BIOGEOGRAPHIA
The Journal of Integrative Biogeography

Biogeographia – The Journal of Integrative Biogeography 2026, 41 (2): a078

https://doi.org/10.21426/B6.68753

The invasion of *Solenopsis invicta* in Italy: wider distribution, penetration into natural habitats, and the surrounding ant fauna

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Keywords: biosurveillance, Formicidae, Invasive Alien Species of Union Concern, Red imported fire ant, RIFA, Sicily.

SUMMARY

The red imported fire ant, *Solenopsis invicta* Buren, 1972, one of the most impactful invasive species worldwide, was first reported in Europe in 2023. Residents' reports led to the discovery of a 23 km long invasion along the southeastern coast of Sicily (Italy). In 2024, local authorities started an eradication programme using hot water and poisonous baits, while the European Commission opened an infringement procedure against Italy for failing to prevent and manage the invasion in a timely manner. Here, we report additional occurrence sites, including from three new provinces about 60 km westward and 120 km north, increasing the area of occupancy from 36 km² to 88 km² and the extent of occurrence from 53 km² to 6,200 km². The species is detected for the first time in woodland sites far from urban and coastal areas. We also gathered 151 literature and 1,858 unpublished occurrence records of other ants in an area of 3,576 km² surrounding the *S. invicta* sites. Seventy-eight other ant species occur near the invaded sites, including 68 native, 6 non-native, and 4 of unknown status. Among the native species detected, 11 are island endemic and subendemic, and three are listed as Vulnerable by the global IUCN Red List. Several non-native ants occurred in coastal areas invaded by *S. invicta.* An updated checklist of the ant fauna of Sicily, counting 136 species, is provided as a tool for researchers and policymakers. This ecological knowledge is important for informing evidence-based conservation policies that aim to mitigate invasive species' impacts while safeguarding native ecosystems.

INTRODUCTION

Among invasive species, the red imported fire ant, *Solenopsis invicta* Buren, 1972, represents a recent and urgent threat in Europe. Native to South America, it has been introduced to many regions of the world, including other parts of North and Central America, China, and Australia (Morrison et al. 2004; Ascunce et al. 2011; Wetterer 2013; Menchetti et al. 2023a; Nagatani et al. 2026). It is listed among the worst Invasive Alien Species (hereafter IAS) and ranks fifth in terms of economic cost worldwide (Luque et al. 2014; Diagne et al. 2021; Angulo et al. 2022). As a generalist predator and territorial species armed with a painful sting, it can disrupt native ecological networks, affect human health, damage electrical systems, to which it gets attracted, and negatively impact agricultural activities and tourism (Tschinkel 2006) – although a significant positive role in the biological control of several agricultural pests is also reported (Schifani et al. 2026). For a long time, no records of *S. invicta* were published from Europe, with the species being intercepted in Europe only on two occasions in Spain and the Netherlands (Fernandez-Melendez et al. 2007; Boer and Vierbergen 2008) and once allegedly reported from a greenhouse in Finland (Aron and Passera 2005).

In 2023, an established population occupying 4.7 ha was found in Italy, near the Sicilian city of Siracusa (Menchetti et al. 2023a). Due to a high number of mature nests and the absence of a nearby port of trade entry, it was suggested that the just discovered invaded area was unlikely to represent the first point of arrival for the species and was probably only the tip of the iceberg of a wider distribution (Menchetti et al. 2023a). This rapidly proved to be true: thanks to public outreach, local residents reported numerous additional occurrence points, revealing an invaded range extending at least 23 km along the southeastern coast from the first detection site (Menchetti et al. 2024). Along this range, *S. invicta* appeared to be widespread in coastal villages (Arenella, Avola, Fontane Bianche, Gallina, Ognina, Piccio). There, before its discovery, its stings caused at least two emergency room cases that failed to raise the alarm (Menchetti et al. 2024). Menchetti et al. (2024) estimated the invasion to be at least 8 years old, with some residents even reporting a much earlier presence dating back to the mid-1990s.

During 2022, *S. invicta* was added to the list of IAS of Union concern by the European Union (Regulation (EU) No 1143/2014 and Commission Implementing Regulation (EU) 2022/1203), requiring Member States to monitor for its presence, notify first records in their territory, and take rapid response action in the event of its discovery. In November 2024, the European Commission opened an infringement procedure INFR(2024)2226 against Italy, followed by a reasoned opinion in June 2025, alleging non-compliance with the IAS Regulation. According to the Commission, Italy delayed notifying EU authorities of the detection, failed to report eradication measures within three months, did not promptly implement measures to prevent the spread of the fire ant, and did not effectively implement the surveillance system for IAS of Union concern. The regional administration of Sicily had approved an eradication plan in July 2024, including both physical and chemical eradication methods: the application of pressurised hot water (> 100 °C) into the nests and the use of insecticides either offered through attractive baits deployed in the infested area or directly sprayed onto the nests (Sicilian Regional resolution No 242, 04.07.2024). Eradication efforts were planned to concentrate initially on the first discovered site and not on the others (Menchetti et al. 2024; Sicilian Regional resolution No 242, 04.07.2024). No insecticide specifically developed for the control of *S. invicta* was available in Italy and the Advion® Fire Ant Bait (Syngenta, Switzerland), based on the indoxacarb compound, was temporarily authorised under a Ministry of Health derogation (DGMF-MDS-P 11.0071924, 26.08.2024) from the EU regulation (Sicilian Regional Assembly interrogation No 1405, 05.03.2025). The eradication plan included outreach to local communities and medical personnel, monitoring emergency room records of insect sting treatments, and incorporating reports from the public (Sicilian Regional resolution No 242, 04.07.2024). In September 2025, the regional administration announced the development of a reporting app as a first dedicated communication channel with the public (Regione Sicilia 2025), while a dedicated website was released shortly after (www.formicadifuoco.it). Since 2024, no further data on the distribution of *S. invicta* in Sicily have been publicly released (Menchetti et al. 2024), except for an alarm by the municipality of Acireale (Catania province) announcing its first findings in its territory in May 2026 (Comune di Acireale 2026). Although region-wide eradication is now unlikely, there is nonetheless a need to control and contain the spread.

Sicily and the circum-Sicilian islands are known to host a remarkable diversity of ants, including several endemics, subendemics (i.e., those occurring in both Sicily and nearby regions such as Malta or Calabria), and non-native species, with the latest checklist, reflecting the 2020 state, counting 117 taxa (Schifani 2022). The island belongs to the Mediterranean ant diversity hotspot, which is particularly rich in rare species with limited distribution ranges (Kass et al. 2022; Oberski et al. 2025). However, it has until recently been largely neglected by myrmecologists. While recent studies partly compensated for it, significant knowledge gaps still exist, and conservation assessments for endemic and subendemic species are not yet available. A baseline knowledge of ant diversity in the southeast of Sicily is important for assessing the effects of both the *S. invicta* invasion and of its eradication attempt on the native fauna. The use of insecticides can be very successful; however, if indiscriminate, these can potentially even favour the more resilient *S. invicta* by reducing competition from native ants (Blake et al. 1959; Summerlin et al. 1977; Stimac and Alves 1994; Tschinkel 2006).

Here we report on new invaded sites situated approximately 60 km west and up to 120 km north of the previously known invaded areas (Menchetti et al. 2023a; 2024), including the administrative provinces of Catania, Messina, and Ragusa in addition to that of Siracusa. For the first time, these include woodland sites far from urban and coastal areas. We also created a dataset on the diversity of other ant species from the areas surrounding the *S. invicta* sites, thereby providing two new datasets (one on fire ant occurrences and the other on occurrences of other ant species) that are relevant both to the management of the *S. invicta* invasion and to the conservation of native ants.

MATERIALS AND METHODS

We defined the spatial extent of the study by generating a regular grid including known occurrences of *S. invicta* in Sicily and surrounding areas. All occurrences were first projected to the WGS 84 / UTM zone 33N coordinate system to allow a more accurate distance-based spatial analysis. The study area was subdivided into equal-sized square cells with a diagonal of 10 km (7,071 m per side, ~50 km²) to include all *S. invicta* records. An additional buffer of two cells was added to cover neighbouring areas. Only grid cells intersecting the geographic boundaries of Sicily were retained, covering a total land area of 3,576 km².

Data collection

New occurrences of *S. invicta* were recorded across multiple visual surveys of the invaded area previously known (Menchetti et al. 2024) in November 2024 (by ES, MM, and RV) and April 2026 (ES, HD, MM, and SM), as well as through observations by GC and SS in August 2025 and April 2026, in new sites far from the previously known range. A brief additional survey was carried out by ES in September 2025 at some of the sites previously discovered by GC in August of the same year, and again by ES, MM, HD, and SM in April 2026. Unlike Menchetti et al. (2023a) at the site of first discovery, the surveys carried out in the context of this study did not aim to estimate the number of nests per site, which was virtually impossible given the time and resources available and the extreme abundance and wide spatial coverage of the *S. invicta* invasion in most sites. Whenever possible, we asked local residents whether they recognised fire ants and recalled their presence in the past to help estimate the age of the invasion. The new occurrences therefore do not correspond to exhaustive nest counts. A further invaded site was announced by the municipality of Acireale (Catania) in May 2026 (Comune di Acireale 2026). We calculated the Extent of Occurrence (EOO) and Area of Occupancy (AOO) of the *S. invicta* records previously published in Menchetti et al. (2023a, 2024), the one of Acireale, and the new ones first reported in this study using R package *red* (Cardoso 2017). New *S. invicta* sites were promptly communicated to the authorities (in September 2025 and April 2026).

A dataset of occurrence data of other ant species from the same areas was assembled based on published literature, community science platforms, and decades of field sampling by the authors and colleagues. Georeferenced literature data were retrieved from Schifani and Alicata (2018), Schifani et al. (2022a,c; 2023; 2025a,b), and Menchetti et al. (2023b). Older, non-georeferenced records from the area were also screened (Emery 1925; Kutter 1927; Santschi 1927; Monastero 1950; Baroni Urbani 1964). Observations from the community science platform iNaturalist.org (uploaded until June 30th, 2026) were also curated and included whenever their species identification was possible based on the pictures. Finally, relevant records were retrieved

from the authors' personal collections, which included samples from the invaded area collected from 1991 to 2026. Dates of collection (or publication, if sampling dates were unavailable) were also retrieved to assess temporal patterns in species documentation.

Taxonomic identification

The taxonomic identification of *S. invicta* is simple only under the assumption that it is the only species of the *Solenopsis saevissima* group to have been introduced in the area and difficult otherwise. The list of IAS of Union concern includes two of the 14 described species of the *S. saevissima* group, *S. invicta* and *S. richteri* Forel, 1909, while other species remain undescribed (Ross et al. 2010; Pitts et al. 2018). These two regularly form hybrids in a contact zone of North America where they have been introduced (Ross and Robertson 1990; Tschinkel 2006). Menchetti et al. (2023a) already identified the fire ant population discovered near Siracusa as *S. invicta* through an integrative approach relying on both morphological and molecular evidence. Therefore, we decided to work under the assumption that no other *S. saevissima* group taxon was introduced in Sicily, considering it reasonably safe. This choice allowed us to avoid a lengthier identification process and speed up the communication of new data to the relevant authorities, avoiding past criticism (see the debate in Genovesi et al. 2024; Menchetti et al. 2024). Voucher specimens were preserved for future additional analyses.

In the context of Sicily, workers and queens of *S. invicta* far outsize native congeneric species (cephalic length ranges from approximately 0.77 to 1.41 mm in the very polymorphic workers, from 1.18 to 1.43 mm in queens), and differ from all other ants by the combination of the two-segmented waist and an antennal club consisting of two flagellomeres (Buren 1972). Males also far outsize the native congeneric species (measuring about 5.4 to 6.3 mm in total length), have the two-segmented waist, and differ from all other male ants by the combination of extremely short scapes, forewings with a closed cubital cell, and postpetiole attached to the gaster anteriorly (Buren 1972). See Buren (1972) for the original description and Emery (1916) for a broad overview of native genera.

As for most Mediterranean regions, no single taxonomic key is available to identify ant species. For the identification of some groups, the only formal basis is still the very outdated key of Emery (1916). However, for many others, more recent information is available, albeit scattered across several different sources: Sanetra et al. (1999), Csősz and Seifert (2003), Bolton and Fisher (2011), Csősz et al. (2015; 2025), Seifert (2018; 2019; 2020; 2025), Seifert et al. (2024), Juvé et al. (2025), Schifani et al. (2022a,c; 2025a,b).

Finally, we updated the latest checklist (Schifani 2022) of ant species found in the administrative region of Sicily (i.e., including circum-Sicilian islands) to provide a tool for researchers and policymakers. The new list incorporates recent literature and novelties as well as the new records published in this study. The last 8 years of studies led to the discovery of 50 species new to the island, including 6 non-native species and 8 species new to science, as well as the removal of 22 taxa (due to misidentifications, taxonomic changes, etc.) from the Sicilian checklist (Schifani 2017; 2026; Schifani and Alicata 2018; Alicata and Schifani 2019; Schär et al. 2020; Schifani et al. 2021; 2022a,b,c; 2025a,b; Menchetti et al. 2023a,b; 2026; Csősz et al. 2024; 2025; Lapeva-Gjonova et al. 2024; Juvé et al. 2025; Alicata et al. 2026). The record of *Formica clara* Forel, 1886 (Schifani et al. 2022b) is here reinterpreted as *F. lusatica* Seifert, 1996 based on the latest taxonomic revision of the group (Schultz and Seifert 2026). The (at least partly) blackish, smooth *Messor* species with reduced gastral pilosity traditionally attributed to a disjunct form of *M. bouvieri* (Bondroit, 1918) (Baroni Urbani 1964; Schär et al. 2020; Schifani et al. 2021) is here treated as *M. minor* (André, 1883), as supported by recent phylogenetic evidence (Menchetti et al. 2026). We distinguished taxa into endemic/subendemic species, non-native species, and species of unknown status (cryptogenic), and highlighted the taxa that occur in areas colonised by *S. invicta*.

RESULTS

Field surveys confirmed the presence of 14 localities where *S. invicta* is recorded, 8 of which are new and include three new provinces (Catania, Messina, and Ragusa) (Figure 1), increasing the Extent of Occurrence from 53 km² to 6,200 km² (+11,598%) and the Area of Occupancy of the species from 36 km² to 88 km² (+144%) (Table 1). In the western range (Figure 1a–c, Catania and Ragusa provinces), trails of workers were observed in August 2025, but

no nests were located. Brief additional visual surveys in September 2025 and April 2026 failed to detect fire ants at the southwestern sites (Figure 1a–c). In the northernmost site (Milazzo, Messina province), we recovered an *S. invicta* colony entirely residing within a pot of soil abandoned at the side of a road as part of an illegal dumping site, with no trace of other colonies nesting in the surroundings.

Many residents gave us detailed accounts recalling the presence of fire ants dating back to 1990–1995 in Avola (Via Lido, next to the Police station), to 2001 near the Anapo and Ciane river estuary ("after the flood"), to 2007–2008 in the Syracuse War Cemetery (after purchasing *Chamaerops* plants from a local plant nursery), to 2008 in Piccio, and to 2020 in Fontane Bianche (Via Pegaso) (Figure 1).

Table 1. Surface area of the S. invicta invasion in Sicily. Extent of Occurrence (EOO) corresponds to the area (km²) within the minimum convex polygon encompassing all records, representing the geographic spread. Area of Occupancy (AOO) is the sum of occupied 2 × 2 km grid cells multiplied by cell area, representing the occupied habitat.

Source	Extent of Occurrence (EOO) (km²)	Area of Occupancy (AOO) (km²)
Menchetti et al. 2023a, 2024	53	36
This study	6,200 (+11,598%)	88 (+144%)

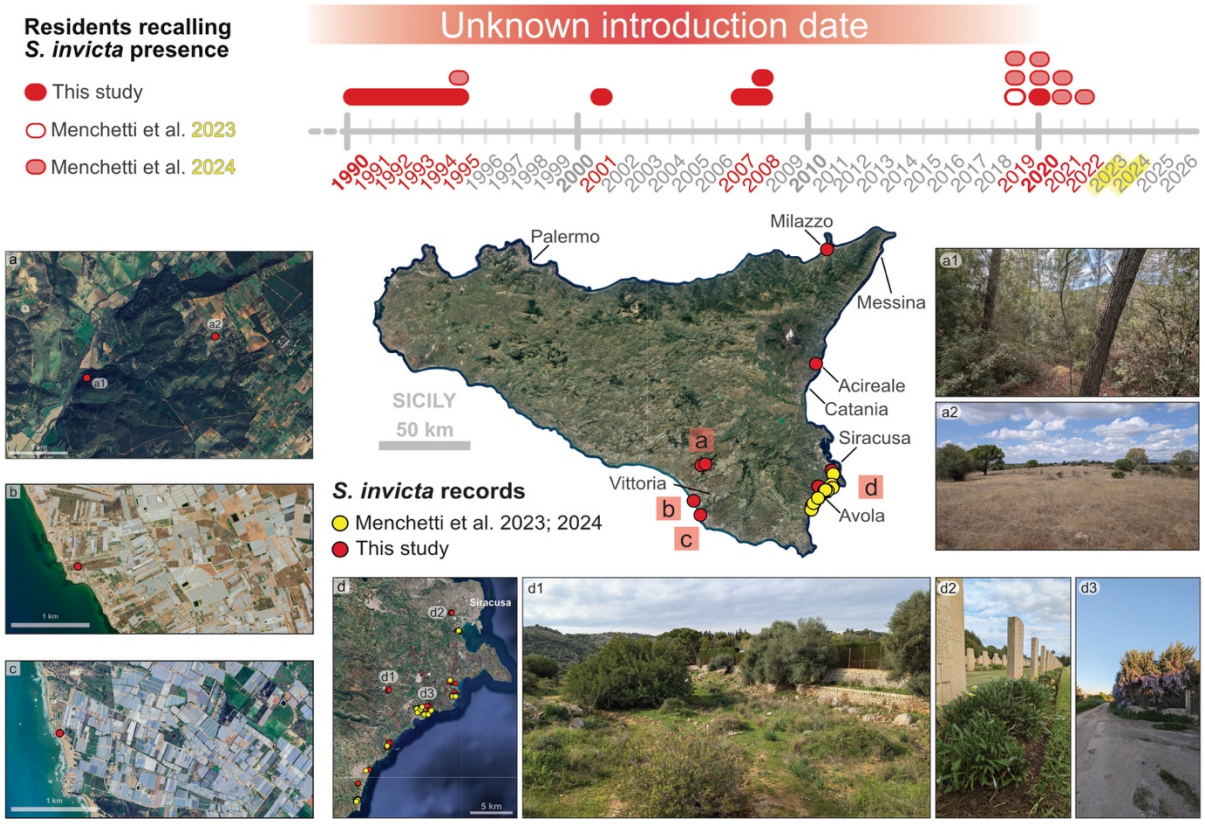

Figure 1. Distribution and reported history of the red imported fire ant, Solenopsis invicta, in Sicily. The chronogram summarises the years in which residents recalled the presence of the species, based on accounts collected in this study and those reported by Menchetti et al. (2023a, 2024). The map shows the known distribution of the species across the island, both records reported in this study (red) and previously published records (yellow). Insets provide detailed locations and examples of the habitats where the species was found. (a) Natural and seminatural environments in the Bosco di Santo Pietro Natural Reserve (a1) and the surrounding area (a2). (b, c) Coastal areas in the province of Ragusa, at Scoglitti and Passo Marinaro, respectively, where extensive greenhouse cultivation has strongly modified the landscape. (d) Coastal area near Siracusa where the species was previously reported, including three newly documented sites: (d1) a seminatural area outside the regional plant nursery "Spinagallo", where numerous mature colonies were observed; (d2) Syracuse War Cemetery, where numerous nests occurred, including within flower beds in front of the headstones; and (d3) an urban area in Fontane Bianche. Satellite imagery from Google Earth (Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat/Copernicus, Airbus).

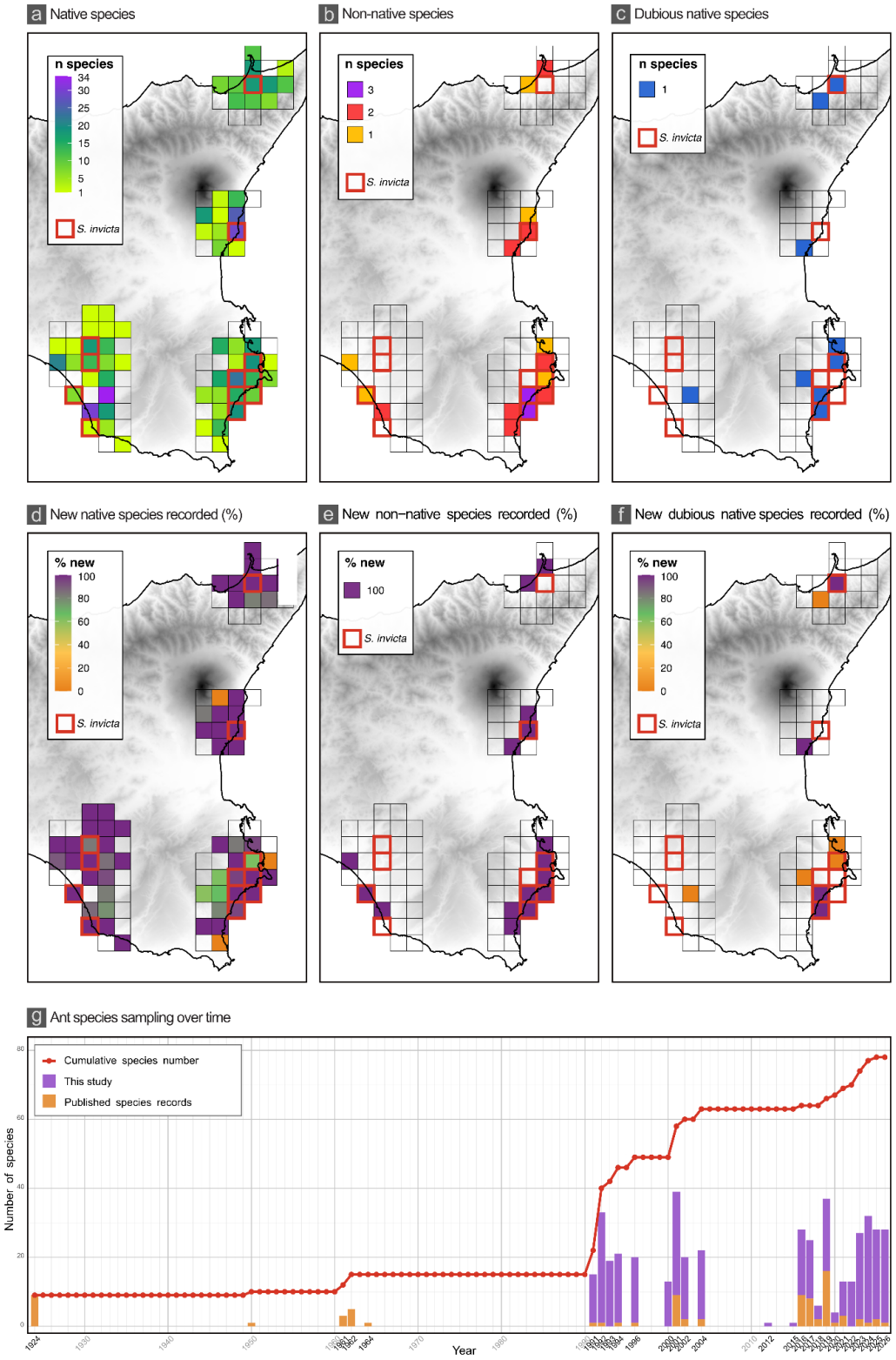

Figure 2. Spatial and temporal patterns of sampling of other ant species within the study area. Each grid cell measures 7.07 × 7.07 km (≈ 50 km²). Cells outlined in red indicate the presence of *S. invicta*, which is excluded from all species counts and proportions. The maps show the number of native (a), non-native (b), and dubious species (c), and the proportion of native (d), non-native (e), and dubious species (f) newly recorded in this study within each cell. The development of knowledge of the local ant fauna over time is shown in (g). Purple and orange bars represent records from this study and previously published records, respectively, while the red line indicates the cumulative number of species recorded.

A total of 2,300 occurrences of ant species in the region (2,031 new, 269 from literature) are presented here. Of these, 291 records belong to *S. invicta* (173 new, 118 from literature), and 2,009 to other ant species (1,858 new, 151 from literature) (Figure 2a–f). Out of the 136 ant species present in Sicily (including circum-Sicilian islands), 79 are reported from the study area, representing approximately 58% of the island's known ant fauna (Figures 3–4). These include 68 natives (Figure 2a), 7 non-natives, including *S. invicta* (Figure 2b), and 4 of unknown status. Among the native species, 11 are endemic or subendemic [*Aphaenogaster semipolita* (Nylander, 1856), *A. subterraneosplendida* André, 1883, *A. trinacriae* Alicata & Schifani, 2019, *Lasius maltaeus* Seifert, 2020, *Leptanilla poggii* Mei, 1995, *Strongylognathus destefanii* Emery, 1915, *Temnothorax laestrygon* (Santschi, 1931), *T. lagrecai* Baroni Urbani, 1964*, T. marae* Alicata, Schifani, & Prebus, 2022, *T. rottenbergii* (Emery, 1870), *T. siculus* Schifani, Alicata, Prebus & Csősz, 2025], and three [*Plagiolepis xene* Stärcke, 1936, *S. destefanii*, *Temnothorax muellerianus* (Finzi, 1922)] that have been categorised as Vulnerable by the IUCN (Social Insects Specialist Group 1996).

In total, 38 species are reported for the first time from the area, an increase of 93% from the 41 species previously known (Figure 2). All occurrence data are available in Supplementary Material 1, with an average of 29 records per species (range 1–291; SD = 53.5).

Solenopsis invicta was found for the first time within a woodland (*Pinus halepensis* Mill. reforestation) part of the Bosco di Santo Pietro Natural Reserve and at the margins of an agricultural area mainly characterised by greenhouses (Figure 1a–c). Large colonies and trails of *Messor minor*, *Tapinoma magnum* Mayr, 1861, and the non-native *Paratrechina longicornis* (Latreille, 1802) were sometimes observed at a few centimetres from those of *S. invicta*, with no visible aggressive interactions.

Besides some old records, mostly from the mid-1920s and early 1960s of the 20th century, almost all data on the ants of the area come from collecting efforts from 1990 to 2004 or from 2015 to the present, with the putative introduction of *S. invicta* possibly falling in the temporal gap between them (Figure 2g).

The updated checklist of the ant fauna of Sicily (including circum-Sicilian islands) is provided in Supplementary Material 2. It includes 136 taxa, of which 21 (15%) are endemic or subendemic species, 12 (9%) non-native species, and 4 of unknown status (3%).

DISCUSSION

Biological invasions are a widespread concern, and 60 of the 114 IAS of Union concern listed under Regulation (EU) No 1143/2014 are already present in the wild in Italy (Commission Implementing Regulation (EU) 2025/1422; ISPRA, www.specieinvasive.isprambiente.it, accessed 11 September 2026). Many species, including charismatic vertebrates such as grey squirrels (*Sciurus carolinensis* Gmelin, 1788) and northern raccoons [*Procyon lotor* (Linnaeus, 1758)], have established multiple populations and are partially managed through ongoing control strategies (Di Febbraro et al. 2019; Falaschi et al. 2025), while others, like Siberian chipmunks [*Eutamias sibiricus* (Laxmann, 1769)] or common mynas [*Acridotheres tristis* (Linnaeus, 1766)], remain largely unmanaged (Mori et al. 2018; Cerri et al. 2020; Magory Cohen et al. 2022). On the other hand, neglected invertebrates are particularly difficult to manage and contain, and are often overlooked; for example, the land flatworms *Bipalium kewense* Moseley, 1878 and *Obama nungara* Carbayo, Álvarez-Presas, Jones & Riutort, 2016 were added only in 2025 to the list of Union concern species, yet they already have widespread and poorly documented distributions in Italy (Mori et al. 2022). Similarly, the invasive crayfish *Procambarus clarkii* (Girard, 1852) has spread across the entire Italian peninsula and major islands in three decades (Lo Parrino et al. 2020), highlighting the challenge of managing highly dispersive invertebrate invaders.

Tackling the invasion

Tracking the spread of fire ants is difficult, as flying queens also exploit human transport to disperse even farther, as documented in the US (Callcott and Collins 1996; Tschinkel 2006). Monitoring the species' actual distribution at the island level remains key to estimating management costs in Sicily and addressing its potential eradication. Our new data expand the known invaded perimeter by 60 km west and 120 km north, more than doubling the species' area of occupancy. According to the suitability model by Menchetti et al. (2023a), almost all new *S. invicta* occurrence points

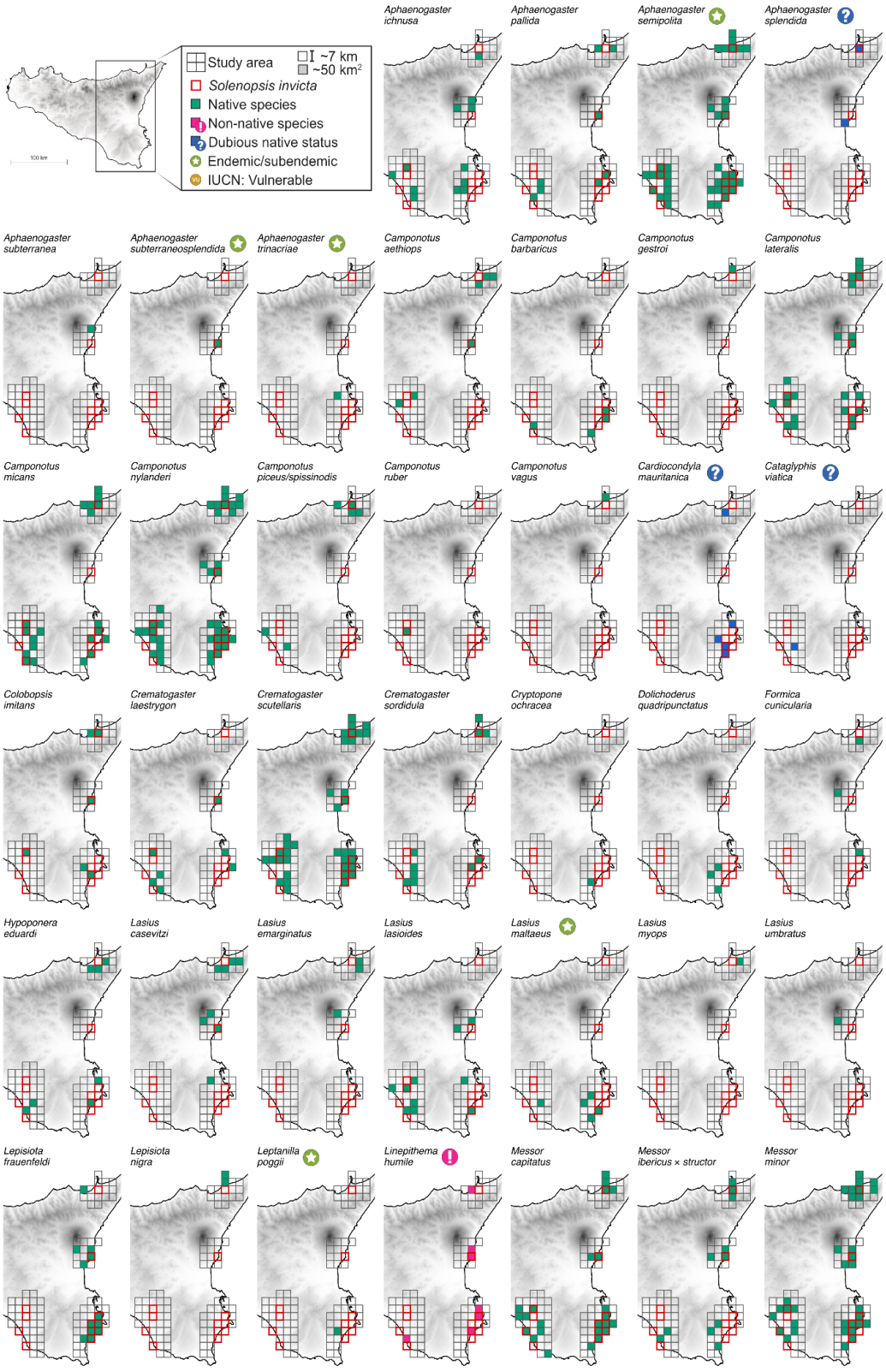

Figure 3. Detailed distribution maps of the ant species recorded in the study area, part 1. Each cell is 7.07 × 7.07 km in size (≈ 50 km²). Thick red lines indicate cells where *Solenopsis invicta* has been found. Coloured cells show the presence of each species: green for native, fuchsia for introduced, and blue for records of species of dubious status. Additional information, such as endemic/subendemic status and IUCN extinction risk category, is provided next to each species.

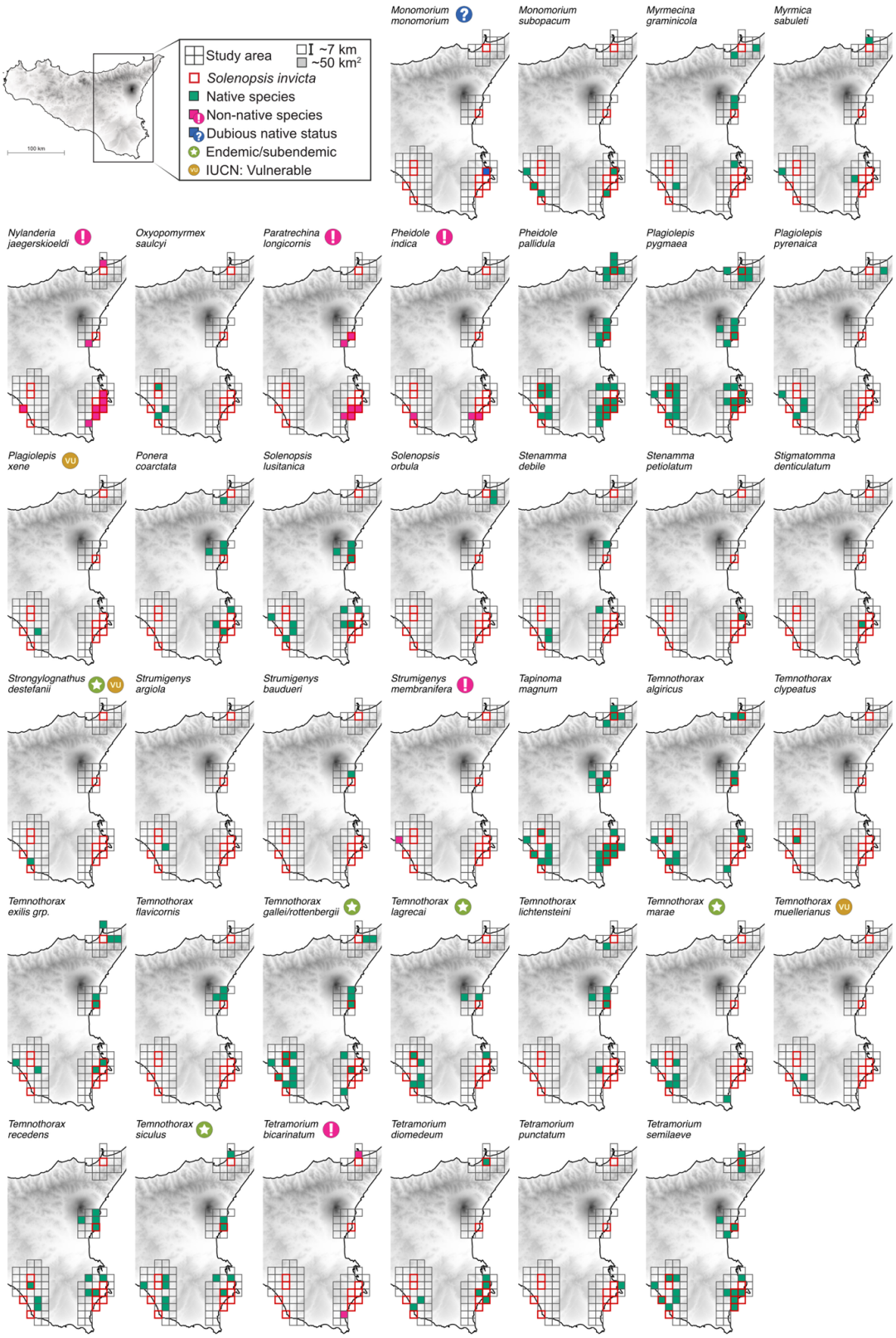

Figure 4. Detailed distribution maps of the ant species recorded in the study area, part 2. Each cell is 7.07 × 7.07 km in size (≈ 50 km²). Thick red lines indicate cells where *Solenopsis invicta* has been found. Coloured cells show the presence of each species: green for native, fuchsia for introduced, and blue for records of species of dubious status. Additional information, such as endemic/subendemic status and IUCN extinction risk category, is provided next to each species.

fall into areas predicted as suitable (except one that is slightly outside the border of a suitable cell), yet their suitability scores are in some cases not high, potentially suggesting that the species can colonise an even wider territory than previously envisioned.

At least until April 2026, *S. invicta* was still abundant and active in the first site of discovery as well as in the other sites across the 23 km range previously reported across the province of Siracusa (Menchetti et al. 2024). In many of these sites, we witnessed public roads surrounded by private gardens being populated by several large nests every few metres. Our access to private gardens was only sporadically possible, and the time effort needed for a detailed description of the fire ant populations of such large and densely invaded areas was beyond our capabilities. Similarly to what had previously been observed in January 2023 (Menchetti et al. 2023a), in both November 2024 and April 2026 winged queens and males were often observable outside nests, suggesting reproductive activities of the colonies.

However, the presence of *S. invicta* is not always easily detectable: nest mounds are not necessarily built (e.g., depending on soil type, vegetation, and sun exposure) and the foraging trails—extending up to at least 30 m from the nest—tend to be subterranean unless impediments like paved surfaces prevent their construction (Markin et al. 1975; Byron and Hays 1986; Tschinkel 2006). We provide the first evidence of *S. invicta* occurring in a woodland habitat within a natural reserve (Bosco di Santo Pietro Natural Reserve, Catania province). A process of expansion towards more natural habitats was recently reported for the electric ant (or little fire ant) *Allomerus auropunctatus* (Roger, 1863) (formerly known as *Wasmannia auropunctata*; Longino and Branstetter 2026) in Spain (Arcos et al. 2025). It is worth paying attention to this development considering the potential impacts of *S. invicta* on the natural ecosystems of the region and the conservation and biogeographic importance of Sicily and the Hyblean sector (Schmitt et al. 2021). However, our second visual survey effort at the woodland site—albeit very brief and limited—did not produce findings of *S. invicta* in and near the natural reserve, indicating that the species' presence may be scarcer in this new area, and raising some hope that natural sites are not as well-suited (Menchetti et al. 2023a). The findings in Passo Marinaro and Scoglitti (Ragusa province) occurred in August near active greenhouses and irrigated areas that were completely dry when we visited them later in September and April without finding fire ants. Nonetheless, the whole area is characterised by a wide extension of greenhouses (Figure 1b,c). Plant trading is one of the most likely vectors of the species' spread, and these worrying findings highlight the need for increased monitoring near plant nurseries and garden centres (Tschinkel 2006; Bertelsmeier et al. 2017). We also discovered *S. invicta* nests at the perimeter of two plant nurseries. One of them, near the village of Cassibile (belonging to the regional administration and currently shut down) and surrounded by a seminatural area with Mediterranean vegetation, is characterised by a high density of mature nests around the exterior perimeter (Figure 1d1). The second one, in Fontane Bianche, belongs to a private company and was also found to have multiple colonies along its exterior perimeter, this time crossing into agricultural land and near the perimeter of private gardens we could not access. The case of the finding in Milazzo is also emblematic, as a full fire ant colony was found within a soil pot of uncertain origins illegally abandoned at the side of a road.

Only New Zealand successfully eradicated *S. invicta* nationwide through early detection and rapid response (Ward 2009; Wetterer 2013). Notably, the origin of one of those incursions – a nest detected in 2006 at Whirinaki, Napier, and eradicated by 2009 – was left unresolved partly because the site's imports came mainly from Europe, then assumed to be free of fire ants (Christian 2009), an assumption that the Sicilian invasion has since disproved. Many campaigns have been carried out worldwide, with different methodologies and results (Ward 2009; Wetterer 2013). The very early approaches that followed the outbreak of the species in the US during the 1940s and 1950s of the last century saw the indiscriminate use of biocides over large areas. This approach proved not only harmful to the environment, but also counterproductive since *S. invicta* could overcome the treatments better than native ant species and then sharply increase its abundance thanks to reduced competition (Summerlin et al. 1977; Stimac and Alves 1994; Tschinkel 2006). Since then, eradication and control approaches have greatly developed to become more environmentally friendly and targeted in their effects (Yue et al. 2025). Still, many methods in use can also attract non-target ants; the biocide substance employed can potentially affect a wide range of organisms, requiring careful use (Moncada 2003; Corsetti 2024). The use of hot water, part of the

eradication plan in Sicily, is among the environmentally safest ones and can also be easily applied by the public to eliminate individual nests at virtually no cost (Li et al. 2024). The indoxacarb compound, also included in the plan, is toxic to a variety of organisms, including birds, fishes, insects, and bees (Moncada 2003), but its application through the Advion® Fire Ant Bait is designed to target ants specifically. However, baits do not exclusively attract fire ants and are very capable of poisoning other ant species as well (Corsetti 2024). Insecticide impacts may be unpredictably different among species within the same ant community (Markin et al. 1974b), and no data are currently available on their effects on Mediterranean ants. Baits meant for ants may also be impactful to other insects (Yu et al. 2015), especially once dominant ants disappear, and baits are not promptly removed (Markin et al. 1974a). Therefore, to be effective and environmentally safe, the use of baits must be grounded in a good understanding of the ecological context.

Australia is likely the country that has been investing the most in the removal of *S. invicta*, with a number of successful local eradications that have required considerable costs: over 1 million Australian dollars (AUD) for each of two single-nest incursions, 2 to 3.8 million AUD for areas approximately similar to the first reported by Menchetti et al. (2023a), and over 433 million AUD across 18 years (until 2019) for an ongoing eradication attempt over a 280 km² area (Wylie et al. 2016; Angulo et al. 2022; Genovesi et al. 2024).

The invasion of the red imported fire ant in Sicily was detected only thanks to fortuitous circumstances several years after it began. The establishment of non-native and invasive ant species in Europe is often discovered by chance by amateurs or people who do not have a specific task in biosurveillance, as in the case of two other species belonging to the list of IAS of Union concern, *A. auropunctatus* in Spain, France, and Cyprus (Espadaler et al. 2018; Demetriou et al. 2022; Blight et al. 2024) and the Asian needle ant *Brachyponera chinensis* (Emery, 1895) in Italy (Menchetti et al. 2022; Schifani et al. 2024a). The latter was added to the EU list in 2025, now representing another threat on which authorities are called to intervene, specifically in the regions of Campania and Lombardy. Many other non-native ant species are likely to establish or may have already done so undetected (Schifani et al. 2024b; Menchetti et al. 2026).

Fire ants and their neighbours

In the face of the uncertain future of the invasion, our data on ant diversity near sites colonised by *S. invicta* provide a baseline on some of the species likely to be impacted by both *S. invicta* itself and by its management. Continuous monitoring is needed to understand both the spread of this species and the dynamics of its interactions with other species.

The Mediterranean region is a biodiversity hotspot for ant richness, with a notable percentage of rare endemic species (Kass et al. 2022). We recorded ant species with very different lifestyles and ecological traits, including social parasites (e.g., *Plagiolepis xene, Strongylognathus destefanii, Temnothorax muellerianus*), arboreal-nesting ants [e.g., *Dolichoderus quadripunctatus* (Linnaeus, 1771)*, Temnothorax clypeatus* (Mayr, 1853)*, T. algiricus* (Forel, 1894)], endogean and leaf litter species [e.g., *Hypoponera eduardi* (Forel, 1894)*, Ponera coarctata* (Latreille, 1802), *Solenopsis lusitanica* Emery, 1915, *Stenamma debile* Foerster, 1850*, Stigmatomma denticulatum* Roger, 1859], xerothermophilous open habitat specialists [e.g., *A. semipolita*, *Cataglyphis viatica* (Fabricius, 1787)*, Messor spp.*], species that form supercolonies (e.g., *Tapinoma magnum*), seed-eaters (e.g., *Oxyopomyrmex saulcyi* Emery, 1889*, Messor* spp.), or predatory specialists (e.g., *S. denticulatum*, *Strumigenys* spp.). Our data also report a high proportion of species endemic to Sicily in the area (or subendemic, extending to nearby Maltese islands or the southernmost parts of the Italian peninsula). While none of these had their conservation status assessed, the small distribution range may represent a vulnerability, as in the case of *T. marae,* which is considered unique to southeastern Sicily and Malta (Schifani et al. 2022a). Many, like *Aphaenogaster trinacriae*, *Lasius maltaeus*, *Temnothorax marae*, or *T. siculus*, were only recently described (Alicata and Schifani 2019; Seifert 2020; Schifani et al. 2022c; 2025a).

We also found non-native ant species, especially in coastal urban and suburban areas. Most sampling activities in the region have long focused on natural habitats, while urban and disturbed areas have been comparatively neglected. Many of these non-native species were only very recently reported from Sicily or Italy, despite a potentially much older first arrival (Schifani and Alicata 2018; Schifani 2019). Thus, the new data presented in this study substantially expand their known distribution: this is

the case of the longhorn crazy ant *Paratrechina longicornis* and *Nylanderia jaegerskioeldi* (Mayr, 1904), both appearing almost ubiquitous across coastal settlements south of Siracusa and previously only known from a handful of sites in Italy (Schifani and Alicata 2018). While these species are less impactful than *S. invicta* (Schifani et al. 2024b), their widespread and undocumented presence is noteworthy. Coastal areas that were deprived of their native Mediterranean ecosystems and plant assemblages with the construction of settlements, irrigated gardens and greenhouses can easily become hotspots for non-native and invasive ant species by providing suitable ecological conditions, reduced competition with native ants, and by actively importing non-native species by trade.

It is uncertain whether four species are native to the island. *Aphaenogaster splendida* (Roger, 1859) and *Cardiocondyla mauritanica* Forel, 1890 occur widely across Sicily but have mostly been collected from disturbed areas and their native ranges are not yet well-defined, while both *C. viatica* and *Monomorium monomorium* Bolton, 1987 were only collected once in Sicily, both from disturbed areas (Schifani and Alicata 2018; Menchetti et al. 2026).

Engaging local communities is crucial to track the *S. invicta* invasion, with the iNaturalist platform having already proved valuable for documenting invasive species and gathering fire ant records (Menchetti et al. 2024; Mason et al. 2025). The species' tendency to nest in human settlements and its painful sting can be exploited to detect its presence, and recent efforts to document urban ants in Italy through public engagement are noteworthy in this regard (Bisanti et al. 2026; Castracani et al. 2026). However, an information campaign and verification by experts stand as essential tools to avoid confusion with other ants. While raising public attention towards the issue, it is important to communicate more broadly about the diversity and ecological role of ants to reduce the risk of misidentifications and avoid a negative perception of the whole group. The reddish colour of fire ants may sometimes be believed to be a distinguishing trait of *S. invicta*, but it is shared with dozens of native and some non-native species occurring in the region (see some examples in Figure 5). The large mounds that *S. invicta* can build do not always occur and can resemble those of the very common *Tapinoma magnum*. Stings producing white pustules on humans are typical of *S. invicta*, but do not emerge on every person. At the same time, some native ants known in the region may (albeit very rarely) sting humans (e.g., *Hypoponera eduardi, Myrmica sabuleti* Meinert, 1861, *Tetramorium semilaeve* André, 1883, *Solenopsis lusitanica*), while others can inflict bites [e.g., *Camponotus barbaricus* Emery, 1905, *Crematogaster scutellaris* (Olivier, 1792), *T. magnum*]. The identification section in the materials and methods of this paper offers a reliable guideline for how to separate *S. invicta* from other species known to occur in Sicily.

CONCLUSIONS

A severe lack of data on both native and non-native ant species allowed *S. invicta* to spread undetected for many years. The limited reach of biosurveillance for non-native ants—only partly compensated by late fortuitous detections—is not unique to Sicily, with similar cases reported from other Italian regions (e.g., *Brachyponera chinensis* in Campania and Lombardy) and European countries (e.g., *Allomerus auropunctatus* in Cyprus, France, and Spain). Understanding the full extent of the *S. invicta* invasion in Sicily is crucial for developing the management and eradication plan and preventing its further spread within Sicily, as well as into mainland Europe and the rest of the Mediterranean. Our new data fill important knowledge gaps in the distribution of both the invasive fire ants and other native and non-native ants of the region. The *S. invicta* invasion spread much farther than previously documented, with a more than hundredfold increase in the known Extent of Occurrence. On the southeastern side of the invaded range, several other non-native species occurred. Updated extinction risk assessments and IUCN red lists for Mediterranean ants could represent a valuable informative tool for managing authorities, with native ants expected to be affected by the fire ant invasion and potentially also by treatments for its removal. Future studies are needed to examine the interactions among *S. invicta*, other non-native species, and the native ant fauna. All these aspects could contribute to effective and sustainable management action.

ACKNOWLEDGEMENTS

This work would not have been possible without the dedication of numerous entomologists who, over the years, collected ants across the region, often driven by a deep passion for this overlooked group. Their

Figure 5. *Solenopsis invicta* and other ant species occurring in surrounding areas in Sicily that could be misidentified as fire ants by non-specialists. Images highlight fire ant workers (a, ph. Jesse Rorabaugh), their typical nest mound (b, in Avola, Siracusa, ph. Mattia Menchetti), and some of the similar-looking species: (c) *Solenopsis lusitanica* (ph. Roberto Piras); (d) *Aphaenogaster ichnusa* Santschi, 1925 (ph. Bernard Noguès); (e) Camponotus *nylanderi* Emery, 1921 (ph. Enrico Schifani); (f) *Crematogaster scutellaris* (ph. Cristina Krippahl); (g) *Messor ibericus* Santschi, 1931 × *M. structor* (Latreille, 1798) (ph. Philippe Geniez); (h) *Monomorium subopacum* (Smith, F., 1858) (ph. Jonghyun Park); (i) *Myrmica sabuleti* (ph. Frederik Leck Fisher); (j) *Pheidole pallidula* (Nylander, 1849) (ph. Sergio Ibarra); (k) *Tetramorium bicarinatum* (Nylander, 1846) (ph. Thomas Shahan).

names are listed in Supplementary Material 1, and to them we extend our deepest gratitude. During the preparation of this manuscript, the authors used generative AI (Claude, Anthropic) to assist with data analysis, figure preparation, and text editing. All outputs were verified against the primary data and critically edited by the authors, who take full responsibility for the accuracy, integrity, and originality of the work. Support for this research was provided to ES through the Juan de la Cierva postdoctoral fellowship programme with the grant JDC2024-054485-I (funded by MICIU/AEI/10.13039/501100011033 and FSE+), to RV by grants PID2022-139689NB-I00 (funded by MICIU/AEI/10.13039/501100011033 and by ERDF, EU) and 2021-SGR-00420 (Departament de Recerca i Universitats, Generalitat de Catalunya), and to MM by the European Union's Horizon Europe programme under Marie Skłodowska-Curie Actions (MSCA) Postdoctoral fellowship grant agreement No 101206623.

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Submitted: 25 August 2026

First decision: 9 September 2026

Accepted: 12 September 2026

Published online: 14 September 2026

Edited by Emiliano Mori