transportation and altered ecological niches (Holway, Lach, Suarez, Ysutsui, & Case, 2002). In fact, this is currently one of the main issues concerning biodiversity at the international level (Madjidian, Morales, & Smith, 2008).

Biological invasions are among the most important causes of the current biodiversity crisis, being involved in over half of the contemporary extinctions (Bertelsmeier, Luque, Hoffmann, & Courchamp, 2015). They constitute a risk to endemic fauna and flora, since they can displace native species by competition for resources, predation, hybridization and pathogen transmission (Goulson, 2003).

Although all regions of the planet are suffering impacts derived from biological invasions, this problem is especially serious on oceanic islands (IUCN, 2000). Insular ecosystems host unique flora and fauna, which have generally less adaptable species, fewer populations and/or smaller population size than continental species. This has led to a particular vulnerability of insular species to the arrival of exotic species (Reaser et al., 2007).

Invasive ants are among the most damaging pests in the world. In fact, 19 have been listed as highly problematic by the IUCN SSC Invasive Species Specialist Group (GISD, 2019). Ants are easily transported by humans because of their small size and the ability to nest in superficial or ephemeral sites such as root masses, leaf litter, logs and plant debris. In fact, exotic ants intercepted at the ports of entry are frequently detected in plant material (Bertelsmeier, Blight, & Courchamp, 2016).

In the Canary Islands, fifty-four ant species have been reported, of which 21 are considered introduced (Gobierno de Canarias, 2018; Schifani, Gentile, Scupola, & Espadaler, 2018; Staab, 2019). However, this number could increase in the coming years due to the continued commerce in agricultural and other carrier materials (including importation of foreign plant species). There is a lack of control measures for entry of exotic species, combined with an appropriate subtropical climate that favours species establishment. In this article, we provide information regarding morphological and genetic identification, distribution, global invasive records and possible impacts of several species that are reported for the first time for the archipelago.

2 | MATERIALS AND METHODS

2.1 | Sampling area

The Canary Islands are a volcanic archipelago comprising seven major islands off the south-west Atlantic coast of Morocco (Figure 1). In order to know the biodiversity of exotic ants in this archipelago, systematic sampling was conducted throughout all islands (including islets) during spring and summer of the years 2016–2018, periods in which ant species are more active at these latitudes (Angulo, Boulay, Ruano, Tinaut, & Cerdá, 2016). Since exotic ant species tend to colonize altered or anthropogenic environments first, especially those with high humidity (Mack et al., 2000), these kinds of habitats were the most sampled. Areas of possible arrival and dispersion such as ports, airports and plant nurseries were also surveyed. Lastly, natural areas were sampled to confirm whether they had been colonized by exotic species.

2.2 | Sampling methods

Two main sampling methods were carried out: pitfall traps and active searching. Pitfall traps are known to be an effective way of obtaining a representative sample of ant communities (quantitative and qualitative data) and are recommended as part of the standard protocol for measuring biodiversity (Alonso & Agosti, 2000; Clarke, Fisher, & LeBuhn, 2008). Traps were sunk into the ground with the top flush with the soil surface. Each trap consisted of a 150-ml plastic container, filled with 25 ml of water and a few drops of detergent to decrease water surface tension. In order to maximize the diversity of ants attracted by the traps, two types of bait were used: (a) tinned tuna, for species that are attracted mainly by protein foods; and (b) sugar water, for the species that prefer sugary foods. In each locality, 10 pitfall traps were placed in line at a distance of 5 m from each other, aiming at the greatest diversity of possible microhabitats (under trees/shrubs, under stones, near water source, etc.). Traps 1, 5 and 9 contained tuna baits and the others sugar water. Once placed, they stayed functional in the field for 48 hr. These traps are not always useful to detect all species (Alonso & Agosti, 2000), and therefore, active searching has to be carried out as well (Majer, 1997). This consists of a thorough 20-min search of each locality at any ant-susceptible site. In addition, occasional sampling was conducted in buildings or areas where it was not possible to carry out a complete survey.

2.3 | Morphological and genetic identification

Specimens were identified morphologically and by DNA barcoding, as the morphological taxonomy of some genera is unclear or complex, such as *Brachymyrmex* (Ortiz-Sepulveda, Bocxlaer, Meneses, & Fernández, 2019), *Pheidole* (Sarnat, Fischer, Guénard, & Economo, 2015), *Tapinoma* (Seifert, D'Eustacchio, Kaufmann, Centorame, & Modica, 2017) and *Technomyrmex* (Bolton, 2007). Firstly, external morphological characters were reviewed following some identification keys, and then, a genetic identification was carried out to confirm the previous one. DNA was extracted using QIAGEN DNeasy Blood and Tissue Kit, and COI was amplified using LCO1490/HCO2980 primers (Folmer, Black, Hoch, Lutz, & Vrijenhowk, 1994). The reaction product was Sanger sequenced, and the obtained sequence was blasted against the GenBank database for a proper taxonomic identification. Only, unambiguously identified sequences were considered, especially in complex genera.

3 | RESULTS

A total of 1,016 localities were sampled, 103 of them by pitfall traps. This survey revealed six new exotic species for the first time in the Canary Islands, more particularly in urban areas on the islands of La Gomera, Tenerife and Gran Canaria (Table 1, Figure 1 and Table S1). This is a 22% increase in the number of introduced ants present in the Canaries. Moreover, three of the six species belong to genera not previously detected in the archipelago (*Strumigenys*, *Technomyrmex* and *Brachymyrmex*). Except for *Technomyrmex pallipes* and *Strumigenys membranifera*, the rest of the species here reported have never been discovered before in the Macaronesian

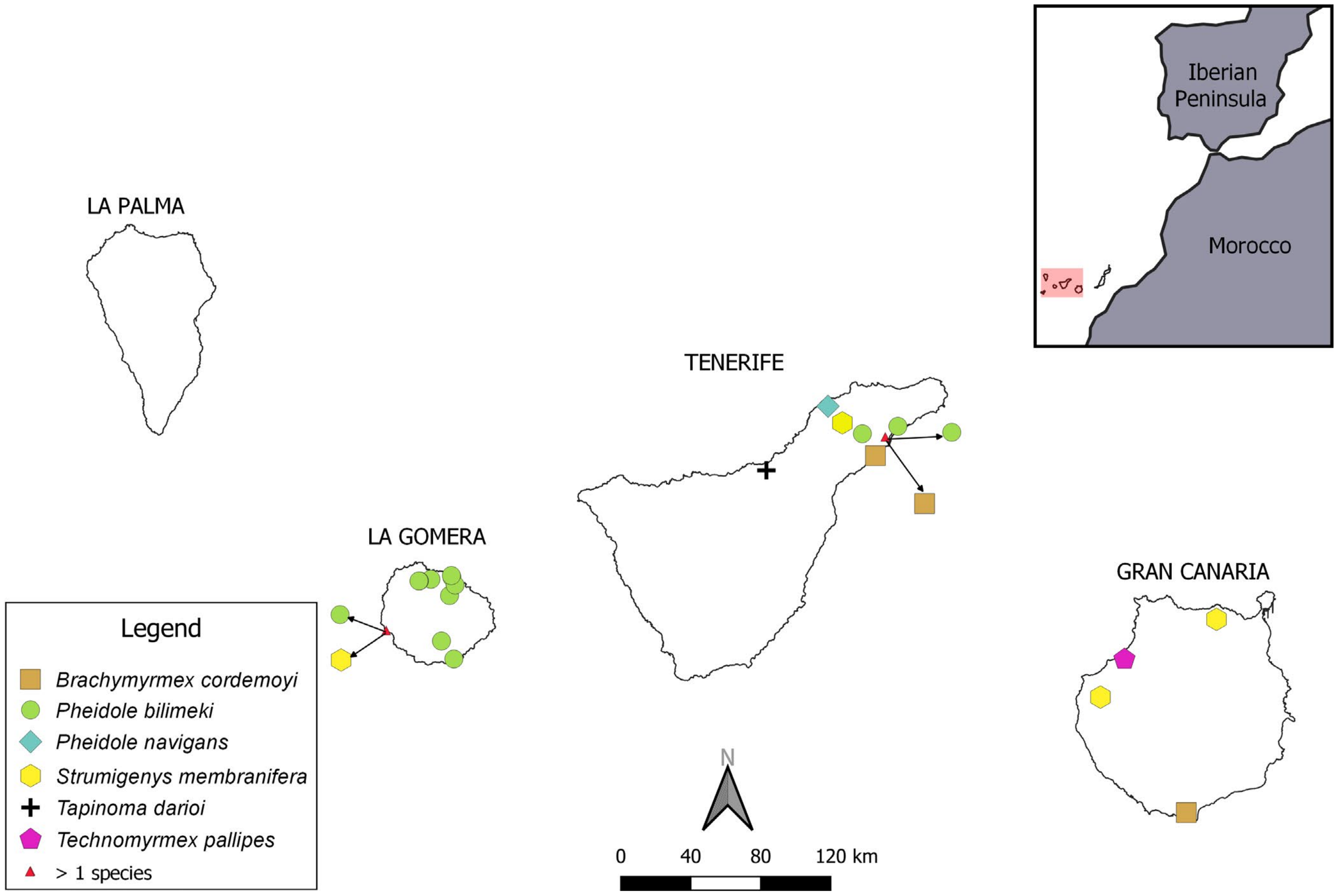

FIGURE 1 Ant sampling sites in the Canary Islands where new exotic ant species were detected. *Brachymyrmex cordemoyi* populations indicated with brown squares, *Pheidole bilimeki* green circles, *Pheidole navigans* blue diamond, *Strumigenys membranifera* yellow circles, *Tapinoma darioi* black crosses, and *Technomyrmex pallipes* pink pentagons. Localities with more than one new exotic ant species detected are marked with red triangles. For details about localities, see Tables S1 and S2

TABLE 1 New records of exotic ants in the Canary Islands, with information about the distribution, and negative effects previously recorded in other countries

Species	Subfamily	Native from	Negative effects	Distribution
Pheidole bilimeki	Myrmicinae	Neotropical region	Yes	TF, LG
Pheidole navigans	Myrmicinae	Neotropical region	Yes	TF
Strumigenys membranifera	Myrmicinae	Afrotropical region	No	TF, GC, LG
Brachymyrmex cordemoyi	Formicinae	Neotropical region	Yes	TF, GC
Tapinoma darioi	Dolichonerinae	Mediterranean region	No	TF
Technomyrmex pallipes	Dolichonerinae	Afrotropical region	Yes	GC

Note: Native distribution data taken from Guénard et al. (2017).
Abbreviations: GC, Gran Canaria; LG, La Gomera; TF, Tenerife.

archipelagos. In addition, two other new exotic ants detected in our survey and recently reported by other authors, namely *Plagiolepis alluaudi* (Staab, 2019) and *Lepisiota frauenfeldi* (Schifani et al., 2018), were genetically confirmed, and their distribution is broadened to other islands.

All identifications were confirmed by morphological and genetic data. Sequences were compared with verified GenBank entries (Table S2). Both approaches gave consistent results. Biological and ecological information is presented hereafter.

3.1 | New records

3.1.1 | *Pheidole bilimeki* (Myrmicinae)

The main feature differentiating *P. bilimeki* from other *Pheidole* species is the shorter scapes (scape length 0.40–0.60 mm; scape index 95–125) (Longino & Cox, 2009). *Pheidole bilimeki* is usually reddish brown, rarely yellowish brown, and with the face and mesosoma uniformly foveolate.

This species is native to the Neotropical region, from the north of South America to the south of North America, and is present throughout the Caribbean (Guénard, Weiser, Gomez, Narula, & Economo, 2017). It has been introduced into the Nearctic and Palaearctic regions (Antweb, 2019; Guénard et al., 2017; Sarnat et al., 2015). In the Canaries, it has only appeared in three localities on Tenerife and ten on La Gomera (Figure 1 and Table S1).

In the regions where it has been introduced, it is occasionally found inside houses, but more frequently in greenhouses (Sarnat et al., 2015). There is little indication that this species causes a significant impact on agricultural systems or native ecosystems. As it has low tolerance for cold climates, it is not considered a highly invasive species (Sarnat et al., 2015).

3.1.2 | *Pheidole navigans* (Myrmicinae)

Pheidole navigans is a small, short-limbed, reddish-brown species belonging to the *P. flavens* complex. Minor workers are impossible to distinguish on the basis of morphological characters, but major can be separated from other species of the *P. flavens* complex. The distinctive characters are the combination of predominantly longitudinal rugae on their posterolateral lobes, the more distinct and narrower antennal scrobe bordered mesially by a strong, unbroken frontal carina and the more continuously glossy scrobe depression (Sarnat et al., 2015).

Pheidole navigans is thought to be native to the Neotropical region (centre and north of South America) and has been introduced into the Palaearctic and Nearctic regions (Sarnat et al., 2015; Wetterer, 2017). In the Canary Islands, it was only collected in a farming area in the north of Tenerife (Figure 1 and Table S1).

This species occurs in both disturbed areas and moist woodlands but rarely enters houses (Deyrup, Davis, & Cover, 2000). It is not considered a major pest; however, in the south-east of the United States, it has been expanding its distribution area since its first record (Sarnat et al., 2015).

3.1.3 | *Strumigenys membranifera* (Myrmicinae)

Strumigenys differs from the rest of the ants present in the Canaries by its characteristic triangular head, six-segmented antennae with a two-segmented smaller antennal club and spongiform appendages on the propodeum and waist. Within this genus, *S. membranifera* differs from other synanthropic species by having mandibles with 12 teeth and its cephalic dorsum pilosity restricted to a pair of hairs at the highest point of the vertex (Sharaf, Fisher, & Aldawood, 2014).

Strumigenys membranifera has achieved broad distributions in both the Old and New World, spread through human commerce (Wetterer, 2011). Although its geographical origin remains unclear (Wetterer, 2011), it seems to be native to the Afrotropical region (Guénard et al., 2017). In the Canary archipelago, it has been found on the islands of Gran Canaria (two localities), Tenerife (one locality) and La Gomera (one locality) (Figure 1 and Table S1).

This species has been reported in gardens, cultivated areas and forests (Sharaf et al., 2014), although open areas seem to be its preferred habitat worldwide (Kitahiro, Yamamoto, Touyama, & Ito, 2014). There is no information regarding impacts (Wetterer, 2011). Nevertheless, its hypogeal and leaf-litter lifestyle makes it a difficult species to detect and therefore to study its possible invasiveness.

3.1.4 | *Brachymyrmex cordemoyi* (Formicinae)

As with all *Brachymyrmex* species, the presence of only nine antennal segments with a lack of a differentiated antennal club distinguishes workers of *Brachymyrmex* from other Formicinae genera (Bolton, 1994) and from all other species in the Canary Islands. This species resembles *B. obscurior* and *B. patagonicus* but differs from the former by having a denser pubescence on the gaster and from the latter by its larger head, more ommatidia along the maximal diameter of the eye and lighter-coloured pubescence. The latter feature is denser on the dorsum of the entire body and appressed on the gaster instead of decumbent in *B. obscurior* (Ortiz-Sepulveda et al., 2019).

Brachymyrmex cordemoyi is native to the Neotropical region and has been introduced in parts of the Afrotropical, Australasian and Palaearctic regions (Guénard et al., 2017; Husemann & Ortiz-Sepulveda, 2019; Ortiz-Sepulveda et al., 2019). Only two populations have been detected on Tenerife and one on Gran Canaria (Figure 1 and Table S1).

In its introduced range, it has been collected both indoors (Husemann & Ortiz-Sepulveda, 2019) and outdoors, nesting in soil (Sharaf, Salman, Aldhafer, Yousef, & Aldawood, 2016). There is not much information about its effects as an invasive species, but it seems they are mild (Jacquot et al., 2017). However, other species of this genus can act as urban pests, such as *B. obscurior* or *B. patagonicus* (Klotz, Mangold, Vail, Davis, & Patterson, 1995; MacGown, Hill, & Deyrup, 2007).

3.1.5 | *Tapinoma darioi* (Dolichoderinae)

The genus *Tapinoma* is easily identified by its flattened petiole and without a conspicuous, dorsally protruding scale. The dorsal face of propodeum is much shorter than the declivitous (posterior) face. The shape of the clypeal excision is one of the characteristics that differentiate species from this genus (Gómez & Espadaler, 2018). *Tapinoma darioi*, which has a completely dark body, belongs to the *T. nigerrimum* complex that includes four species that have been recently described (Seifert et al., 2017). Furthermore, the depth-to-width ratio of clypeal excision and length-to-width ratio of second funiculus segment are on average larger than in the other species (Seifert et al., 2017).

This ant is originally from the Mediterranean basin, showing preference for coastal areas (Seifert et al., 2017). Outside its native area, it had been introduced only in the Netherlands (Guénard et al., 2017). On Tenerife, it has only appeared in one locality in a greenhouse in Valle de La Orotava (Figure 1 and Table S1). We found individuals of this species together with others of *Pheidole pallidula* in a group of olive trees introduced from the Iberian Peninsula, where both species are very common in olive groves (Moreno-García, Reyes-López, Repullo-Ruibérriz de Torres, & Carbonell-Bojollo, 2017).

Tapinoma darioi has never been recorded as invasive, except a possible case in the Netherlands (Seifert et al., 2017). Other species within the complex, such as *T. magnum*, have a considerable invasive potential (Seifert et al., 2017).

3.1.6 | *Technomyrmex pallipes* (Dolichoderinae)

The genus *Technomyrmex* belongs to the subfamily Dolichoderinae and is characterized by its 12-segmented antennae without a terminal club, reduced petiole and gaster with five tergites visible in dorsal view (Bolton, 2007). Within this genus, *T. pallipes* can be distinguished from another widespread introduced species by having the dorsum behind the level of the posterior margin of the eye with two pairs of very short, stubbly setae (Fernández & Guerrero, 2008).

This species is of Afrotropical origin and has been introduced to the Palaearctic, Nearctic, Indo-Malayan and Australian regions (Bolton, 2007; Guénard et al., 2017). In the Canary Islands, it has reported for just one single locality of Gran Canaria (Figure 1 and Table S1).

In its introduced range, this species is found in greenhouses and houses (Wetterer, Espadaler, Wetterer, Aguin-Pombo, & Franquinho-Aguiar, 2007), but it is also common in outdoor areas such as parks and gardens in warmer countries (Bolton, 2007). Moreover, it has been reported as an occasional locally serious pest in citrus orchards (Bolton, 2007; Samways, Nel, & Prins, 1982). Although no major negative impacts have been reported to date, it could act as invasive such as other species of this genus like *T. albipes*.

3.2 | Species confirmation

Although Schifani et al. (2018) and Staab (2019) have already reported *L. frauenfeldi* and *P. alluaudi*, respectively, our data allow us to genetically confirm the identity of the species. They show their establishment and spread in the archipelago by detecting their presence in more locations and islands.

3.2.1 | *Plagiolepis alluaudi* (Formicinae)

Plagiolepis alluaudi is a tiny yellow ant (total length 1.5 mm approximately), whose workers have eleven antennal segments. In addition, this ant has a round head with strongly convex posterior margins unlike *P. exigua* (also yellowish), which has an oblong head (Wetterer, 2014).

This ant is primarily a tropical species, native to the Afrotropical region (Guénard et al., 2017). It has been introduced into the Australasian, Indo-Malayan, Neotropical, Oriental and Palaearctic regions (Wetterer, 2014), and has been spread worldwide through human commerce (Wetterer, 2014). In the Canary Islands, Staab (2019) recently reported it for Tenerife, but in our sampling, it was detected in three localities on Gran Canaria, one on La Palma and one on Tenerife (Figure 1 and Table S1).

Outside its native area, it has been detected in natural areas such as forests, primarily in the Afrotropical region (Wetterer, 2014), as well as indoors in the Palaearctic region (Guénard et al., 2017). Apart from having a short life cycle and a wide tolerance to temperature and humidity, its success in new localities may be due to its ability to co-exist with dominant invasive ants like *Pheidole megacephala* (Smith, 1957; Wetterer, 2014). It has become a minor household and agricultural pest in some areas, especially in the Pacific islands and in European greenhouses (Wetterer, 2014).

3.2.2 | *Lepisiota frauenfeldi* (Formicinae)

Within the Formicinae subfamily, the genus *Lepisiota* is the only one that has its propodeum armed with spines or teeth (Fisher & Bolton, 2016). It can be distinguished from *L. capensis*, which is reported for the Canary Islands, by having a petiole with asymmetrical spine-shaped dorsolateral apices, while *L. capensis* has a sharply bidentate petiole (Espadaler & Fernández, 2014).

Although its origin seems Palaearctic, this species is more densely distributed in the Mediterranean area and the Middle East and has been introduced on some islands of the Afrotropical, Indo-Malayan and Nearctic region as well as in the Australasia region (Guénard et al., 2017). Schifani et al. (2018) recently discovered it on the islands of Tenerife and Fuerteventura. In our sampling, it was also detected on Lanzarote and La Gomera as well as the islands where it was previously reported.

Lepisiota frauenfeldi is considered an invasive species (FAO, 2018), which eats and displaces native ant species, as well as other insects in the infested area (Commonwealth of Australia, 2019). In Australia, it is a serious environmental pest (Commonwealth of Australia, 2019) and currently is under national eradication there (Commonwealth of Australia, 2018).

4 | DISCUSSION

The geographical situation of the Canary Islands and its links with America, Africa and Europe facilitates the arrival of numerous exotic species on these islands due to the increase in sea and air traffic. Human trading activity has been breaking down biogeographical barriers and spreading species around the world (Bertelsmeier, Ollier, Liebhold, & Keller, 2017). In fact, the new exotic ant species here reported originate from different regions (Table 1): three of them have a Neotropical origin (*B. cordemoyi*, *P. bilimeki* and *P. navigans*), two Afrotropical (*S. membranifera* and *T. pallipes*), and one is from the Mediterranean basin (*T. darioi*). Moreover, the colonization of the Canary Islands by these exotic ants may serve as a focus of dispersion to nearby areas such as Africa and Europe. For instance, *B. cordemoyi* and both *Pheidole* species, which are barely present in the Mediterranean basin, could become a threat to this region after their establishment as an intermediate step in the Canary Islands.

Together with the current disturbed state of the habitats, the prevailing subtropical climate consisting of relatively constant mild temperatures year-round facilitates the establishment of many of these introduced species and their expansion throughout the archipelago, especially those from warm climates. Moreover, species from places with cold winters can be active the whole year in these islands. Conversely, tropical and subtropical ants cannot survive in geographical areas with cold winter conditions and are restricted to indoor locations (Ivanov, 2016). For example, *P. bilimeki* in central Europe is restricted to houses and greenhouses (AntWeb, 2019; Boer & Vierbergen, 2008). However, the climatic conditions in the Canaries allow their populations to become established in outdoor areas in addition to inside buildings. This facilitates their colonization of different habitats and expansion throughout the archipelago. Currently, the distribution of these six new exotic ants recorded for the Canaries is restricted to a few locations, all of them in human-disturbed areas. This finding reinforces the hypothesis that the arrivals of these species in these islands were relatively recent.

The arrival of alien species on oceanic islands threatens their biodiversity and causes socio-economic impacts. Intensive and long-term surveys allow the study of changes in ant fauna on islands and the early detection of exotic species (Hoffmann, Graham, & Smith, 2017; Moreau, Deyrup, & Davis, 2014). Correct identification is essential to assess the severity of these new introductions. As suggested by our data, the combined use of barcoding identification and recent taxonomic revisions is fundamental in order to properly identify Formicidae specimens, especially in complex genera. Subsequently, risk assessment for these new exotic ants is necessary to minimize potential damage. *Brachymyrmex cordemoyi* is known to cause damage to native fauna in other regions (Jacquot et al., 2017). Moreover, species belonging to genera that include highly invasive species such as *Pheidole* should be considered as potential invasive species. In fact, *P. bilimeki* and *P. navigans* have caused some negative impacts in other warm regions (Sarnat et al., 2015). Species associated with honeydew-producing Hemiptera, such as *T. darioi* and *T. pallipes* (Bolton, 2007; Seifert et al., 2017), could be potential crop pests. Additionally, some of these ants stand out for their predator potential, such as *S. membranifera* in the soil, whose impact on other tiny soil arthropods could be substantial (Wetterer, 2011).

In this study, we provide six new records of ants recently found in the Canaries for the first time, which notably increase the number of exotic ants. Given these new records, exotic ants constitute 45% of all ant species present in the archipelago. The presence of a higher proportion of introduced ants compared with native ants seems to be common in oceanic archipelagos worldwide, such as the other Macaronesian archipelagos, Hawaii or Galapagos (AntWeb, 2019; Borges et al., 2008, 2010). In contrast, the percentage of native species is much higher in mainland areas such as the Iberian Peninsula and Morocco (González-Martín & Espadaler, 2011; Taheri & Reyes-López, 2018).

To effectively manage exotic ants, a comprehensive plan should be developed with actions at all stages of the invasion. It should at least include prevention, detection, response, containment and management actions (Commonwealth of Australia, 2018). Border controls are the principal defence lines to prevent the arrival of exotic species (Hayden & White, 2003); however, for those already established a rapid response is needed to prevent their expansion. Eradication, the main objective, is only possible when ant populations are established in a small area. However, if the populations have spread, the use of control techniques to mitigate their impact is recommended (Commonwealth of Australia, 2018; Krushelnycky, Loope, & Reimer, 2005). The six species here reported are plausible candidates for wider expansion in the future, so regular monitoring should be maintained, as well as implementing eradication or control efforts when required.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

DH-T, AJP-D and DS surveyed the sampling areas and collected data. JR-L led the morphological identifications. DS and DH-T did the molecular analysis. All authors contributed to the writing. All authors read and approved the manuscript.

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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