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RESEARCH ARTICLE - ANTS

Citizen-science Supplements Species Inventories and Reveals the Invasion of *Monomorium exiguum* and *Pheidole parva* (Hymenoptera: Formicidae) in Cyprus

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Abstract

Citizen science has become more popular over the past few decades, aided by advancements in smartphone technologies and web platforms to build a community. Nevertheless, taxa that are difficult to identify and/or minute in size are often neglected. In this study, students of the rural Asomatos primary school (Limassol, Cyprus) were given ant collection kits and asked to collect specimens inside their houses within one or two weeks from the 3rd to the 16th of November 2023. Upon inspection, the native *Lepisiota* cf. *nigra* and *Tetramorium schmidti* Forel, 1904 are recorded for the first time from the island. A single peculiar specimen of *Pheidole* Westwood, 1839, was recorded indoors next to a plant nursery. As such, the plant nursery was surveyed, providing additional samples identified as *Pheidole parva* Mayr, 1865. Specimens from Cyprus previously identified as *Pheidole fadli* Sharaf, 2007, were re-examined, assigning them to *P. parva*. Additionally, a single specimen of *Monomorium exiguum* Forel, 1894 was also collected. Both alien species were most probably introduced through the horticultural pathway. This article presents the first records of the alien *M. exiguum* and *P. parva* from the island, correcting previous records and highlighting the importance of citizen science in detecting and mapping the distribution of alien and native species.

Introduction

Ants are a vital component of the ecosphere; they mediate and facilitate several important ecological functions, including nutrient availability and cycling, soil enrichment, drainage and aeration, and the dispersal of both plant seeds (myrmecochory) and fungal spores (Jones et al., 1997; Folgarait, 1998; Jouquet et al., 2006; Lengyel et al., 2010; del Toro et al., 2012; de Almeida, 2020; Rocha et al., 2024). It is globally estimated that their total global biomass reaches 12 megatons of dry carbon (Schultheiss et al., 2022), and their evolutionary history on our planet has shaped its

biodiversity amongst others through competition, mutualism, and predation of or by other taxa (Parker & Kronauer, 2021). However, ants have also been moved outside their native ranges, colonising new parts of the world, throughout the ever-increasing transportation of people and goods worldwide (Hulme, 2009; Parker & Kronauer, 2021; Wong et al., 2023).

According to Wong et al. (2023), 520 species of ants have been transported worldwide, with border interceptions missing two-thirds of alien species with naturalization capacity. However, less than one-tenth of these alien species have become invasive, i.e., inflicting substantial socioeconomic and environmental impacts (Angulo et al., 2022; Gruber et al., 2022; Wong et al., 2023). Some of the most noteworthy cases include the red imported fire ant, *Solenopsis invicta* Buren, 1972, the little fire ant *Wasmannia auropunctata* (Roger, 1863), the African big-headed ant *Pheidole megacephala* (Fabricius, 1793), the Argentine ant *Linepithema humile* (Mayr, 1868), and the yellow crazy ant *Anoplolepis gracilipes* (Smith, F., 1857) (Gruber et al., 2022; Wong et al., 2023), all of which have been named among the 100 worst invasive alien species (GISD, 2025). These invasive ant species have been notoriously shown to displace native arthropods and vertebrates, inflict painful and potentially life-threatening stings, and amount to billions of USD annually for managing their spread, impact, and eradication (Jemal & Hugh-Jones, 1993; Wetterer & Porter, 2003; Lard et al., 2006; Tschinkel, 2006; Wetterer, 2012; Gruber et al., 2022; Lee & Yang, 2022; Montgomery et al., 2022; Wong et al., 2023; Angulo et al., 2024; GISD, 2025). Despite the overwhelming impacts of invasive alien species globally, curbing their impacts is both urgent and achievable (Roy et al., 2024a).

Citizen science, i.e., public participation in scientific research, is a vital partnership in invasion biology, offering novel possibilities and assisting the early detection, distribution, and impact mapping of alien species (Pocock et al., 2023; Roy et al., 2024b). Public participation in scientific research has been increasing in popularity, with technological advancements in camera and smartphone technologies, making vast amounts of photographic material and species occurrence records widely available in various biodiversity data platforms such as GBIF, iNaturalist, etc. (Johnson, 2020). Nevertheless, in the case of insects, records are largely biased towards charismatic, colourful, and/or species larger in size, with minuscule species and various taxa not perceived as pests often being neglected (Caley et al., 2020). In such cases, specimen identification from taxonomic experts is necessary, leading to specimen collection and/or revisiting sites where specimens of interest were photographed or reported.

With more than 15,000 species described, ants represent such a case due to their high biodiversity, small size, and challenging taxonomy (Bolton, 2025). However, citizen-science has been effectively used for ant taxa with unambiguous morphological features that enable their identification through photographic material, as well as through the examination of specimens collected by citizen scientists and identified under a stereomicroscope (Lucky et al., 2014; Hart et al., 2018; Castracani et al., 2020; Sheard et al., 2020; Sorvari, 2021; Báthori et al., 2022; Krapf, 2023; Hsu et al., 2024). In this study, students of the rural Asomatos primary school (Limassol, Cyprus) were given ant collection kits and asked to collect specimens inside their houses. Ants were collected within one or two weeks from the 3rd to the 16th of November 2023. The results of the citizen-science scheme regarding both native and alien species are presented, including new records of the native *Lepisiota* cf. *nigra*, *Tetramorium schmidti* Forel, 1904 and the alien *Pheidole parva* Mayr, 1865 collected indoors. A subsequent survey of a neighbouring plant nursery provided more specimens of *P. parva* and a single worker of the alien *Monomorium exiguum* Forel, 1894. Upon the inspection of both major and minor workers, the single minor worker of *Pheidole fadli* Sharaf, 2007, previously collected from Cyprus (Demetriou et al., 2023), was also re-examined and proved to be *P. parva*. The distribution, ecology, introduction pathways, and impacts of *M. exiguum* and *P. parva* are discussed alongside the importance of citizen science in invasion biology and ant research.

Materials and methods

Study area and period

The rural village of Asomatos is located approximately 7 km west of Limassol, mainly within the Akrotiri UK Sovereign Base Area and partly within the Republic of Cyprus, near the southernmost tip of the island. The village covers an area of approx. 14 km², most of which encompasses the Akrotiri salt lake and wetland, a designated RAMSAR site, the largest on the island, as well as one of the very few major salt lakes within the eastern Mediterranean in semi-natural condition (SBAA, 2012). According to the last available census, the village has a population of 831 people. Asomatos has been mainly an agricultural village with extensive cotton cultivation in the old times and, more recently, *Citrus* cultivation. However, nowadays, the area is heavily urbanised. On the 3rd of November 2023, we visited the Asomatos primary school for educational purposes, giving talks on the biodiversity and importance of arthropods. A total of 32 citizen-science kits for the collection of ants indoors were given to students, and 16 were returned by the 16th of November 2023 (Figure 1).

Citizen science kit

Students were first given a talk on the ecological importance of ants in ecosystem functioning and the harmful impacts of invasive alien species on native biodiversity, human health, and other socioeconomic parameters. Emphasis was given on our knowledge of the myrmecofauna of Cyprus, and students were asked whether they would like to participate in the "ANTovreis" citizen-science initiative study (deriving from the English word "ant" capitalised and the Greek phrase "an to vreis = αν το βρεις" meaning "if you find it") to map the biodiversity and distribution of Cypriot ants. Students

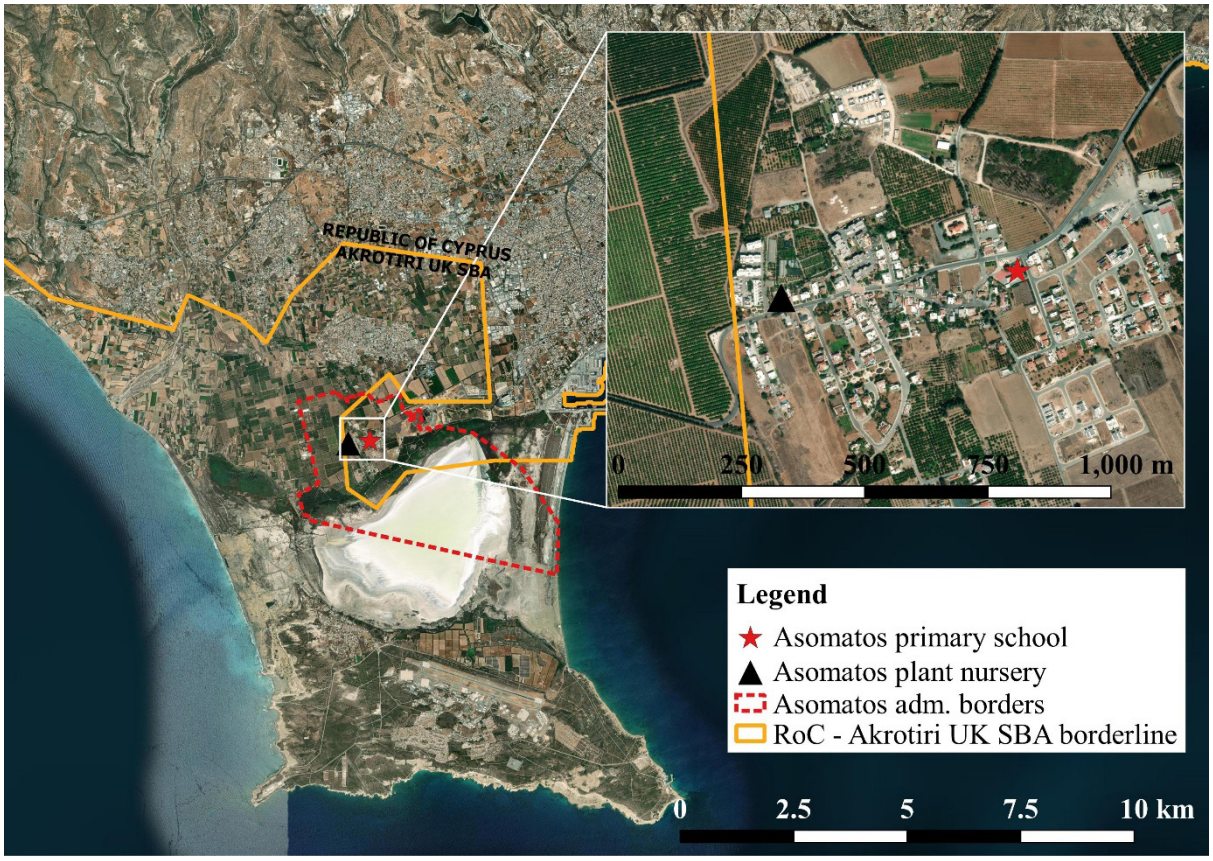

Fig 1. Map of study area.

were instructed on how to collect ants, asked questions on how they would differentiate between species, and provided details on easily observable variations in size, caste, colour, etc. Students wishing to participate in the scheme were given specialized citizen science kits.

Each citizen science kit contained a sealable cardboard box with five 2 ml O-ring vials with 70% ethanol in a small zip lock bag. Additionally, each kit included an A4-sized paper sheet including instructions in English and Greek on how to collect ants, as well as a laminated QR code, which, when scanned, directed participants to the "Ants of Cyprus" website (Demetriou et al., 2025) (Figure 2).

Specimen identification and photography

Collected specimens were identified by JD, LB, and SS through a stereomicroscope, using the identification keys of Borowiec and Salata (2022), Demetriou et al. (2023), and Salata et al. (2023a,b,c). Specimens of *M. exiguum* and *P. parva* were identified based on the identification keys of Sharaf et al. (2021) and Sarnat et al. (2015), respectively, and photographed by LB using Nikon SMZ18 and Nikon SMZ 1500 stereomicroscopes, Nikon D5200 camera, and Helicon Focus software.

Distributional map

Maps were created in QGIS, a free, open-source Geographic Information System Version 3.18.2 (https://qgis.org/en/site/).

Fig 2. An example of the ant collecting kit provided to the students.

Results

A total of 14 different species of ants were collected from students inside their houses, including eight native and six alien species (Table 1). To protect the personal details of minors, data for all collected specimens are presented with the following metadata: Limassol, Asomatos village, 34.6383° N, 32.9609° E, 500 m accuracy radius, 5 m alt., 03-16.xi.2023, leg. Asomatos primary school students, ident. J. Demetriou, L. Borowiec & S. Salata.

The subsequent material survey in the plant nursery near where *P. parva* was collected provided an additional 16 specimens (2 major and 14 minor workers) of *P. parva* (Figure 3). Additionally, the following species were collected from the plant nursery (number of workers indicated in parentheses): *Cardiocondyla mauritanica* Forel, 1890 (2), *Monomorium bicolor* (1), *Monomorium exiguum* – **new record** (1) (Figure 4), *Nylanderia jaegerskioeldi* (Mayr, 1904) (2), *Paratrechina longicornis* (3), *Pheidole indica* (3), *Plagiolepis pallescens* Forel, 1889 (1), and *Tetramorium bicarinatum* (Nylander, 1846) (3). Specimens' metadata are given: Limassol, Asomatos village, plant nursery, 34.6378° N, 32.9557° E, 7 m alt., 17.xi.2023, leg. J. Demetriou, L. Borowiec & S. Salata.

The single minor worker of *P. fadli* previously collected from a plant nursery in Paphos district (Demetriou et al., 2023) was re-examined, keyed based on Sarnat et al. (2015), and compared with the newly collected specimens of *P. parva* from Asomatos. As a result, that specimen is currently assigned to *P. parva*, with *P. fadli* being removed from the list of alien ants on Cyprus (Demetriou et al., 2023).

Discussion

This study contributes to ongoing research on the ant biodiversity of Cyprus, with the pilot of the "ANTovreis" citizen science project providing further distributional data on ants in anthropogenic habitats and showing their preference in urban habitats (Demetriou et al., 2023). Amongst the native

Table 1. Species and number of specimens collected by a total of 16 participants. Taxa in bold constitute new records for the myrmecofauna of Cyprus.

No.	Species	Status	Participants' codes															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dolichoderinae																		
1	*Tapinoma glabrella* (Nylander, 1849)	native		4					4							5		
Formicinae																		
2	*Camponotus jaliensis* Dalla Torre, 1893	native												1				
3	*Camponotus sanctus* Forel, 1904	native									2					1		
4	***Lepisiota* cf. *nigra***	native																1
5	*Nylanderia jaegerskioeldi* (Mayr, 1904)	alien	4															
6	*Paratrechina longicornis* (Latreille, 1802)	alien	1	5		3	9	4		10			8		109	8	52	25
Myrmicinae																		
7	*Aphaenogaster sporadis* Santschi, 1933	native		1														
8	*Messor orientalis* (Emery, 1898)	native					1				3							
9	*Monomorium bicolor* Emery, 1877	alien			20	10	6						6					5
10	*Pheidole indica* Mayr, 1879	alien	17	2										1	3	15		2
11	*Pheidole koshewnikovi* Ruzsky, 1905	native								4					26			
12	***Pheidole parva* Mayr, 1865**	alien								1								
13	*Tetramorium bicarinatum* (Nylander, 1846)	alien	3													1		
14	***Tetramorium schmidti* Forel, 1904**	native														8		

Fig 3. Habitus of *Pheidole parva* Mayr, 1865: major (above) and minor (below) workers, collected from the plant nursery in Asomatos, in dorsal and lateral views.

Fig 4. Habitus of *Monomorium exiguum* Forel, 1894 worker collected from the plant nursery in Asomatos, in dorsal (above) and lateral (below) views.

species collected by the students, *L.* cf *nigra* and *T. schmidti* are recorded for the first time from the island. Regarding alien species, *Paratrechina longicornis* (Latreille, 1802), *Monomorium bicolor* Emery, 1877, and *Pheidole indica* Mayr, 1879 were the most common species collected by most participants. This outcome is not surprising since they are already widespread on the island (Demetriou et al., 2023).

The sole peculiar minor worker of *Pheidole* Westwood, 1839, collected by a primary school student indoors, raised questions regarding its identity and introduction pathway to the area. As such, we conducted additional surveys in potential points of entry, i.e., the plant nursery near the first collection site. As the taxonomy of *Pheidole* worldwide poses challenges due to the high diversity, dimorphism in worker castes, and the lack of identification keys for the genus (Sarnat et al., 2015), the collection of specimens from both worker castes from the plant nursery in Asomatos significantly aided identification efforts. Additionally, specimens were compared with both the single minor worker collected indoors in Asomatos and the "*P. fadli*" minor worker collected from a plant nursery in Paphos (Demetriou et al., 2023), shedding light on the invasion of *P. parva* on the island and correcting the previous misidentification with *P. fadli*.

Native to Indomalaya, *P. parva* has been introduced outside south-eastern Asia, reaching countries of the Arabian Peninsula i.e. Saudi Arabia, the United Arab Emirates and Oman (Fischer & Fisher, 2013; Sharaf et al., 2018), Africa i.e. Seychelles (Forel, 1907; Wheeler, 1922; Dorow, 1995; Fisher, 1997; Gaigher et al., 2012; Fischer & Fisher, 2013), and the Mascarene Islands (Donisthorpe, 1947; Mamet, 1954; Fisher, 2005; Fischer & Fisher, 2013). In Europe, *P. parva* has been collected indoors in Austria and Germany (Eguchi, 2008). According to Sarnat et al. (2015), the biology of *P. parva* is largely unknown and is suspected to have expanded its distribution due to human commerce and its high tolerance for disturbance. In the Arabian Peninsula, Mauritius, and the Seychelles, it has been collected nesting and foraging in various substrates and collected from natural and man-made habitats at altitudes under 1000 m (Fischer & Fisher, 2013). Nevertheless, no adverse impacts have been observed or reported (Sarnat et al., 2015), although *P. parva* may become a nuisance indoors, as reported for healthcare facilities in Singapore (Man & Lee, 2012). Records of *P. parva* on Cyprus represent most likely the first record of the species in the Mediterranean region.

On the contrary, native to Africa and the Arabian peninsula, *M. exiguum* has been previously detected in the Mediterranean in Egypt (Bakr et al., 2007) as well as the islands of Crete and Ibiza, where it is regarded as introduced (Gómez & Espadaler, 2006; Borowiec et al., 2023). Borowiec et al. (2023) hypothesised the species' introduction accidentally through human activity or the migration of a single queen carried by winds from North Africa (Egypt) or the Arabian Peninsula. Our record from the plant nursery on Cyprus, an island with similar climatic conditions laying north of Egypt, the lack of specimens collected in any natural habitats, as well as the fact that records from Crete, Cyprus and Ibiza all stem from artificial habitats (i.e. irrigated gardens and a plant nursery) support a human-mediated introduction of *M. exiguum* in the Mediterranean islands. However, due to the limited availability of specimens and distributional data, no negative impacts on native biodiversity or socioeconomic parameters have been reported. This finding raises the total number of alien ant species on the island to 18 (Demetriou et al., 2023, present study).

The presence of *M. exiguum* and *P. parva* in plant nurseries indicates their probable introduction to Cyprus as contaminants of nursery material. However, as live colonies of *P. parva* have been reported from ships (Fischer & Fisher, 2013; Sarnat et al., 2015), this species could also reach the island as a stowaway in ships or containers. The horticultural pathway has been shown as crucial in the global movement of alien ants, transported predominantly as contaminants of plant nursery material and frequently found in greenhouses (Pospischil, 2011; Blatrix et al., 2018; Rabitsch & Blight, 2021; Demetriou et al., 2023; Báthori et al., 2024; Freyhof & Janke, 2024). Further investigations in urban green spaces, plant nurseries, and greenhouses could uncover novel localities. Nevertheless, both species are reportedly introduced indoors and confined to plant nurseries and houses. However, as *P. parva* has also been collected from natural habitats within its introduced range, the potential presence and spread of both species in the protected Akrotiri salt lake and wetland is important to clarify. As such, more research into their distribution and impacts is necessary.

Nevertheless, it is possible that *P. parva* was previously recorded from the Mediterranean as *P. faldi.* The morphology of two syntypes (available on AntWeb.org, CASENT0919804, CASENT0919803) and description of the collecting site (Fadl et al., 2007) indicate that the species is very similar in both these aspects to its invasive congener. However, this taxonomic uncertainty has to be resolved based on the personal investigation of types and a more comprehensive investigation of the morphological variability of both species.

This study highlights the importance of citizen science in detecting both native and alien species, even in cases where their identification necessitates verification by experts, as well as the importance of citizen-science data in supplementing our knowledge of species distribution. Students were excited and seemed to enjoy their involvement in the project. However, only half of the participants returned the provided collection kit, and many visits were made to the primary school to remind students to return their kits. Therefore, similar projects could consider this when estimating consumables' costs, quantities, and the time necessary to construct and receive back the citizen science kits. Despite these drawbacks, this small scale study with data from only 16 participants managed to uncover the presence of three newly detected species i.e. the

native *L.* cf *nigra* and *T. schmidti* and the alien *P. parva*, thus emphasising the importance of citizen science. In addition, these data allowed further material investigations of potential points of spread (i.e., the Asomatos plant nursery), leading to the detection of the alien *M. exiguum*.

The "ANTovreis" citizen science initiative could be implemented island-wide in schools, raising public awareness of the importance of ants and the impacts of invasive alien species, supplementing species inventories, and mapping species distribution indoors and in natural habitats. Similar citizen science projects could also focus on the interrelationships between ants and other easily spotted insects, such as aphids and scale insects. Similar studies in more populated areas, as well as plant nurseries, could potentially uncover the presence of other indoor-dwelling alien ant species such as the Pharaoh ant *Monomorium pharaonis* (Linnaeus, 1758), the ghost ant *Tapinoma melanocephalum* (Fabricius, 1793), as well as other alien ants currently spreading in the Mediterranean, such as *Brachyponera chinensis* (Emery, 1895), *Nylanderia vividula* (Nylander, 1846), and *Solenopsis invicta* Buren, 1972 (Menchetti et al., 2022, 2023; Schifani et al., 2024).

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Conceptualization: JD, AFM;
Methodology: JD, CG, AFM, SS;
Validation-verification: LB, CG, SS;
Formal analysis: JD;
Investigation: JD, AFM;
Resources: CG, HER, AFM, SS;
Data curation: JD, LB, CG, EPE, HER, AFM, SS;
Writing-original draft: JD;
Writing-review & editing: JD, LB, CG, EPE, HER, AFM, SS;
Visualization: JD, LB;
Supervision: CG, HER, AFM, SS;
Project administration: HER, AFM;
Funding acquisition: HER, AFM.

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