

## Comparison of the exotic and native ant communities (Hymenoptera: Formicidae) in urban green areas at inland, coastal and insular sites in Spain

JOAQUÍN REYES-LÓPEZ and SOLEDAD CARPINTERO

Ecology Area, University of Cordoba, Edificio C-4 “Celestino Mutis”, Campus de Rabanales, Ctra. Madrid, Km. 396, 14071 Cordoba, Spain; e-mails: joaquin@uco.es; solecarpintero@gmail.com

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**Abstract.** Currently the introduction and spread of invasive species is an issue of great concern. To effectively manage this problem it is essential to know what constitute invasion hotspots. In this respect, the role of urban green areas in the conservation of biodiversity is a controversial matter. These areas may either favour colonization by alien species or shelter species of high conservation value. We evaluated the influence of location (island, coastal or inland) on the exotic and native ant fauna recorded in 27 urban green areas in Spain. A forward-stepwise discriminant analysis revealed differences between these locations in terms of the composition of the fauna, with exotic species identified as being the most important discriminating variable. There is a gradient: inland-coastal-island, along which there is significant increase in importance in terms of species richness and abundance of particular exotic species and decrease in the dominance of both common and rare native species. Areas located on the Island were more susceptible to invasion by alien ants. Coastal areas were also more susceptible to invasion than inland areas. These results possibly reflect the greater probability of an invasive species reaching these locations and the milder weather conditions at these sites, which would favour their establishment.

### INTRODUCTION

The loss of natural habitats due to increasing urbanization constitutes one of the biggest problems for the conservation of species. Today, almost half of humanity lives in urban areas and by the year 2050 urban areas are expected to be home to more than two thirds of the world's population (United Nations, 2010). In the face of urban sprawl, native species either adapt or disappear. There are some species that are preadapted to living in humanized habitats and many studies report homogenization of the fauna in these habitats (McKinney, 2006; Lizée et al., 2011; Buczkowski & Richmond, 2013). Exotic species are frequently favoured by these circumstances (Reyes-López et al., 2008; Stringer et al., 2009), a fact which aggravates the situation of native species (Lososová et al., 2012).

Other studies indicate that urban environments are not lost habitats for wildlife but rather new habitats that, with the proper management, have the potential to support diverse communities (Sattler et al., 2011; Trueman & Young, 2012). In particular, urban parks and gardens are possible refuges for native species of animals and plants (Adams, 1994). Many publications have sought to discover the characteristics of these green islands that help to maintain diverse communities, by providing space for conservation, restoration and reconciliation ecology (see for example in: Adams, 1994; Nilton, 2011). In summary, a controversy surrounds the true value of urban habitats for conservation purposes and much local work on this topic needs to be done.

Ants commonly feature in urban studies due to their abundance in these habitats (McIntyre et al., 2001; Whitmore et al., 2002) and their values as bioindicators (Brown 1997; Dekoninck et al., 2008; Ribas et al., 2012; Slipinski

et al., 2012). In general, because of their ecological dominance they play crucial roles in ecosystems as predators, scavengers and indirect herbivores (Wilson & Hölldobler, 2005). In addition, invasive ants have received a great deal of attention. Some of them are among the most ubiquitous and harmful invaders worldwide (Berman et al., 2013) and are particularly dangerous on islands (see examples in Williams, 1994 and in Holway et al., 2002). Island and coastal areas are very sensitive to invasion by exotic species (Martínez et al., 2007), but, it is unknown whether this is true of urban areas or if the level of faunal homogenization is such that the location of the urban green area does not affect the composition of the community. Numerous studies have examined the effect of exotic species of ants on islands and, additionally, there is a growing interest in understanding the effect of urbanization on ant communities. However, no study has identified an explicit connection between urbanization and the coastal or continental character of specific habitats, such as urban green areas, on ant communities. The current study compares the percentage of exotic versus native species of ants in inland, continental coastal and island urban green areas over a wide geographic area of Spain and identifies important species in terms of conservation.

### MATERIAL AND METHODS

#### Study sites

We sampled 27 urban green spaces at three different locations: in the main Andalusian coastal cities of Huelva, Cadiz, Malaga and Almeria; the Spanish island Gran Canaria; and two major inland cities along the river Guadalquivir, Seville and Cordoba. The last two cities were selected because rivers constitute natural corridors that promote the dispersion of many exotic species (Roura-

TABLE 1. Location of urban green spaces studied, type of locality and number of transects with 10 pitfall traps.

Park	Province	Coordinates GPS	Type of locality	No. of transects
Colegio Mayor de la Asunción Gardens	Cordoba	37°52'01.66"N – 4°47'40.26"W	Inland	10
Cruz Conde Park	Cordoba	37°52'19.56"N – 4°47'22.49"W	Inland	7
Paseo de Córdoba Gardens	Cordoba	37°53'27.24"N – 4°47'01.00"W	Inland	15
Dr. Alfonso Carpintero Park	Cordoba	37°53'54.50"N – 4°45'57.55"W	Inland	9
Vallellano Gardens	Cordoba	37°52'40.70"N – 4°47'07.95"W	Inland	7
Escritora Elena Fortún Park	Cordoba	37°52'39.21"N – 4°47'57.67"W	Inland	6
Miraflores Park	Seville	37°24'41.99"N – 5°58'00.06"W	Inland	5
Chapina Gardens	Seville	37°23'15.59"N – 6°00'10.51"W	Inland	5
El Valle Gardens	Seville	37°23'43.93"N – 5°58'58.31"W	Inland	5
María Luisa Park	Seville	37°22'31.99"N – 5°59'27.22"W	Inland	12
Alamillo Park	Seville	37°24'54.70"N – 5°59'38.13"W	Inland	13
Gardens of the University Pablo de Olavide	Seville	37°21'36.37"N – 5°56'30.61"W	Inland	6
Gardens of Alcazaba	Malaga	36°43'28.00"N – 4°24'92.29"W	Coast	2
Gibralfaro gardens	Malaga	36°43'24.76"N – 4°24'38.56"W	Coast	1
Paloma park	Malaga	36°35'60.95"N – 4°31'72.25"W	Coast	7
Picasso gardens	Malaga	36°43'00.11"N – 4°26'07.67"W	Coast	16
El Muelle gardens	Huelva	37°15'34.42"N – 6°57'49.93"W	Coast	2
El Boticario park	Almeria	36°51'83.83"N – 2°23'36.26"W	Coast	6
Costa Ballena gardens	Cadiz	36°41'43.45"N – 6°24'47.56"W	Coast	11
Guadalete river gardens	Cadiz	36°35'54.72"N – 6°13'23.80"W	Coast	1
Camping "Las Dunas" gardens	Cadiz	36°35'15.40"N – 6°14'27.37"W	Coast	1
El Polvorista square gardens	Cadiz	36°35'69.92"N – 6°13'63.85"W	Coast	1
La Feria square gardens	Las Palmas	28°6'48.02"N – 15°25'13.97"W	Insular	3
San Telmo park	Las Palmas	28°6'31.19"N – 15°25'0.75"W	Insular	1
Parque Romano	Las Palmas	28°7'28.85"N – 15°25'37.32"W	Insular	4
Veterinary Faculty gardens (Aruacas)	Las Palmas	28°8'20.31"N – 15°30'21.88"W	Insular	2
Parque de Cardones	Las Palmas	28°7'56.64"N – 15°30'45.27"W	Insular	1

Pascual et al., 2009; Säumel & Kowarik, 2010). Locations of the urban green spaces studied are in Table 1.

All of the urban green spaces are municipal gardens, located within residential areas. Although there are slight differences in their internal structure, current ways of gardening lead to a general resemblance, with extensive lawns and dispersed trees and bushes.

Andalusian coast has a coastal Mediterranean climate with dry warm summers and mild winters, softened by the influence of the sea. Cordoba and Seville have a hot inland Mediterranean climate with temperate winters and dry hot summers, with some of the highest European temperature records. Climate of Gran Canaria is subtropical with constant warm temperatures throughout the year and little rain (Climate data in Table 2).

TABLE 2. Climate of the provinces in which the study sites are located. T – mean annual temperature (°C); TM – mean daily maximum temperature (°C); Tm – mean daily minimum temperature (°C); P – mean annual precipitation (mm); H – mean relative humidity (%). Data from AEMET (State Meteorology Agency). Period 1971–2000.

Province	T	TM	Tm	P	H
Cordoba	17.6	24.6	10.7	536	62
Seville	18.6	24.9	12.2	534	61
Huelva	18.1	23.5	12.7	490	64
Cadiz	17.7	23.9	11.6	598	67
Malaga	18.0	22.9	13.1	524	66
Almeria	18.7	23.1	14.3	196	66
Las Palmas	20.7	23.8	17.7	134	68

## Sampling techniques

To estimate ant abundance and species richness, we sampled the urban green areas using pitfall traps. Pitfall traps are considered to be an effective way of obtaining a representative sample of ant communities and are recommended as part of the standard protocol for measuring biodiversity (Agosti et al., 2000; Clarke et al., 2008). Traps were sunk into the ground with the tops flush with soil surface. Each trap consisted of a 100 ml plastic container, 6 cm wide (internal diameter of opening) (REF. 409702, DELTALAB SL.) filled with 25 ml of water and a few drops of detergent to lower surface tension. They stayed open in the field for 48 h. The sampling periods at all 27 sites were in the springs and summers of the years 2003–2006 and 2010. At these latitudes, ants are most active in these seasons (Jimenez & Tinaut, 1992; Carpintero et al., 2007).

Urban green areas were sampled using different numbers of pitfall traps, depending on the area sampled, in order to maximize the number of species trapped (see species-accumulation curves Fig. 1). They were set at 2-meter intervals along linear transects, each comprising 10 traps, and placed in such a way to include the maximum number of microhabitats, making a total of 1 560 traps. Each park was sampled only once. After collecting the traps, ants were extracted and stored in 70% ethanol. All specimens were identified to species and counted, with the exception the genus *Solenopsis* the taxonomy of which is still under debate in Europe (see Bernadou et al., 2013); therefore all native species of this genus are treated as a group. We only distinguished one exotic species of *Solenopsis* (*S. Espadaler*, pers. commun.).

Every species was assigned to one of three categories: (1) Exotic; (2) Native-common; (3) Native-rare. Rare species include those in Spain that have less than 10% of the citations (Magur-

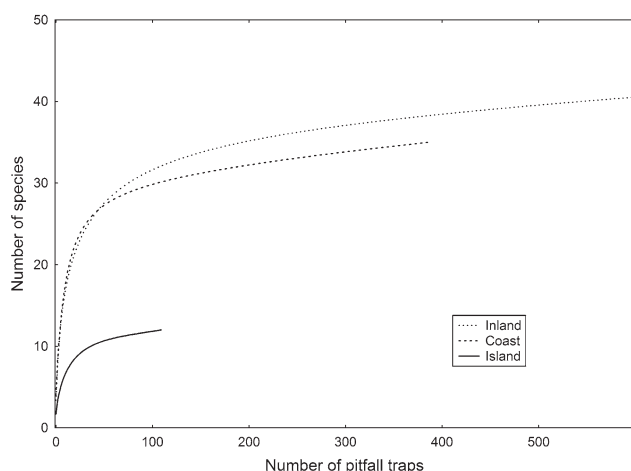


Fig. 1. Number of species recorded in the urban green areas at the three locations studied as a function of cumulative sampling effort – number of pitfall traps.

ran & McGill, 2010) in the bibliography of Hormigas.org (2013). This a web site designed by ant specialists (X. Espadaler and K. Gómez), which includes a complete bibliography of Spanish ants. For every species of ant it gives how many times it has been cited in scientific papers. In natural environments it is universally the case that some species are very abundant, while the majority is rare or scarce (Magurran & McGill, 2010). When the natural environment is perturbed, for example due to urbanization, this pattern can be affected. Usually, only certain species are able to survive the new conditions and so these species dominate while others become less abundant or disappear. Therefore, rare species (non abundant species) are considered to be indicators of healthy ecosystems.

#### Statistical analyses

A forward-stepwise discriminant analysis was performed to test if the fauna at the locations selected differed and, if so, to identify which of the species best distinguished the locations. To fulfill the statistical requirements, non-normally distributed variables (abundance of species) were transformed to natural logarithms. Individual sampling units for each of the analyses were the 10 pitfall trap transects.

To evaluate possible differences between the locations (inland, coastal and insular) chosen in terms of richness and total number of individuals of common, rare and exotic species, we performed two Kruskal-Wallis ANOVA tests on ranks. All analyses were carried out using the statistical package Statistica v7.1 (StatSoft, Tulsa, OK, USA).

#### RESULTS

A total of 44,930 ants were captured during this study, belonging to 23 genera and 55 species: 5,371 on Gran Canaria (120 traps); 11,877 along the coast (480 traps); and 27,682 in inland cities (1,000 traps). Eleven of the species were non-native. Native species were categorized as common (31 species) or rare (13 species) (Magurran & McGill, 2010). Forty four species were trapped in urban green spaces inland (5 exotic and 12 rare, 11.36 and 27.27%, respectively); 32 at coastal locations (8 exotic and 3 rare, 25.0 and 9.37%, respectively); and 12 on Gran Canaria (6 exotic and 0 rare, 50.0 and 0%, respectively).

The most abundant species at inland locations were: *Lasius grandis*, *Tapinoma nigerrimum*, *Myrmica aloba*,

*Pheidole pallidula* and *Cardiocondyla mauritanica*. At coastal locations some of the species were the same (*T. nigerrimum*, *P. pallidula*, *L. grandis*), but there were also some exotic species: *Solenopsis* sp. (accounting for 8.89% of individuals collected) and *Nylanderia jaegerskioeldi* (6.16%). At the locations on the island, the four most abundant (97.92% of individuals collected) were exotic species: *Pheidole megacephala*, *N. jaegerskioeldi*, *Cardiocondyla emeryi* and *Paratrechina longicornis*. The harmful invasive Argentine ant (*Linepithema humile*) was only found, in this study, at inland and coastal locations, and never abundant. Overall, the majority of the species were scarce with only a few of them very abundant (Table 3).

Results of a forward-stepwise discriminant analysis revealed differences between the locations selected (island, coastal and inland) in terms of the compositions of their fauna, with exotic species identified as being the most important discriminating variables (Table 4).

This study revealed the following gradient: inland-coastal-island along which there is a significant increase in importance in terms of species richness and abundance of exotic species and decrease in dominance of native species (both common and rare species) (Table 5, Figs 2 and 3).

#### DISCUSSION AND CONCLUSIONS

In the present study, in all the areas sampled, the most abundant native species were: *T. nigerrimum*, *L. grandis* and *P. pallidula*. They are opportunistic, generalist and anthropophilic species, common in urban green areas in places with a Mediterranean climate (Carpintero & Reyes-López, 2014). Among the most abundant there were also some exotic species: *C. mauritanica*, which is widely distributed and high densities of *P. megacephala*, *N. jaegerskioeldi* and *Solenopsis* sp. on Gran Canaria and/or at coastal locations. In general, the majority of the species were scarce and only a few of them were very abundant (Table 3). It is a common phenomenon that certain species can be very abundant in urban habitats. In this regard, it is quite usual for tramp-species to have well populated nests (Passera, 1994; Holway et al., 2002). Furthermore, not only exotic but also native species can reach high densities in urban areas, usually because food is more abundant there (Ditchkoff et al., 2006; Shochat & Ovadia, 2011). Generally, the consequences of urbanization are a reduction in species richness and homogenization in species composition. In this respect, some faunistic groups decrease or disappear, while others are favoured (McKinney, 2006; Shochat et al., 2006). Other urban studies record a large proportion of opportunistic and generalist species (Pisarski & Czechowski, 1978; Vepsäläinen et al., 2008; Menke et al., 2011). Exotic species constitute one of the groups that are usually favoured, with consequent negative effects on biodiversity (Heterick et al., 2000; McKinney, 2006).

It is necessary to have the right environment if exotic ants are to thrive and become abundant (Krushelnysky et al., 2010). The regular watering of urban green areas, especially during hot, dry Mediterranean summers, converts these areas into “ant hospitable habitats” (Gómez & Espa-

TABLE 3. Percentage of the total number trapped ants made up of individuals of each of the species per locality studied, with each species categorized in terms of whether it is native or exotic and if native common or rare (Type).

Species	Inland	Coast	Island	Type
<i>Aphaenogaster dulcinea</i> Emery, 1924	0.01	0.00	0.00	Native-rare
<i>Aphaenogaster gibbosa</i> (Latreille, 1798)	0.66	0.00	0.00	Native-common
<i>Aphaenogaster iberica</i> Emery, 1908	0.71	0.04	0.00	Native-common
<i>Aphaenogaster senilis</i> Mayr, 1853	2.88	1.31	0.00	Native-common
<i>Camponotus fallax</i> (Nylander, 1856)	0.01	0.00	0.00	Native-rare
<i>Camponotus piceus</i> (Leach, 1825)	0.01	0.00	0.00	Native-common
<i>Camponotus pilicornis</i> (Roger, 1859)	0.68	0.15	0.00	Native-common
<i>Cardiocondyla batesii</i> Forel, 1894	0.03	0.00	0.00	Native-rare
<i>Cardiocondyla elegans</i> Emery, 1869	0.01	0.00	0.00	Native-rare
<i>Cardiocondyla emeryi</i> Forel, 1881	0.00	0.01	2.90	Exotic
<i>Cardiocondyla mauritanica</i> Forel, 1890	5.08	1.55	0.28	Exotic
<i>Cataglyphis ibericus</i> (Emery, 1906)	0.00	1.11	0.00	Native-common
<i>Cataglyphis rosenhaueri</i> Santschi, 1925	0.61	0.00	0.00	Native-common
<i>Cataglyphis velox</i> Santschi, 1929	0.23	0.00	0.00	Native-common
<i>Crematogaster auberti</i> Emery, 1869	0.27	0.45	0.00	Native-common
<i>Crematogaster scutellaris</i> (Olivier, 1792)	2.26	0.15	0.00	Native-common
Exotic <i>Solenopsis</i> sp.	0.00	8.89	0.00	Exotic
<i>Formica cunicularia</i> Latreille, 1798	3.56	0.00	0.00	Native-common
<i>Goniomma hispanicum</i> (André, 1883)	0.06	0.01	0.00	Native-rare
<i>Hypoponera eduardi</i> (Forel, 1894)	0.74	0.23	0.00	Native-common
<i>Lasius grandis</i> Forel, 1909	21.95	10.11	0.00	Native-common
<i>Lasius lasioides</i> (Emery, 1869)	0.02	0.00	0.00	Native-rare
<i>Linepithema humile</i> (Mayr, 1868)	1.36	0.39	0.00	Exotic
<i>Messor bouvieri</i> Bondroit, 1918	0.01	1.50	0.00	Native-common
<i>Messor barbarus</i> (Linnaeus, 1767)	0.42	1.29	0.00	Native-common
<i>Messor celiae</i> Reyes, 1985	0.01	0.00	0.00	Native-rare
<i>Messor hesperius</i> Santschi, 1927	0.00	0.00	0.07	Native-common
<i>Messor structor</i> (Latreille, 1798)	0.05	0.00	0.00	Native-common
<i>Monomorium andrei</i> Saunders, 1890	0.00	0.05	0.00	Native-rare
<i>Monomorium monomorium</i> Bolton, 1987	0.13	0.00	0.00	Native-rare
<i>Monomorium subopacum</i> (F. Smith, 1858)	0.00	6.04	0.00	Native-common
<i>Myrmica aloba</i> Forel, 1909	12.60	0.00	0.00	Native-common
Native <i>Solenopsis</i> spp. Westwood, 1840	4.40	3.74	0.78	Native-common
<i>Nylanderia jaegerskioeldi</i> (Mayr, 1904)	0.00	6.16	3.85	Exotic
<i>Paratrechina longicornis</i> (Latreille, 1802)	0.36	3.86	1.64	Exotic
<i>Pheidole megacephala</i> (Fabricius, 1793)	0.00	0.00	89.13	Exotic
<i>Pheidole pallidula</i> (Nylander, 1849)	10.43	10.69	0.02	Native-common
<i>Plagiolepis schmitzii</i> Forel, 1895	0.71	0.61	0.02	Native-common
<i>Plagiolepis barbara</i> Santschi, 1911	0.00	0.00	0.35	Native-common
<i>Plagiolepis pygmaea</i> (Latreille, 1798)	4.50	0.60	0.00	Native-common
<i>Plagiolepis</i> sp.	0.01	0.00	0.00	Native-rare
<i>Proformica ferreri</i> Bondroit, 1918	0.04	0.00	0.00	Native-rare
<i>Pyramica membranifera</i> (Emery, 1869)	0.06	0.04	0.00	Exotic
<i>Tapinoma erraticum</i> (Latreille, 1798)	1.42	0.44	0.00	Native-common
<i>Tapinoma madeirense</i> Forel, 1895	0.09	0.00	0.00	Native-rare
<i>Tapinoma nigerrimum</i> (Nylander, 1856)	16.88	33.68	0.00	Native-common
<i>Temnothorax racovitzai</i> Bondroit, 1918	0.57	0.02	0.00	Native-common
<i>Temnothorax recedens</i> (Nylander, 1856)	0.06	0.00	0.00	Native-common
<i>Temnothorax pardo</i> Tinaut, 1987	0.19	0.01	0.00	Native-rare
<i>Tetramorium bicarinatum</i> (Nylander, 1846)	0.01	0.00	0.00	Exotic
<i>Tetramorium caldarium</i> (Roger, 1857)	0.00	0.00	0.61	Exotic
<i>Tetramorium</i> cf. <i>caespitum</i> (Linnaeus, 1758)	3.21	0.92	0.00	Native-common
<i>Tetramorium forte</i> Forel, 1904	0.20	2.80	0.00	Native-common
<i>Tetramorium lanuginosum</i> Mayr, 1870	0.00	2.43	0.00	Exotic
<i>Tetramorium semilaeve</i> André, 1883	2.53	0.70	0.34	Native-common

daler, 2006). Moreover, the vegetation in urban green areas frequently comes from tropical greenhouses and garden centers, which are sources of exotic species (Durán et al., 1994; Boer & Vierbergen, 2008). In this study, it is worth pointing out that two of the invasive species: *L. humile*

(Argentine ant) and *P. megacephala* (Bigheaded ant), are listed by the IUCN as being in the top 100 of the “World’s Most Invasive Alien Species” (Lowe et al., 2004). Both species have spread worldwide, beyond their original range (Roura-Pascual et al., 2011). Besides being a threat



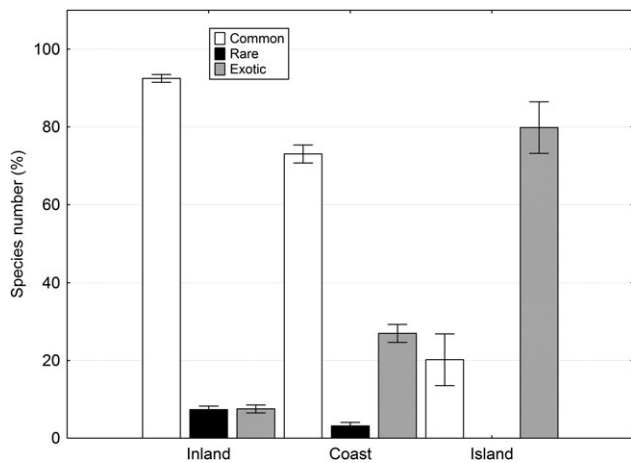


Fig. 2. Means percentages of the numbers of native-common, native-rare and exotic species caught at the inland, coastal and island locations. The catches of ten traps constituted a sample.

to native ant communities, they can cause severe economic problems (Vander Meer et al., 1990). In the present study *L. humile* was present at inland and coastal locations and its presence on Gran Canaria is recorded by other authors (Espadaler & Bernal, 2003). *P. megacephala*, a widespread invasive tramp ant throughout the world, made up a large percentage (89.13%) of the ants captured on Gran Canaria. The exotic pest species *N. jaegerskioeldi* and *P. longicornis* were mainly recorded along the coast (see also Martínez et al., 2007). The percentage of exotic species was significantly higher on Gran Canaria than along the coast and at inland locations. On the other hand, native species (both common and rare) showed the opposite tendency (Figs 2 and 3, Table 5). Ant communities at the three locations differed (Table 4). In terms of the percentage composition, the largest percentage of exotic species is found on islands

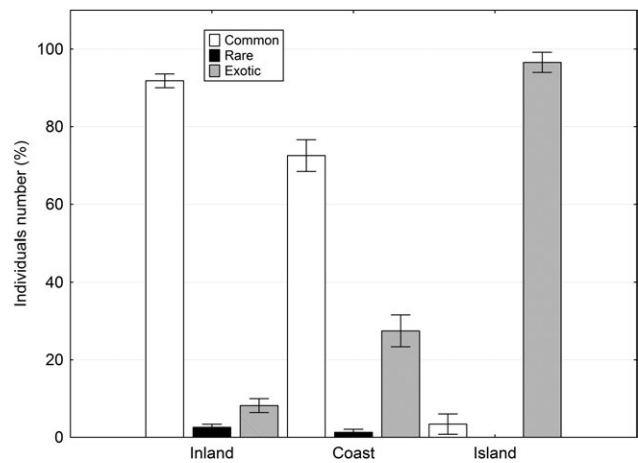


Fig. 3. Means percentages of the number of individuals of native-common, native-rare and exotic species caught at the inland, coastal and island locations. The catches of ten traps constituted a sample.

and in coastal locations for several reasons. For permanent settlement in a new area exotic species need first to reach the new location and, second, find the right habitat (Lonsdale, 1999). Common ways in which exotic species are introduced into an area are by trade, tourism and transportation (Levine & D'Antonio, 2003; Ruiz & Carlton, 2003; Perrings et al., 2005; Tatem, 2009). The Spanish coastal areas and cities on the island studied are top tourism destinations with a high level of international air and sea traffic, both for tourism and trade. Successful invasion by exotic species is enhanced by similarity in the physical environment between the source and target areas (Brown, 1989). Most of the exotic species captured originate from tropical or subtropical areas. In this study, the majority came from old world tropics, either Africa or Asia, and one of them, the Argentine ant, from South America (see in Brown & Wilson, 1959; McGlynn, 1999; Bolton et al., 2006; Wetterer et al., 2007). The climate of islands and coastal cities favours these species, as the influence of the sea softens the temperatures, which are more extreme in the interior of the Iberian Peninsula.

Islands are a special case. If there is a universal pattern in the biology of invasions, it is that islands are highly sensitive to invasion (Brown, 1989; McGlynn, 1999; Mooney & Cleland, 2001). This is particularly serious as islands are also refuges for many endemic species (Whittaker &

TABLE 4. Results of the forward-stepwise discriminant analysis: Grouping variable – type of location (island, coastal or inland); Independent variable – natural logarithms of species abundance. Observed classification indicates the level of overall classification expected on the basis of chance alone.

Forward-stepwise Discriminant: Wilks' $\lambda = 0.01$ , $p < 0.01$			
Percentage of observed classifications	Inland	Coastal	Island
	100	83.33	100
No. of variables in model 11			
Independent variable <sup>a</sup>	Wilk's $\lambda$ F-remove p-value		
<i>P. megacephala</i> (E)	0.15	976.61	<0.01
<i>C. emeryi</i> (E)	0.02	73.89	<0.01
<i>M. hesperius</i> (N)	0.01	36.19	<0.01
<i>T. lanuginosum</i> (E)	0.01	28.78	<0.01
<i>Solenopsis</i> sp (E)	0.01	29.93	<0.01
<i>C. ibericus</i> (N)	0.01	13.06	<0.01
<i>P. longicornis</i> (E)	0.01	25.17	<0.01
<i>P. barbara</i> (N)	0.01	12.97	<0.01
<i>T. forte</i> (N)	0.01	13.83	<0.01
<i>N. jaegerskioeldi</i> (E)	0.01	11.36	<0.01
<i>M. subopacum</i> (N)	0.01	7.61	<0.01

<sup>a</sup> E – exotic species; N – native species.

TABLE 5. Kruskal-Wallis ANOVA by ranks: Grouping variable: location (inland, coastal, island); Dependent variable: First analysis, species richness of common, rare and exotic species; Second analysis, abundance of common, rare and exotic species.

Kruskal-Wallis ANOVA by ranks. Independent (grouping) variable: location (inland, coastal, island).			
Dependent variable	Common species	Rare	Exotic
Species richness	H = 61.19 ( $p < 0.01$ )	H = 14.49 ( $p < 0.01$ )	H = 75.19 ( $p < 0.01$ )
Abundance	H = 53.74 ( $p < 0.01$ )	H = 12.68 ( $p < 0.01$ )	H = 59.89 ( $p < 0.01$ )

Fernández-Palacios, 2007; Walsh et al., 2012). This pattern is accounted for in terms of different aspects of island communities. First of all, communities on islands are species poor, which is considered to be an important factor favouring invasibility (Elton, 1958). It is also frequently suggested that invasive species face few strong competitors on islands; lower resistance from native species to invasion due to evolutionary isolation; no specific predators; and their distance from sources of colonizing species makes it more likely there are vacant niches on islands (see Levine & D'Antonio, 1999). Nevertheless, this issue is very speculative (Colautti et al., 2004). Recent research indicates that the relationship between native and alien species richness is scale-dependent, and that habitats that favour native species richness may also favour alien species richness (Lonsdale, 1999; Borges et al., 2006). According to Herben (2005) and Daehler (2006), the factor that is positively associated with the invasibility of an island is not lower species richness but smaller species pools. This implies that there is a low probability that small species pools include fast growing species, which are more likely to exclude random invaders. Be that as it may, Lonsdale (1999) in his review of exotic plants from 184 sites around the world found that in terms of percentage composition there are three times more exotic species on islands than in mainland areas. In our study not only is this difference in the urban ant fauna much greater in terms of the richness of exotic or native species, but, it is even greater when the density of exotic or native individuals is considered (Figs 2 and 3). Although it is likely that our data for island urban green areas are biased by the dominance of *P. megacephala* on the only island included in this study, other studies also support the idea that island ecosystems are particularly vulnerable to invasive ants (see for example McGlynn et al., 1999; Espadaler & Bernal, 2003; Wetterer et al., 2004; Ward et al., 2006; Rizali et al., 2010; Cerdá et al., 2011; Economo & Sardat, 2012). In this regard, Gómez & Espadaler (2006) report that on other Spanish islands the Balearics, 25% of the fauna is composed of exotic species, with the Argentine ant the most alarming species.

In contrast, rare species are more abundant in inland urban green areas. As mentioned above these species are considered to be rare because it is estimated that low numbers occur in Spain, and because of their endemic character or peculiar behaviour. In general, this group includes important species from a conservation point of view, such as: *Proformica ferrerii* and *Messor celiae*, endemic species on the Iberian Peninsula; cryptic species, for example *Monomorium andrei* and *Aphaenogaster dulcinea*, or those belonging to the genus *Temnothorax*; species typical of mature ecosystems, that are more abundant in colder or woody habitats, such as *Camponotus fallax* or *Lasius lasioides*; or parasitic species *Plagiolepis* sp., a very rare species that is still in the process of being described (X. Espadaler, pers. commun. 2010).

The role of urban green areas in the conservation of biodiversity is a debatable issue (Fattorini, 2011). These areas can act as bridging locations, which enable alien species

to colonize natural environments. Conversely, from a conservation point of view such areas may shelter high value species. The percentage of both types of species is influenced by many factors; for example, based on the results of this study, distance from the shore, however, this needs to be confirmed by similar studies carried out on islands and along coasts. Undoubtedly, it should be possible to manage urban green areas in such a way that the balance between the two types of species is altered to favour native ones (Blaustein, 2013; Susinsky et al., 2013).

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