ANTS OF SARDINIA: AN UPDATED CHECKLIST BASED ON NEW FAUNISTIC, MORPHOLOGICAL AND BIOGEOGRAPHICAL NOTES

* Department of Chemistry, Life Sciences & Environmental Sustainability, University of Parma, Parco Area delle Scienze 11/a, 43124 Parma, Italy
* Department of Biosciences, University of Milan “la Statale”, Via Giovanni Celoria 26, 20133 Milan, Italy
* Corso Umberto I 301, 80058 Torre Annunziata (NA), Italy
* Department of Life and Environmental Sciences, University of Cagliari, Via Sant’Ignazio da Laconi 13, 09123 Cagliari, Italy
* Via Mascagni 3, 09020 Ussana (CA), Italy
* Via Zeffiro 8, 09130 Cagliari (CA), Italy

Corresponding Author: Enrico Schifani; enrs8@gmail.com

Sardinia is the second largest island in the Mediterranean region, receiving significant attention due to its interesting fauna and flora. The last checklist of Sardinian ants was published more than a decade ago, and, since then, it got outdated by numerous taxonomic and faunistic novelties. As a result of recent collecting efforts across the island, we present the first Sardinian records of Messor iberus, Santschi, 1931, Solenopsis lusitanica, Emery, 1915 (new to Italy), Temnothorax aveli, Bondroit, 1918 and Tetramorium atratulum, (Schenck, 1852), while proposing to consider Solenopsis fugax, (Latreille, 1798) and Temnothorax affinis, (Mayr, 1855) as absent. We report for the first time a parasite-host association between Tetramorium atratulum and Tetramorium semilaeve. Andrê, 1883, and the conspicuous presence of ergatogynes within a Solenopsis colony (S. lusitanica). Morphological insights on the little known S. lusitanica and S. orbula, Emery, 1875 are also discussed. We combined the new findings and previous literature data into an updated checklist of 77 taxa and discuss a first biogeographical analysis of the Sardinian ants aided by chorotypes. Eurasian, European, Euro-Mediterranean and West-Mediterranean taxa are the numerically prevalent groups, while the overall number of species is significantly lower than in the other large Mediterranean islands. Considerable knowledge gaps still remain and some species are known to require additional taxonomic investigation.

KEY WORDS: mirmecofauna; Solenopsis; ergatogynes; Tuscan Archipelago

INTRODUCTION

The Mediterranean basin is an important diversity hotspot worldwide (MÉDAIL & QUEZEL, 1997; MÉDAIL, 2017), hosting a very large number of unique ant species (BOROWIEC, 2014). Sardinia is the second largest Mediterranean island, covering about 24,000 km² and being only slightly smaller (~1.7 km²) than Sicily. Thanks to its variety of landforms, complex orographic patterns (with hilly lands, plateaus, mountain and plains), heterogeneous geological substrata and climate variability (BAZZATO et al., 2021), the island is characterized by high levels of biodiversity and it is broadly known to host a significant endemic component in its fauna and flora (BACCELLI, 1983; GRILL et al., 2007) in addition to a wide variety of Potential Natural Vegetations (FARRIS et al., 2010; BACCHETTA et al., 2009). Ants (Hymenoptera, Formicidae) are one of the ecologically more impactful insect groups in both natural and anthropogenic ecosystems (HÖLDOBLER & WILSON, 1990; LACH et al., 2010), including Mediterranean forests and agroecosystems across Italy and Sardinia (e.g. LOI et al., 2012; CAMPOLI et al., 2015; CASTRACANI et al., 2017; GIANNETTI et al., 2019; SCHIFANI et al., 2020a). The oldest checklist of the Sardinian ant fauna was published by EMERY (1915) and included 47 taxa. Later on, this number increased to 57 in the Italian checklist published by BARONI URBANI (1971), and to 68 according to POLDI et al. (1995). However, the latest checklist, published by VERDINELLI et al. (2007), brought the total number up to 70. Since then, several other species were recorded as a result of a few faunistic surveys (RIGATO & TONI, 2011; LOI, 2013), suggesting that further efforts are still needed to uncover the island’s true myrmecological diversity. In addition, relevant changes occurred due to taxonomic revisions involving species present in Sardinia (e.g. SEIFFERT et al., 2017) and presently, no updated checklist of the island is available.

Different independent collective efforts on the Sardinian ant fauna were conducted by the authors of this paper, which resulted in a significant amount of new species records and the collection of new or little-known forms and a new parasite-host association in ants. In addition, a review of the relevant taxonomic and faunistic literature allowed us to compile a new and updated checklist to summarize current faunistic knowledge over the island’s ants, providing a key source of information to facilitate future investigations on Sardinian and Western-Mediterranean ants and their biogeography.
MATERIALS AND METHODS

Collecting efforts were conducted in the years 2017-2019 by employing both direct sampling and pitfall traps filled with wine-vinegar saturated by sodium chloride as preservation method (see AGOSTI et al., 2001; BRANDMAYR et al., 2005) across four of the five administrative regions of Sardinia: the Metropolitan City of Cagliari (CA) (see PALUMBO et al., 2020), and the provinces of Nuoro (NU), Oristano (OR) and South Sardinia (SU). In addition, we consulted material stored at the Milan Natural History Museum (Museo Civico di Storia Naturale, Milan, Italy - MSNM) and in authors personal collections, from Sardinia and also from neighboring regions whenever relevant. All specimens were identified under stereomicroscopes. Relevant taxonomic sources are mentioned for each taxon. Whenever geographic coordinates of the sampling sites are given, error range is estimated to be ± 15 m.

Morphometric characters presented in this paper for Solenopsis refer to the morphometries used by GALKOWSKI et al. (2009), but French acronyms were abandoned in favour of the English-based acronyms proposed by SEIFERT (2018). Therefore, the following characters and acronyms were used (English equivalents are indicated in brackets): CW, maximum head width, across the eyes (LaT); CL, maximum head length in median line (LoT); SL, maximum scape length as a straight line, excluding the articular condyle and its neck (LoSc); EL, maximum diameter of the compound eyes, including unpigmented ommatidia (Diam. oeil); ML, maximum length of the mesosoma (LoM); MW, maximum width of the mesosoma (LaM); Mh, maximum height of the mesosoma (HM); PeH, maximum height of the petiole (HP); PPH, maximum height of the postpetiole (HPP); PW, maximum width of the petiole (LaP); PPW, maximum width of the postpetiole (LPP). These measurements were obtained using the software ImageJ (SCHNEIDER et al., 2012) and high quality pictures of the specimens taken at up to 10x magnification using a Canon EOS 1300D camera and micro photography lens.

To facilitate a first biogeographic analysis of the checklist, we attempted to rely on the most broadly utilized chorotypes model proposed by VIGNA TAGLIANTI et al. (1999). However, in the framework of ant biogeography, we found highly limiting to miss chorotypes defining Maghrebian and South-Western European distributions, both disappearing under the wider Western-Mediterranean chorotype sensu VIGNA TAGLIANTI et al. (1999). PARENZAN (1994) proposed to use the acronyms NAW and ESW to refer to these distributions, so we follow his nomenclature for these two types. As a result, the following chorotypes were used: ASE, Asiatic-European; EME, East-Mediterranean; ESW, South-West European; EUR, European; CEM, Central Asiatic-European-Mediterranean; MED, Mediterranean; NAF, North-African; NAW, South-Western Mediterranean; SACO, Sardo-Corsican endemic; SARD, Sardinian endemic; SEU, South-European; TEM, Turano-European-Mediterranean; TUE, Turano-European; TYRR, Tyrrenian endemic; WME, West-Mediterranean. Chorotypes were assigned to each taxon mainly on the basis of species distribution data from AntMediterraneo (see JANICKI et al., 2016; GUÉNARD et al., 2017).

NEW SPECIES RECORDS

Messor Forel, 1890

Messor ibericus Santschi, 1931

Examined material - Sardinia: All the specimens are stored in the University of Cagliari collection deposited in the Zoological Research Museum Alexander Koenig (Bonn, Germany): Sa Guardia Lada, Simbrizzi, Quartu Sant’Elena (CA), 16.VII-03.XII.2018, 12 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Sirigrigiu, Corongiu, Maracalagonis (CA), 22.VIII.2018, 3 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. C. D’Aquila, Stagno di Quarti, Quarto Sant’Elena (CA), 16.VII.2018-II.2019, 4 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Teplina Spada, Stagno di Quarti, Quarto Sant’Elena (CA), VII-VIII.2018, 2 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Via Belgio, Sant’Antonio, Quarto Sant’Elena (CA), II.2019, 1 worker, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani.

Remarks: This species appears to be sole representative of the Messor structor complex in the Western Mediterranean region, where it was known under the name M. structor until recently (STEINER et al., 2018). All Sardinian specimens we examined were expectedly identified as M. ibericus according to the discriminant function proposed by STEINER et al. (2018). Under these conditions, all previous records of M. structor from the island should provisionally be attributed to M. ibericus, removing M. structor from the Sardinian checklist. According to the few verified data (STEINER et al., 2018; SCHIFANI & ALICATA, 2018; SCHAR et al., 2020), M. ibericus may be the sole species of this complex also in the rest of Italy, while some recent mentions for the peninsula (RIGATO & WETTERER, 2018; SCUPOLA, 2018) refer to identifications prior to the taxonomic revision of STEINER et al. (2018).

Solenopsis Westwood, 1840

Solenopsis lusitanica Emery, 1915

Examined material - Sardinia: Domus de Maria (SU), 38.945720, 8.813108, 05.IX.2018, 63 males, 4 queens, 20 ergatogynes, 210 minor workers, 143 major workers, E. Nalini legit, det. E. Nalini & E. Schifani. E. Nalini collection. Iglesias (SU), 19.IX-03.X.2006, 1 queen and 1 male, G. Chessa legit, det. E. Nalini, Museo Civico di Storia Naturale di Milano (MSNM) – published in RIGATO & TONI (2011). Nacar (SU), 02.X.2018, 1 queen and 1 male, E. Nalini legit, det. E. Nalini, E. SCHIFANI ET AL. REDIA. Vol. 104, 2021
Nalini collection. Pantaleo (SU), 39.090699, 8.802370, 09.IX.2018, 27 males, 28 queens, 98 minor workers, 18 major workers (two colonies), E. Nalini legit, det. E. Nalini. E. Nalini collection.

In addition to the abovementioned Sardinian material, further Italian specimens belonging to the same morphospecies were found from the Tuscan Archipelago, representing a significant novelty that we also report on: Isola d’Elba, 17.IX-03.X.2000, 1 queen and 2 males, P. Scaramozzino legit, det. E. Nalini. MSNM. Isola di Montecristo, 1 queen (15-26.IX.1999) and male (15-25.IX.2000), F. Strumia legit, det. E. Nalini, MSNM. Isola di Pianosa, 15-26.IX.2000, 1 queen and 2 males, P. Scaramozzino legit, det. E. Nalini, MSNM.

Remarks: This species is new to Italy (POLDI et al., 1995). However, attribution of the examined material to this taxon bears an inevitable degree of uncertainty until a proper taxonomic revision of the group is produced. GALKOWSKI et al. (2010) started to revise the nomenclatural chaos that reigns over the difficult taxonomy of Mediterranean Solenopsis, a genus that includes a wide amount of very poorly described taxa whose identity is difficult to delimit. The S. lusitanica group appears distinguishable among the Solenopsis of South-Western Europe by morphological characters provided by GALKOWSKI et al. (2010). At the same time, no distinction is actually possible between S. lusitanica and the other valid taxa of the same group, S. balachowskyi Bernard, 1959 and S. gallica Santschi, 1934, both considered of uncertain identity (GALKOWSKI et al., 2010). For this reason, and since S. lusitanica is also the sole of the three currently considered present in any nearby region (see the Corsican checklists by BLATRIX et al., 2018; 2020) we provisionally name the Sardinian Solenopsis material belonging to the S. lusitanica group as S. lusitanica until a proper taxonomic revision assesses the validity of S. balachowskyi and S. gallica. Further information on this identification is given in the morphological section of this paper. Considering the extreme uncertainty around the true identity of S. fugax (Latreille, 1798) until recently (GALKOWSKI et al., 2010), it is unsurprising that all the Sardinian material previously identified as S. fugax we managed to examine (see RIGATO & TONI, 2011) corresponds to S. lusitanica instead. In a similar fashion, recent attempts to find S. fugax in Sicily yielded no results, as only a form tentatively named S. latro Forel, 1894 was recovered by SCHAR et al. (2020). While we have verified records of S. fugax from other regions of Italy (at least across the Po Plain - Emiliana-Romagna: SCHIFANI et al., 2020a; Lombardy: CASTRACANI et al., 2020, and also Trezzo sull’Adda (MI), 45.612021, 9.522218, 10.IX.2019, E. Nalini leg., E. Nalini personal collection; Veneto: Bovolone (VR), 27.VIII.2014, E. Nalini leg. and Spinea (VE), 14.IX.2017, D. Vallotto leg., E. Nalini personal collection), we provisionally propose to remove this species from the Sardinian checklist. The findings of S. lusitanica in the Tuscan Archipelago (biogeographically close to both Corsica and the Tuscan coast, see FATTORINI, 2009; DAPPORO et al., 2017) may suggest its presence on mainland Italy, perhaps unnoticed due to misidentifications with S. fugax. A proper assessment over the identity and distribution of the Italian Solenopsis spp. is evidently required, but it depends on a satisfactory resolution of at least some of the taxonomic problems affecting this genus in the Mediterranean region.

**Tetramorium Mayr, 1861**

* Tetramorium aveli* (Bondroit, 1918)

Examined material - Sardinia: Piscinas, Arbus (SU), 0 m, 39.5404, 8.4521, 25.V.2006, P. Cornacchia, M. Bardiani, D. Birtele & D. Whitmore legit, 1 worker labeled as *Tetramorium affinis*, det. E. Schifani, Bosco Fontana Natural Reserve ant collection (Lombardy) - published in RIGATO & TONI (2011).

Remarks: Current uncertainty over the separation of *T. aveli* from *T. italicus* (Consani, 1952) complicates naming of the Sardinian population: populations from France (including Corsica) and Iberia have been traditionally identified as *T. aveli* (or as one of its junior synonyms, see for example BUSCHINGER et al., 1988; COLLINGWOOD & PRINCE, 1998; ARNAN et al., 2007; HERNÁNDEZ CUBA et al., 2006; PLATEAUX & CAGNIANT, 2012; ESPADALER et al., 2013; TINAUT, 2016; BLATRIX et al., 2018), while those of the Italian peninsula and North-Western Balkans as *T. italicus* (e.g. BRACKO, 2007; 2017; SCHULZ et al., 2006; CASTRACANI et al., 2010; RIGATO & WETTERER, 2018; SCUPOLA, 2018; GIANNETTI et al., 2019; 2021; SCHIFANI et al., 2020a). *Tetramorium aveli* was described from France (BONDROT 1918), while *T. italicus* from Central/Northern Italy (CONSANI & ZANGHERI 1952). However, one of the few qualitative characters provided by CONSANI & ZANGHERI (1952) to separate *T. italicus* from *T. aveli* appears fully reliable following a comparison of French *T. aveli* (type material and other material generously shared with us by C. Galkowski and R. Blatrix) and Italian material of *T. italicus* (published in GIANNETTI et al., 2019; SCHIFANI et al., 2020a), and the two taxa have been suggested to be potential synonyms (SCUPOLA, 2018). While an attempt to shed light over this taxonomic uncertainty is ongoing, we provisionally decided to use the name *T. aveli* due to the lack of darkened antennal clubs typical of *T. italicus* according to CONSANI & ZANGHERI (1952). The examined specimen had previously been identified as *T. affinis* (RIGATO & TONI, 2011): while there are evident similarities in shape and color between *T. affinis* and *T. aveli/T. italicus*, *T. affinis* is characterized by an evidently much coarser body sculpture (SEIFFERT, 2018) and by a much less prominent subpetiolar process. As a result of our new identification, which was further aided by direct comparison with several *T. affinis* workers from Italy and Central Europe, *T. affinis* is provisionally excluded from the Sardinian fauna.

**Tetramorium Mayr, 1855**

* Tetramorium atratum* (Schenk, 1952)

Examined material - Sardinia: Dorgali (NU), 21.VIII.
2018, 1 queen and 1 male from a T. semilaeve nest, M. Plumari legit, det. V. Gentile, V. Gentile collection. Dorgali (NU), 21.VIII.2018, 1 queen and 1 male from a T. semilaeve nest, M. Plumari leg., det. V. Gentile, M. Plumari collection. Narcao (SU), 39.1670, 8.6628, 2.IX.2018, 1 queen and 1 male from a T. semilaeve nest, E. Nalini legit, det. E. Nalini, E. Nalini collection.

Remarks: Inquiline social parasite ants as T. atratulum are very easily overlooked during faunistic surveys, sometimes severely hinder a correct understanding of their rarity, distribution and conservation status (Espadales & López-Soria, 1991; Schifani, 2017). Although still treated as Vulnerable in the IUCN Red List (Social Insects Specialist Group, 1996), T. atratulum is one of the few exceptions: records of this species are quite numerous and its geographic range widely extends from the West Palearctic, where it is native, to the Neartic region, where it was introduced alongside one of its host species, Tetramorium immigrans Santschi, 1927 (Dash & Sánchez, 2009; Seifert, 2018; Zhang et al., 2019). Interestingly, there are many different Tetramorium host species that T. atratulum is known to exploit. Three belong to the T. caespitum complex (Wagner et al., 2017), one to the T. cheffhei species complex and one to the T. ferox species complex (Sanetra et al., 1999; for complexes definitions see Csösz et al., 2005; Csösz & Schultz, 2010). The most interesting aspect of this first Sardinian record is that in all findings the host species was T. semilaeve André, 1883, which does not belong to any of these complexes and was never recorded as a host for T. atratulum before. Sanetra et al. (1999) had speculated that T. semilaeve could be a host for T. atratulum in Italy but no findings ever occurred. It is worth mentioning that the Sardinian populations of T. semilaeve, somewhat similarly to those of Calabria and Sicily (Fig. I; Schär et al. 2020), at least chromatically sometimes deviate from the definition given by Borowiec et al. (2015) ("never dark brown"). In addition, none of the known host species of T. atratulum is known to occur in Sardinia, with the sole exception of T. immigrans which is probably introduced on the island (see Wagner et al., 2017; Castracani et al., 2020).

**MORPHOLOGICAL NOTES**

*Solenopsis lusitanica* Emery, 1915

There are at least two reasons that make worth offering a morphological overview of the Sardinian material we identified as *S. lusitanica*. First is obviously the scarceness of information currently available over the morphological identity of this taxon and the taxonomic confusion which reigns over the *S. lusitanica* complex, hindering a proper biological and biogeographical understanding. Second, the extraordinary finding of 20 ergatogynes within one of the examined *S. lusitanica* colonies (Fig. II), which represents an unexpected and very rare case within *Solenopsis*.

As mentioned above, the original description of *S. lusitanica* is almost completely useless to its identification (see Emery, 1915) and the sole information available was provided by Galkowski et al. (2010), consisting in a brief description and morphometric characterization of one queen and one male specimen (alongside 1 queen and 1 male of *S. balachowskyi*). However, we compared our material with the definition and morphometric data provided by Galkowski et al. (2010) and to some *S. lusitanica* specimens from Spain kindly sent to us by C. Galkowski. In order to do so, we recorded the 12 morphometric characters used by Galkowski et al. (2010) on 31 specimens from 3 colonies (Tab. 1). Despite past confusion, Solenopsis lusitanica males and queens are much smaller than those of *S. fugax*, and queens lack the longitudinal rugae running from the front to the ocelli in *S. fugax* (Fig. II). Distinction of workers appears to be considerably more difficult, especially for minors. Major workers have darkened heads (often slightly darkened near the vertex in minors too), and both minors and majors appear to be less hairy than *S. fugax* (Fig. III). It is worth noting that the type worker of *S. lusitanica gaetula* Santschi, 1936 (AntWeb CASENT0913907), an even more ambiguously defined taxon from Morocco (Santschi, 1936), is clearly outside any imaginable in specific variation of the form we examined, and may instead be more closely related to the *S. orbula* complex.

Regarding the collected ergatogynes, these showed a significant morphological diversification, encompassing individuals more closely resembling queens and others more closely resembling workers (Fig. III). Ergatogynes represent one of the several different morphological mosaics found in ants (Schifani et al., 2020b), they are classified as either intercastes (i.e. rarely generated hybrid phenotypes usually unable to reproduce) or ergatoids (a distinct kind of specialized reproducers which may be even more common or replace queens in some species) (Peeters, 1991). The very high number of ergatogynes found within a single nest in our case timidly suggests that they may represent functional ergatoids, however documentation of ergatogynes in *Solenopsis* is almost non-existent, recommending prudence in taking interpretations (Glancey et al., 1980). Further investigation should aim to see whether ergatogynes are routinely produced by the colonies of this species.

*Solenopsis orbula* Emery, 1875

Examined material - Sardinia: Mari Ermi, Cabras (OR), 05.VII.2017, 2 queens and 1 male, Emilio Villani legit, det. V. Gentile, V. Gentile collection. Specimens stored at the in the University of Cagliari collection deposited in the deposited in the Zoological Research Museum Alexander Koenig (Bonn, Germany): Sirigragiu, Corongiu, Maracalagonis (CA), 1.VI-18.VII.2018, 2 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Piscina Nuxadda, Quartucciu (CA), 18.VII-21.VIII.2018, 2 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Str. Comunale Cani Nieddu, Quartu Sant’Elena (CA), 17.VII-21.VIII.2018,
1 worker, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Riu Monte Nieddu, Maracalagonis (CA), 17.VII-21.VIII.2018, 1 worker, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Via Lago di Varese, Quartu Sant’Elena (CA), 16.VII-29.X.2018, 3 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani. Via Riccione, Porticciolo, Quartu Sant’Elena (CA), 20.VIII-30.X.2018, 28 workers, E. Bazzato, D. Cillo, M. Caria & Cesare Ancona legit, det. E. Schifani.

Fig. I - *Tetramorium semilaeve* worker from a Sardinian colony hosting *Tetramorium atratulum*. 1: lateral view, 2: dorsal view, 3: head view. Scale bar: 0.5 mm. Photos by Elia Nalini.

Fig. II - *Solenopsis lusitanica* colony from Sardinia. Blue arrows indicate ergatogynes, while the rest of wingless individuals are workers of different size and winged individuals are one queen (upper right side) and four males (on the left). Photo by Elia Nalini.
Fig. III - *Solenopsis lusitanica* from Sardinia. 1-3: male, 4-6: queen, 7-12: ergatogynes, 13-15: major worker, 16-18: minor worker. Scale bars 1 mm (images 2,3,5,6) and 0.5 mm (others). Photos by Elia Nalini.
The identity of this peculiar species has long been vague. It was originally described from Corsica on the basis of its worker caste (EMERY, 1875a; a separate description also in EMERY, 1875b) and then ANDRÉ (1883) provided a brief description of a S. orbula queen from Algeria. Later on, FOREL (1905) described the subspecies S. orbula ternisiensis Forel, 1905 from some Algerian workers and a Spanish queen. However, differences between the two subspecies remain barely defined and only described for the worker caste (e.g., EMERY, 1909; 1916). As a result, the status of ssp. ternisiensis continued to be dubious (e.g., MEI, 1995), while significant morphological data from the type population of Corsica were more recently provided by GALKOWSKI et al. (2010) for all three castes. Despite these long-lasting taxonomic uncertainties, the name S. orbula s.l. and S. orbula ternisiensis have been widely used in the Mediterranean region: in Sardinia (EMERY 1916, ssp. orbula), Sicilian Channel (EMERY 1916, ssp. ternisiensis), peninsular Italy (POLDI, 1992), Maltese Islands (SCHEMBRI & COLLINGWOOD, 1981), mainland France (CASEVITZ-WEULERSSE & GALKOWSKI, 2009), Spain (COLLINGWOOD & YARROW, 1969), Tunisia (FOREL, 1890; 1905, as ssp. ternisiensis in the latter), Lybia (FINZI, 1940, ssp. ternisiensis), Egypt (GRANDI, 1935, ssp. ternisiensis), Israel (VONSHAK & JONESCU-HIRSCH, 2009, ssp. ternisiensis), Lebanon (TOHMÉ, 1969), Syria (TOHMÉ & TOHMÉ, 1980), Turkey (AKTAÇ, 1988), Crete and in some Aegean Islands (SALATA & BOROWIEC, 2018). Moreover, in North Africa, several other vaguely defined taxa show similar morphological traits to S. orbula: S. atlantis Santschi, 1934, S. longiceps Forel, 1907, its subspecies S. longiceps barbara Santschi, 1934 (FOREL 1907; SANTSCHI 1934), in addition to the aforementioned S. latistitana gaetula. The only North-African species similar to S. orbula but at the same time safely distinguishable on the basis of the existing literature is the Egyptian S. cooperi Donisthorpe, 1947 thanks to the efforts of SHARAF et al. (2009). Due to biogeographical reasons, the conspecificity of the Sardinian population with that of Corsica has never been questioned (EMERY, 1916; VERDİNELLI et al., 2007). On the other hand, at least some of the abovementioned Mediterranean records probably belong to different species. For example, TOHMÉ & TOHMÉ (1980) described in detail a Persian ‘variety’ of S. orbula which clearly looks morphologically different from the Corsican S. orbula (also see GALKOWSKI et al., 2010). A quite different form of Solenopsis from Afghanistan was also described as a subspecies of S. orbula by PTSARSKI (1967), and only later recognized as a different taxon, S. knuti PISARSKI, 1967 (DULUSSKY & RADCHENKO, 1994). In the case of most records though, doubts cannot be solved

Table 1: Morphometric characters of examined Solenopsis latistitana specimens. Definition of morphometric characters follows GALKOWSKI et al. (2010), nomenclature adapted to the English standard proposed by SEIFERT (2018) and French equivalents in parentheses when possible. Values are given in µm (mean ± standard deviation (minimum – maximum).

|                | males (7 specimens, 3 colonies) | queens (6 specimens, 3 colonies) | ergatogynes (5 specimens, 1 colony) | minor workers (7 specimens, 1 colony) | major workers (6 specimens, 1 colony) |
|----------------|---------------------------------|----------------------------------|------------------------------------|--------------------------------------|----------------------------------------|
| CW (LaT)       | 600 ± 18 (570 - 621)            | 808 ± 23 (785 - 845)             | 566 ± 34 (539 - 623)               | 400 ± 12 (381 - 418)                 | 475 ± 36 (439 - 537)                   |
| CL (LaT)       | 470 ± 83 (429 - 528)            | 748 ± 27 (713 - 779)             | 500 ± 31 (475 - 412)               | 456 ± 48 (429 - 541)                 | 544 ± 21 (511 - 571)                   |
| SL (LaSc)      | 193 ± 7 (113 - 133)             | 512 ± 13 (493 - 529)             | 370 ± 48 (329 - 392)               | 308 ± 48 (294 - 319)                 | 347 ± 14 (335 - 368)                   |
| SL/HW          | 0.21 ± 0.01 (0.18 - 0.22)       | 0.63 ± 0.01 (0.61 - 0.65)        | 0.66 ± 0.07 (0.52 - 0.59)          | 0.77 ± 0.03 (0.70 - 0.80)            | 0.73 ± 0.03 (0.68 - 0.78)              |
| SL/HL          | 0.27 ± 0.03 (0.22 - 0.31)       | 0.69 ± 0.07 (0.65 - 0.74)        | 0.62 ± 0.06 (0.51 - 0.66)          | 0.65 ± 0.02 (0.61 - 0.77)            | 0.64 ± 0.01 (0.63 - 0.64)              |
| CW/CL          | 1.28 ± 0.97 (1.18 - 1.40)       | 1.08 ± 0.05 (1.01 - 1.16)        | 0.94 ± 0.02 (0.92 - 0.97)          | 0.84 ± 0.01 (0.83 - 0.86)            | 0.87 ± 0.04 (0.86 - 0.94)              |
| Ocellus diameter | 785 ± 17 (69 - 84)               | 831 ± 17 (68 - 117)              | -                                  | -                                    | -                                      |
| ML (LaM)       | 1235 ± 70 (1154 - 1332)         | 1502 ± 55 (1410 - 1563)          | 710 ± 47 (649 - 747)               | 481 ± 19 (456 - 508)                 | 565 ± 35 (536 - 606)                   |
| MW (LaM)       | 1841 ± 38 (1789 - 880)          | 253 ± 48 (251 - 874)             | 323 ± 42 (321 - 412)               | 246 ± 20 (244 - 260)                 | 291 ± 19 (266 - 307)                   |
| MH (HM)        | 795 ± 42 (714 - 840)            | 94 ± 35 (870 - 992)              | 441 ± 57 (349 - 483)               | -                                    | -                                      |
| PeH (HP)       | 215 ± 12 (195 - 227)            | 372 ± 21 (379 - 400)             | 211 ± 19 (182 - 229)               | 161 ± 13 (157 - 166)                 | 186 ± 5 (181 - 193)                    |
| PPH (HP)       | 261 ± 25 (220 - 266)            | 364 ± 42 (320 - 384)             | 188 ± 24 (150 - 213)               | 124 ± 9 (114 - 137)                  | 153 ± 9 (138 - 165)                    |
| PW (LaP)       | 230 ± 16 (206 - 254)            | 326 ± 21 (308 - 366)             | 181 ± 15 (161 - 197)               | 127 ± 13 (124 - 132)                 | 150 ± 9 (138 - 164)                    |
| PPW (LPP)      | 265 ± 6 (259 - 275)             | 367 ± 17 (338 - 380)             | 196 ± 14 (183 - 217)               | 142 ± 7 (135 - 157)                  | 158 ± 10 (149 - 177)                   |
Fig. IV - *Solenopsis orbula* from Sardinia. Up to bottom: male, queen, workers. Scale bars: 0.5 mm. 1-3: male, 4-6: queen, 7-9: major worker, 10: medium-sized worker, 11: minor worker. Photos by Enrico Schifani.

Fig. V - Biogeographic components of the Sardinian ant fauna according to chorotypes.
from the scarce indications published.

The material we collected in Sardinia included swarming sexuals collected in July (the same period reported for nuptial flights in Tuscany by Politi (1992)) and allows us to highlight a number of peculiar morphological characteristics of this species, hopefully providing some useful indication for the study of other Mediterranean populations until a proper taxonomic revision of the group is produced. The following morphological traits seem particularly distinctive of this taxon (Fig. IV):

- Small-sized queen caste characterized by a remarkably thin mesosoma (visibly much thinner than the head), an elongated rectangular-shaped head, a mostly dark-colored body contrasting with a yellowish gaster and feebble sculpture.

- Polymorphic workers with elongated, rectangular-shaped heads and a relatively characteristic mesosoma profile with a high and long propodeum. The occiput is not excavated as in species like S. cooperi. Most of the workers are uniformly yellow but the largest workers possess a contrasting dark head. This characteristic is visually impressive and clearly distinctive, but seems surprisingly neglected in the existing literature where is almost never reported (e.g. not in Galkowski et al., 2010).

The Corsican population possesses the same habits of the Sardinian specimens (see https://www.myrmecofournis.fr/Solenopsis/orbula, accessed: 23.06.2020) and so does the Maltese one according to Baroni Urbani (1968). A comparison with pictures from the Balearic Islands (kindly shared with us by JoseAlberto Fernández) also appears to testify there the presence of the exact same form.

Finally, male morphology (Fig. III) may also be quite distinctive, but the lack of information over the morphological traits of most other species does not allow us to elaborate further.

CHECKLIST AND BIOGEOGRAPHY

By reviewing the existing literature, and especially those new records or taxonomic changes that were published since 2007, and in consideration of the novelties proposed in this paper, we list a total of 77 taxa (Tab. 2). In comparison to the checklist by Verdinelli et al. (2007), we add 10 new species, 4 of which are the result of data presented in this study. Moreover, 5 other species are removed. Most of the species forming the Sardinian ant fauna belong to the subfamily Myrmicinae Lepeletier de Saint-Fargeau, 1835 (57%), about one third to Formicinae Latreille, 1809 (30%) while Dolichoderinae Forel, 1878 and Ponerinae Lepeletier de Saint-Fargeau, 1835 are much smaller groups (about 5% each) and finally Leptanillinae Emery, 1910 represent less than 3%.

Tapinoma magnum Mayr, 1861 is added on the basis of the records published by Seifert et al. (2016). This species was previously considered under the name Tapinoma nigerrimum Nylander, 1856 in Italy (Politi et al., 1995). Verdinelli et al. (2007) had not included T. nigerrimum in their checklist without providing any explanation, however records of this species on the island exist at least since a century (Emery, 1914). On the other hand, the presence of the rarely collected inquiline social parasite Plagiolepis xene Stärcke, 1936, whose host is P. pygmaea (Latreille, 1798), was discovered recently (Lol, 2013). Camponotus universitatis Forel, 1890, Formica clara Forel, 1886 Lasius platythorax Seifert, 1991 and Tapinoma madeirensse Forel, 1895 were recorded for the first time by Rigato & Toni (2011) (alongside T. affinis, but see the new species records section). The presence of T. madeirensse in Sardinia (recorded by Rigato & Toni, 2011) was then implicitly questioned by the following description of its cryptic species T. subboreale Seifert, 2012 from continental Europe (Seifert, 2012) but data later published by Seifert et al. (2016) confirmed the presence of the true T. madeirensse in Sardinia. At the same time, Aphaenogaster florii Emery, 1915 and A. subterranea (Latreille, 1798) were considered absent in Sardinia by Alichata & Schifani (2019) and Galkowski et al. (2019) respectively. Moreover, Rigato & Toni (2011) suggested that all past records of Formica rufibarbis Fabricius, 1793 from Sardinia should be attributed to F. clara instead. In addition, Ponera sulcata Stafani, 1970 (a supposed endemic) was declared to be a junior synonym of the tramp species Hypoponera punctatissima (Roper, 1859) (Bolton & Fisher, 2011) and Leptothorax exilis specularris Emery, 1916 a junior synonym of Temnothorax exilis (Salata et al., 2018). Finally, Wagner et al. (2017) recorded T. immigrans and Seifert (2020) recorded Lasius grandis Forel, 1909 for the first time.

Biogeographically (see Fig. V), the Sardinian ant fauna contains a large number of widely-distributed species (48%): 23% of the Sardinian species fall into the Paleartic distribution category (ASE+CEM+TEM+TUE) and 25% in the European category (EUR+SEU) sensu Vigna Taglianti et al. (1999). It may be worth mentioning that widely distributed European species account for a smaller proportion of taxa among Sardinian ants in comparison to what they do in the context of other faunistic assemblages (Stoch & Vigna Taglianti, 2005). Mediterranean species are only slightly less numerous, amounting to about 45% of Sardinia’s ant species. These are dominated by species with a Western Mediterranean distribution amounting to 32% of the fauna (WME, 8%; ESW, 13%; SARD: 5%; NAW, TYRR and SACO combined: 6%) and circum-Mediterranean species (13%, MED). The distinction between Maghrebian and South-Western European species is highly informative, as 10 species belong to the latter category and only 1 to the first. The prevalence of Sardinian endemics to Sardo-Corsican ones is 4:1 and well-reflects the general traits of the Sardinian biogeography (Baccetti, 1983). Among endemic taxa, it is worth noting that S. sardoum was until recently erroneously considered to extend its distribution to mainland Europe (see Rigato, 2011). Eastern-Mediterranean influences are about completely absent as expected (Schifani & Alichata, 2019). Exotic species are not particularly numerous (6%), although the status of some taxa such as C. mauritanica or even L. niger is unclear and targeted investigations in anthropo-
genic and urban areas are likely to discover additional taxa (SCHIFANI, 2019; BLATRIX et al., 2020).

**Table 2 -** Checklist of Sardinian ants and chorotypes of each species. Subfamilies are indicated by letters: D (Dolichoderinae), F (Formicinae), L (Leptanillinae) and M (Myrmicinae).

| Sf | Species                     | Ch | Sf | Species                     | Ch |
|----|-----------------------------|----|----|-----------------------------|----|
| D  | Linepithema humile (Mayr, 1868) | exotic M | Monomorium subopacum (Smith, F., 1858) | MED |
| D  | Tapinoma madeirensense Forel, 1895 | ESW M | Myrmecina graminicola (Lateille, 1802) | EUR |
| D  | Tapinoma magnus Mayr, 1861 | WME M | Myrmecina melonii Rigato, 1999 | SARD |
| D  | Tapinoma simrothi Krausse, 1911 | MED M | Myrmica spinosior Santschi, 1931 | ESW |
| F  | Camponotus aethiops (Lateille, 1798) | SEU M | Pheidole pallidula (Nylander, 1849) | ESW |
| F  | Camponotus falax (Nylander, 1856) | TEM M | Solenopsis lusitanica Emery, 1915 | WME |
| F  | Camponotus gestroi Emery, 1878 | MED M | Solenopsis ornitha Emery, 1875 | MED |
| F  | Camponotus lateralis (Olivier, 1792) | MED M | Stenamma deblie (Foerster, 1850) | EUR |
| F  | Camponotus piceus (Leach, 1825) | ESW M | Stenamma sardoun Emery, 1915 | SARD |
| F  | Camponotus univittatus Forel, 1890 | SEU M | Stenamma striatulum Emery, 1895 | SEU |
| F  | Camponotus vagus (Scopoli, 1763) | CEM M | Strongylognathus testaceus (Schenck, 1852) | TUE |
| F  | Coleobopsis truncata (Spinola, 1808) | TEM M | Strambigenys argiola (Emery, 1869) | SEU |
| F  | Formica clara Forel, 1886 | ASE M | Strambigenys baudieri (Emery, 1875) | SEU |
| F  | Formica curculiaora Lateille, 1798 | ASE M | Strambigenys membranifer Emery, 1869 | exotic |
| F  | Formica lugubris Zetterstedt, 1838 | exotic M | Strambigenys teniupila Emery, 1915 | SEU |
| F  | Lasius bicornis (Foerster, 1850) | ASE M | Temnothorax aevi (Boudriot, 1918) | ESW |
| F  | Lasius brunneus (Lateille, 1798) | ASE M | Temnothorax exilis (Emery, 1869) | SEU |
| F  | Lasius flavus (Fabricius, 1782) | ASE M | Temnothorax krausei (Emery, 1915) | SEU |
| F  | Lasius emarginatus (Olivier, 1792) | EUR M | Temnothorax lichtensteini (Boudriot, 1918) | SEU |
| F  | Lasius grandis Forel, 1909 | ESW M | Temnothorax mediterraneus Ward et al. 2014 | ESW |
| F  | Lasius lasioides (Emery, 1869) | MED M | Temnothorax nyalandi (Foerster, 1850) | EUR |
| F  | Lasius niger (Linnaeus, 1758) | ASE M | Temnothorax parvulus (Schenck, 1852) | EUR |
| F  | Lasius paraliennus Seifert, 1992 | EUR M | Temnothorax ravouxi (André, 1896) | EUR |
| F  | Lasius platythyrea Seifert, 1991 | ASE M | Temnothorax recedens (Nylander, 1856) | MED |
| F  | Plagiolepis palleceus Forel, 1889 | ASE M | Temnothorax sardos (Santschi, 1909) | SARD |
| F  | Plagiolepis pygmea (Lateille, 1798) | ASE M | Temnothorax tuberum (Fabricius, 1775) | ASE |
| F  | Plagiolepis zene Scbcke, 1936 | ESW M | Temnothorax unifasciatus (Lateille, 1798) | TEM |
| L  | Leptanilla doderoi Emery, 1915 | SARD M | Tetramorium atratum (Schenck, 1852) | TUE |
| L  | Leptanilla revelieri Emery, 1870 | WME M | Tetramorium brevicorne Bondroit, 1918 | SACO |
| M  | Aphaenogaster ichu-us Santschi, 1925 | ESW M | Tetramorium caespitum (Linnaeus, 1752) | EUR |
| M  | Aphaenogaster sordo Mayr, 1853 | NAW M | Tetramorium immigrans Santschi, 1927 | exotic |
| M  | Aphaenogaster sendr Mayr, 1853 | ESW M | Tetramorium meridionale Emery, 1870 | MED |
| M  | Aphanogaster spinosa Emery, 1878 | TYRR M | Tetramorium semilaeve André, 1883 | WME |
| M  | Cardiocondyla mauritania Forel, 1890 | NAF M | Cryptopone ochracea (Mayr, 1855) | TUE |
| M  | Cretemogaster scutellaris (Olivier, 1792) | WME M | Hypoponera eduardi (Forel, 1894) | MED |
| M  | Messor capitatus (Lateille, 1798) | WME P | Hypoponera punctatissima (Roger, 1859) | exotic |
| M  | Messor ibericus Santschi, 1931 | SEU P | Ponera coarctata (Lateille, 1802) | TUE |
| M  | Messor minor (André, 1883) | MED P | Ponera testaceus (Emery, 1895) | EUR |
| M  | Messor wasmanni Krausse, 1910 | EME P | | |

**CONCLUSIONS**

The present study offers several faunistic novelties and a comprehensive summary over the Sardinian ant fauna, in addition to morphological information of general interest for the difficult study of the Mediterranean *Solenopsis*. While the understanding of some ant genera in Sardinia seems quite satisfactory (perhaps even for the enigmatic genus *Leptanilla*, see LEÔ & FANELLO, 1990), the overall picture is definitely far from being conclusive. The number of 79 taxa currently considered to be present is not particularly high. In comparison, Sicily, which is about the same size of Sardinia, is grossly estimated to be inhabited by about 150 species (SCHIFANI & ALICATA, 2018) and the nearby Corsica, less than one third of the size of Sardinia, hosts 91 species according to the latest checklist (BLATRIX et al., 2018; 2020). Even the much smaller island of Crete is thought to be home to 100 taxa (SALATA et al., 2020), while there is no recent estimate for Cyprus. The reason behind this comparatively smaller number is most likely explained in part by still insufficient investigation. The considerable number of new species records recently produced by relatively limited investigation efforts reinforce this idea. At the same time, a role was likely also played by higher biogeographic isolation of Sardinia in comparison with both Corsica and Sicily. Viable connections between Corsica and Tuscany and between Sicily and Calabria are important to explain their current ant fauna assemblages. Many continental species are not found in Sardinia but inhabit Corsica, Sicily or both (e.g. *Myrmica sabuleti* Meinert, 1861, *Aphaenogaster italicus* Bondroit, 1918, *A. subterranea* - see VERDINELLI et al., 2007; SCHIFANI & ALICATA, 2018; SEIFERT, 2018; GALKOWSKI et al., 2019). In addition, Sicily’s high number of species may be explained by Maghrebian and Balkan influxes only marginally able to reach Sardinia (ALICATA & SCHIFANI, 2019; SCHIFANI & ALICATA, 2019; CENTORAME et al., 2020). In particular, *Aphaenogaster sardoa* and *Myrmecina melonii* are the only two elements of the Sardinian fauna that testify an ancient colonization of Southern-Tyrenian species (SCHIFANI et al., 2020c). On the other hand, it is notable that both
Corsica and Sardinia entirely lack the subfamily Proceratiniinae, which is found elsewhere in all neighbouring Mediterranean regions.

Taxonomic uncertainty is already quite evident for some species inhabiting Sardinia (in addition to those mentioned in this paper, see for example the Sardinian *Formica cunicularia* Latreille, 1798 according to SEIFERT & SCHULZ, 2009). Moreover, BLATRIX et al. (2020) proposed to consider the Corsican *T. unifasciatus* populations as a cryptic species (*T. cordieri* Bondroit, 1918) due to spines length and mtDNA differences and suggested that the local form chromatically similar to *L. emarginatus* and morphometrically clustering within *L. granidis* (see SEIFERT, 2020) may be an undescribed cryptic species. Among the endemic species, the status of *T. sardous* requires a proper assessment, as different authors have been treating it either as a good species or as a subspecies of *T. rottenberghi* (Emery, 1870) without presenting any proper argument or discussion (see KRAUSSE, 1912; EMERY, 1914; 1916; 1924; BONDROYT, 1918; BARONI URBANI, 1971; BOLTON, 1995; 2003; FOLDI et al., 1995; BOROWIEC, 2014; VERDINELLI et al., 2007; LEBAS et al., 2016 - in this paper we simply followed the choice made in the last Sardinian checklist by VERDINELLI et al., 2007). Moreover, there are a number of old species records that we maintained in the list but that clearly need to be verified due to the taxonomic advancements of the last years. Good examples can be found for the genera Lasius, *Ponera* and *Temnothorax* which witnessed major taxonomic improvements over the last few decades (e.g. SEIFERT, 2020; CSÖSZ & SEIFERT, 2003; CSÖSZ et al., 2015). The old, isolated finding of *H. punctatissima* could potentially represent instead *H. erigandiandria* (Forel, 1893), a cryptic tramp species whose presence in Italy has never been checked for despite being recorded across Europe (SEIFERT, 2013).

While many novelties are expected from further investigation, the figure regarding the main biogeographical traits of the Sardinian ant fauna that were identified in this paper is unlikely to change dramatically. The present checklist will offer a useful and solid basis to direct future researches.

ACKNOWLEDGEMENTS

We wish to thank Fabrizio Rigato (Museo Civico di Storia Naturale, Milan, Italy) and Ilaria Toni (Bosco Fontana Natural Reserve, Italy) for giving us access to the ant collections of their respective institutions. We also very grateful to the Supervisor Prof. Michela Marignani of Erika Bazzato, PhD project in ‘Earth and Environmental Sciences and Technologies’ of the University of Cagliari, for providing the financial support to fieldwork in the Metropolitan City of Cagliari.

REFERENCES

AGOSTI D., MAIER J., ALONSO L.E., SCHULTZ T., 2000 – *Ants: standard methods for measuring and monitoring biodiversity*. - Smithsonian Institution Press: Washington D.C., U.S.A.

AKTAÇ N., 1988 – *Doğu Anadolu Bölgesi Karançalarının Vertical Dağlımları*. - Proceeding of 9th National Congress of Biology. Vol. 2, Cumhuriyet University, Sivas, Turkey.

ALICATA A., SCHIFANI E., 2019. – *Three endemic Aphaenogaster from the Siculo-Maltese archipelago and the Italian Peninsula: part of a hitherto unrecognized species group from the Maghreb* (Hymenoptera: Formicidae: Myrmicinae). - Acta Entomologica Musei Nationalis Pragae, 59: 1-16.

ANDRÉ E., 1885 – 1881-1886. *Species des Hyménoptères d’Europe et d’Algérie. Tome Deuxième*. Beaune: Edmond André.

ARNA N X., RODRIGO A., RETANA J., 2007 – *Uncoupling the effects of shade and food resources of vegetation on Mediterranean ants: an experimental approach at the community level*. - Ecography, 30: 161-172.

BACCETTI B., 1983 – *Biogeografia sarda venti anni dopo*. - Biogeografia, 8: 859-870.

BARONI URBANI C., 1968 – Studi sulla mirmecofauna d’Italia. IV. La fauna mirmecologica delle isole Maltesi ed il suo significato ecologico e biogeografico. - Annali del Museo Civico di Storia Naturale Giacomo Doria, 77: 408-559.

BACCHetta G., BAGELLA S., BIOND E., FARRIS E., FILIGHEddU R., MOSSA L., 2009 – *Vegetazione forestale e serie di vegetazione della Sardegna (con rappresentazione cartografica alla scala 1:350.000).* – Fitosociologia, 46: 3-82.

BARONI URBANI C., 1971 – *Catalogo delle specie di Formicidae d’Italia*. (Studi sulla mirmecofauna d’Italia). - Memorie della Società Entomologica Italiana, 50: 5-287.

Bazzato E., ROSATI L., CANU S., FIORI M., FARRIS E., MARIGNANI, M., 2021 – *High spatial resolution bioclimatic variables to support ecological modelling in a Mediterranean biodiversity hotspot*. - Ecological Modelling, 441: 109354.

BLATRIX R., COLINDRE L., WEGNEZ P., GALKOWSKI C., COLIN T., 2018 – *Atlas des fourmis de Corse*. - Editions de l’Office de l’Environnement de la Corse. Corte, 148 pp.

BLATRIX R., AUBERT C., DECAENS T., BERQUIER C., ANDREI-RIUZ M.C., GALKOWSKI C. 2020 – *Contribution of a DNA barcode for assessing the specificity of ant taxa (Hymenoptera: Formicidae) in Corsica*. - European Journal of Entomology, 117: 420-429.

BOLTON B., 1995 – *A new general catalogue of the ants of the world*. - Harvard University Press, 504 pp.

BOLTON B., 2003 – *Synopsis and classification of Formicidae*. - Memoirs of the American Entomological Institute, 71: 1-370.

BOLTON B., FISHER B. L., 2011 – *Taxonomy of afrotropical and west palaearctic ants of the ponerine genus Hypoponera Santschi (Hymenoptera: Formicidae)*. – Zootaxa, 2843: 1-118.

BONDROY T., 1918 – *Les fourmis de France et de Belgique*. - Annales de la Société Entomologique de
France, 87: 1-174.
BOROWIEC L., 2014 – Catalogue of ants of Europe, the Mediterranean Basin and adjacent regions (Hymenoptera: Formicidae). - Genus, 25: 1-340.
BOROWIEC L., GALKOWSKI C., SALATA S., 2015 – What is Tetramorium semilaeve André, 1883? (Hymenoptera, Formicidae). - ZooKeys, 512: 39-62.
BRACKO G., 2007 – Checklist of the ants of Slovenia (Hymenoptera: Formicidae). - Natura Sloveniae, 9: 15-24.
BRACKO G., 2017 – First discoveries of colonies of the rare ant species Camponotus tergestinus Müller, 1921 (Hymenoptera: Formicidae) in situ. - Natura Sloveniae, 19: 5-14.
BRANDMAYR P., ZETTO T., PEZZOLOTTO R. 2005 – I coleotteri carabidi per la valutazione ambientale e la conservazione della biodiversità: manuale operativo. - APAT. Manuali e Linee guida: Rome, Italy.
BUSCHINGER A., EHRHARDT W., FISCHER K., OFER J., 1988 – The slave-making ant genus Chalceopoxenus (Hymenoptera, Formicidae). I. Review of literature, range, slave species. - Zoologische Jahrbücher, Abteilung für Systematik, Geographie und Biologie der Tiere, 115: 383-401.
CAMPOLO O., PALMERI V., MALACRINÒ A., LAUDANI F., CASTRACANI C., MORI A., GRASSO D.A., 2015 - Interaction between ants and the Mediterranean fruit fly: New insights for biological control. - Biological Control, 90: 120-127.
CASEVITZ-WEULERSSE J., GALKOWSKI, C., 2009 – Liste actualisée des fourmis de France (Hymenoptera, Formicidae). - Bulletin de la Société entomologique de France, 114: 475-510.
CASTRACANI C., GRASSO D.A., FANFANI A., MORI A., 2010 – The ant fauna of Castelporziano Provincial Reserve (Rome, Italy) as a model for the analysis of ant community structure in relation to environmental variation in Mediterranean ecosystems. - Journal of Insect Conservation, 14: 585-594.
CASTRACANI C., BULGARINI G., GIANNETTI D., SPOTI F.A., MAISTRELLI L., MORI A., GRASSO D.A., 2017 – Predatory ability of the ant Crematogaster scutellaris on the brown marmorated stink bug Halyomorpha halys. - Journal of Pest Science, 90: 1181-1190.
CASTRACANI C., SPOTI F.A., SCHIFANI E., GIANNETTI D., GHIZZONI M., GRASSO D.A., MORI A., 2020 – Public engagement provides first insights on Po Plain ant communities and reveals the ubiquity of the cryptic alien Tetramorium immigrans (Hymenoptera, Formicidae). - Insects, 11: 678.
CENTORAME M., ANGELINO D., BONANNI R., FANFANI A., 2020 – Static and evolutionary allometry in the Italian endemic ant species Cataglyphis italicus (Emery 1906). - Ethology Ecology & Evolution, 32: 16-28.
COLLINGWOOD C.A., YARROW I.H.H., 1969 – A survey of Iberian Formicidae. - Eos, Revista Española de Entomología, 44: 53-101.
COLLINGWOOD C.A., PRINCE A., 1998 – A guide to ants of continental Portugal (Hymenoptera: Formicidae). - Sociedade Portuguesa de Entomologia.
CONSANI M., ZANGHERI P., 1952 – Fauna di Romagna. Imenotteri – Formicidi. - Memorie della Società Entomologica Italiana, 31: 38-48.
CSÓSZ S., SEIFERT B., 2003 – Ponera testacea Emery, 1895 stat n.–a sister species of P. coarctata (Lateille, 1802) (Hymenoptera, Formicidae). - Acta Zoologica Academiae Scientiarum Hungaricae, 49: 201-214.
CSÓSZ S., RADCHENKO A., SCHULZ A., 2007 – Taxonomic revision of the Palaearctic Tetramorium cheffeki species complex (Hymenoptera: Formicidae). - Zootaxa, 1405: 1-38.
CSÓSZ S., SCHULZ A., 2010 – A taxonomic review of the Palaearctic Tetramorium ferox species-complex (Hymenoptera, Formicidae). - Zootaxa, 2401: 1-29.
CSÓSZ S., HEINZE J., MIKÓ I. 2015 - Taxonomic synopsis of the Ponto-Mediterranean ants of Temnothorax nylanderi species-group. - PloS One, 10: e0140000.
DAPPORTO, L., CINI A., MENCHETTI M., VODÀ R., BONELLI S., CASACCI L. P., DENCÀ V., SCALERCIO S., HINOJOsa J.C., BERMANN H., FIORBONI L., MAZZANTINI U., VENTURI L., ZANCHIELLI F., BALLETTO E., SHREEVE T.G., DENNIS R.L.H., VILA R. 2017 – Rise and fall of island butterfly diversity: Understanding genetic differentiation and extinction in a highly diverse archipelago. - Diversity and Distributions, 23: 1169-1181.
DASH S.T., & SANCHEZ L., 2009 – New distribution record for the social parasitic ant Anergates atratus (Schenck, 1852) (Hymenoptera: Formicidae): an IUCN red-listed species. - Western North American Naturalist, 69: 140-141.
DLSUSKY G.M., RADCHENKO A.G., 1994 – Ants of the genus Diplorhoptrum (Hymenoptera, Formicidae) from the central Palearctic. - Zoologicheski Zhurnal, 73: 102-111.
EMERY C., 1875a – Ueber hypogaecae Ameisen. - Stettiner Entomologische Zeitung, 37: 71-76.
EMERY C., 1875b – Le formiche ipogee con descrizioni di specie nuove o poco note. - Annali del Museo Civico di Storia Naturale, 7: 465-474.
EMERY C., 1909 – Beiträge zur Monographie der Formiciden des paläarktischen Faunengebietes. (Hym.) Teil VI. - Deutsche Entomologische Zeitschrift: 19-37.
EMERY C., 1914 – Wissenschaftliche Ergebnisse der Bearbeitung von O. Leonhard’s Sammlungen. 5. Südeuropäische Ameisen (Hym.). - Entomologische Mitteilungen, 3:156-159.
EMERY C., 1915 – Contributo alla conoscenza delle formiche delle isole italiane. Descrizioni di forme mediterranee nuove o critiche. - Annali del Museo Civico di Storia Naturale Giacomo Doria, 6: 244-270.
EMERY C., 1916 – Fauna entomologica italiana. I. Hymenoptera.-Formicidae. - Bollettino della Società Entomologica Italiana, 47: 79-275.
Emery C., 1924 – Hymenoptera. Fam. Formicidae. Subfam. Myrmicinae. [concl.]. - Genera Insectorum, 174: 207-397.

Espadaler X., López-Soria L., 1991 – Rariness of certain Mediterranean ant species: fact or artifact? - Insectes Sociaux, 38: 365-377.

Espadaler X., García F., Roig X., Vila R., 2013 – rion & Fernández (2009). - Journal of Biogeography, 37: 2211-2213.

Fattorini S., 2009 – Both Recent and Pleistocene geography determine animal distributional patterns in the Tuscan Archipelago. - Journal of Zoology, 277: 291-301.

Finzi, B., 1940 – Formiche della Libia. - Memorie della Società Entomologica Italiana, 18: 155-166.

Forel. A., 1890 – Fourmis de Tunisie et de l’Algérie orientale. - Annales de la Société Entomologique de Belgique, 34: 61-76.

Forel. A., 1905 – Miscellanea myrmécologiques II. - Annales de la Société Entomologique de Belgique, 49: 155-185.

Forel. A., 1907 – Fourmis nouvelles de Kairouan et d’Orient. - Annales de la Société Entomologique de Belgique, 51: 201-208.

Galkowski C., Casevitz-Weulersse J., Cagniant H., 2010 – Redescription of Solenopsis fugax (Latreille, 1798) et notes sur les Solenopsis of France. - Revue française d’Entomologie, 32: 151-163.

Galkowski C., Aubert C., Blatrix R., 2019 – Aphaenogaster ichnusa Santschi, 1925, bona species, and redescription of Aphaenogaster subterranea (Latreille, 1798) (Hymenoptera, Formicidae). - Sociobiology, 66: 420-425.

Giannetti D., Castracani C., Spotti F.A., Mori A., Grasso D.A., 2019 – Gall-Colonizing Ants and Their Role as Plant Defenders: From ‘Bad Job’ to ‘Useful Service’. - Insects, 10, 392.

Giannetti D., Mandrioli M., Schifani E., Castracani C., Spotti F.A., Mori A., Grasso D.A., 2021 – First Report on the Acrobat Ant Cretemogaster scutellaris Storing Live Aphids in Its Oak-Gall Nests. - Insects, 12, 108.

Glancey B.M., Vander Meer R.K., Glover A., Lofgren C.S., 1980 – Observations of intercasts in Solenopsis invicta Buren. - Florida Entomologist, 63: 346-350.

Grandi G., 1935 – Contributi alla conoscenza degli Imenotteri Aculeati. XV. - Bollettino dell’Istituto di Entomologia della Regia Università degli Studi di Bologna, 8: 27-121.

Grill A., Casula P., Lecis R., Menken S., 2007 – Endemism in Sardinia. In: Phylogeography of Southern European refugia, Weiss S. & Ferrand N., Ed., Springer, Dordrecht, pp. 273-296.

Guénard B., Weiser M., Gómez K., Narula N., Economo E.P., 2017 – The Global Ant Biodiversity Informatics (GABI) database: a synthesis of ant species geographic distributions. - Myrmecological News, 24: 83-89.

Hernández-Cuba O., Pérez-Bote J.I., García J., 2006 – Los Formícidos (Hymenoptera: Formicidae) Hormigas (Hymenoptera, Formicidae) del Parc del Castell de Montseguí (Osona, noreste de la península Ibérica). - Boletín de la Sociedad entomológica Aragonesa, 53: 223-227.

Farris E., Filibeck G., Marignani M., Rosati L., 2010 – The power of potential natural vegetation (and of spatial-temporal scale): a response to Car-del Parque Natural de Cornalvo (suroeste de la Península Ibérica). - Boletín de la Sociedad Entomológica Aragonesa, 38: 356-358.

Hölldobler B., Wilson E.O., 1990 – The ants. - Harvard University Press: Cambridge, U.S.A.

Janicki J., Narula N., Ziegler M., Guénard B., Economo E.P. 2016 – Visualizing and interacting with large-volume biodiversity data using client-server web-mapping applications: The design and implementation of antmaps.org. - Ecological Informatics, 32: 185-193.

Krause A.S., 1912 – Ueber sardische Ameisen. - Archiv für Naturgeschichte, 78: 162-166.

Lach L., Parr C., Abbott K., 2010 – Ant ecology. - Oxford University Press: Oxford, U.K.

Lebas C., Galkowski C., Blatrix R., Wegnez P., 2016 – Guide Delachaux: Fourmis d’Europe occidentale. - Delachaux et Niestlé, 415 pp.

Leo P., Fancello L., 1990 – Osservazioni sul genere Leptanilla Emery in Sardegna e riabilitazione di L. doderoi Emery. - Bollettino della Società Entomologica Italiana, 122: 128-132.

Loi A., Luciano P., Gilioli G., Bodini A., 2012 – Lasius brunneus (Formicidae Formicinae) and Stomaphis quercus (Aphidoidea Aphididae): trophobionts harmful to cork oak forest in Sardinia (Italy). - Redia, 95: 21-29.

Loi A., 2013 – Osservazioni sulla mirmecofauna e l’afidofauna della quercia da sughero in Sardegna. - Doctoral Thesis at the University of Sassari.

 Médail F., Quezel P. 1997 – Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. - Annals of the Missouri Botanical Garden, 84: 112-127.

 Médail F., 2017 – The specific vulnerability of plant biodiversity and vegetation on Mediterranean islands in the face of global change. - Regional Environmental Change, 17: 1775-1790.

Mei M., 1995 – Arthropoda of Lampedusa, Linosa and Pantelleria (Cenale di Sicilia, Mar Mediterraneo). Hymnoptera Formicidae (con diagnosi di due nuove specie). – Il Naturalista Siciliano, 19: 753-772.

Palumbo M.E., Mundula L., Ballotto G., Bazzato E., Marignani M., 2020 – Environmental Dimension into Strategic Planning. The Case of Metropolitan City of Cagliari. In: Gervasi O. et al. (eds) Computational Science and Its Applications – ICCSA 2020. ICCSA 2020. Lecture Notes in Computer Science, vol 12255. Springer, Cham.

Parezan P., 1994 – Proposta di codificazione per una gestione informatica dei corotipi W-paleartici, con particolare riferimento alla fauna italiana. - Entomologica, 28: 93-98.

Peeters C.P., 1991 – Ergatoid queens and intercasts in ants: two distinct adult forms which look...
morphologically intermediate between workers and winged queens. - Insectes Sociaux, 38: 1-15.

Pisarski B., 1967 – Fourmis (Hymenoptera: Formicidae) d’Afghanistan récoltées par M. Dr. K. Lindberg. - Annales Zoologici, 24: 375-425.

Plateaux L., Cagniant H., 2012 – Quelques synonymies dans le genre Temnothorax Mayr, 1855 (Hymenoptera, Formicidae).- Bulletin de la Société entomologique de France, 117: 427-440.

Poldi B., 1992 – A poorly known taxon: Diplorhoptrum orbulum (Emery 1875). - Ethology Ecology & Evolution, 4: 91-94.

Poldi B., Mei M., Rigato F., 1995 – Hymenoptera Formicidae. - In: Checklist delle Specie della Fauna Italiana, A. Minelli, S. Ruffo, S. & La Posta Ed., Calderini, Bologna, pp. 1-10.

Rigato F., Toni L., 2011 – Short notes 21. Hymenoptera, Formicidae.- Research in the framework of the ICP Forests network. Conservazione Habitat Invertebrati, 5: 873-882.

Rigato F. 2011 – Contributions to the taxonomy of West European and North African Stenamma of the westwoodii species-group. (Hymenoptera Formicidae). - Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano, 37: 1-56.

Rigato F., Wetterer J.K., 2018 – Ants (Hymenoptera: Formicidae) of San Marino. - Natural History Sciences, 5.

Salata S., Borowiec L., Trichas A., 2018 – Taxonomic revision of the Cretan fauna of the genus Temnothorax Mayr, 1861 (Hymenoptera: Formicidae), with notes on the endemism of ant fauna of Crete. - Annales Zoologici, 68: 769-808.

Salata S., Borowiec L., Trichas A., 2020 – Review of ants (Hymenoptera: Formicidae) of Crete, with keys to species determination and zoogeographical remarks. - Monographs of the Upper Silesian Museum, 12: 5-296.

Santschi F., 1934 – Contribution aux Solenopsis paléarctiques. - Revue Suisse de Zoologie, 41: 565-592.

Santschi F., 1936 – Liste et descriptions de fourmis du Maroc. - Bulletin de la Société des Sciences Naturelles du Maroc, 16:198-210.

Sanetra M., Gütsten R., Schulz A., 1999 – On the taxonomy and distribution of Italian Tetramorium species and their social parasites. - Memorie della Società Entomologica Italiana, 77: 317-357.

Schar S., Menchetti M., Schifani E., Hinojoa J.C., Platania L., Dappporto L., Vila R., 2020 – Integrative biodiversity inventory of ants from a Sicilian archipelago reveals high diversity on young volcanic islands (Hymenoptera: Formicidae). - Organisms Diversity and Evolution, 20: 405-416.

Schembri S.P., Collingwood C.A., 1981 – A revision of the myrmecofauna of the Maltese Islands (Hymenoptera, Formicidae). - Annali del Museo Civico di Storia Naturale Giacomo Doria, 83: 417-442.

Schifani, E., 2017 – First record of the vulnerable social parasite ant Plagiolepis grassei in Italy (Hymenoptera: Formicidae). - Fragmenta entomologica, 49: 61-64.

Schifani E., Alicata A., 2018 – Exploring the myrmecofauna of Sicily: thirty-two new ant species recorded, including six new to Italy and many new aliens (Hymenoptera, Formicidae). - Polish Journal of Entomology, 87: 323-348.

Schifani E., Alicata A., 2019 – Aphaenogaster finzi Müller, 1921, a trans-Ionian species new to Italy (Hymenoptera, Formicidae). - Biogeographia, 34: 51-57.

Schifani E. 2019 – Exotic ants (Hymenoptera, Formicidae) invading Mediterranean Europe: a brief summary over about 200 years of documented introductions. - Sociobiology, 66: 198-208.

Schifani E., Castracani C., Giannetti D., Spotti F.A., Reggiani R., Leonardi S., Mori A., Grasso D.A., 2020a – New Tools for Conservation Biological Control: Testing Ant-Attracting Artificial Nectaries to Employ Ants as Plant Defenders. - Insects, 11: 129.

Schifani E., Castracani C., Spotti F.A., Giannetti D., Ghizzoni M., Gobbi M., Pedrotti L., Grasso D.A., Mori A., 2020b – Ergatandromorphism in the Ant Myrmica ibolucinoris Nylander, 1857 (Formicidae: Myrmicinae). - Sociobiology, 67: 330-334.

Schifani E., Scupola A., Alicata A., 2020c – Morphology, ecology and biogeography of Myrmecina sicula André, 1882, rediscovered after 140 years (Hymenoptera, Formicidae). - Biogeography, 35: 105-116.

Schneider C.A., Rasband W.S., Eliceiri K.W., 2012 – NIH Image to ImageJ: 25 years of image analysis. - Nature Methods, 9: 671-675.

Schulz A., Heinze J., Pusch, K., 2007 – Description of two new Temnothorax species (Hymenoptera: Formicidae) from Italy. - Zootaxa, 1471: 1-14.

Scupola A., 2018 – Le formiche del Veneto. - WBA Handbooks, 9, 336.

Seifert B., Schultz R., 2009 – A taxonomic revision of the Formica rubifibris Fabricius, 1793 group (Hymenoptera: Formicidae). - Myrmecological News, 12: 255-272.

Seifert B., 2012 – Clarifying naming and identification of the outdoor species of the ant genus Tapinoma Förster, 1850 (Hymenoptera: Formicidae) in Europe north of the Mediterranean region with description of a new species. - Myrmecological News, 16: 139-147.

Seifert B., 2013 – Hypoponera ergatandria (Forel, 1893) – a cosmopolitan trapn species different from H. punctatissima (Roger, 1859) (Hymenoptera: Formicidae). - Soil Organisms, 85: 189-201.

Seifert B., D’Eustacchio D., Kaufmann B., Centorame M., Lorite P., Modica M., 2017 – Four species within the supercolonial ants of the Tapinoma nigerriimum complex revealed by integrative taxonomy (Hymenoptera: Formicidae). - Myrmecological News, 24: 123-144.

Seifert B., 2018 – The Ants of Central and North Europe. - Lutra Verlags- und Vertriebsgesellschaft: 34
ANTS OF SARDINIA: AN UPDATED CHECKLIST BASED ON NEW FAUNISTIC, MORPHOLOGICAL AND...

Seifert B., 2020 – A taxonomic revision of the Palaearctic members of the subgenus Lasius s. str. (Hymenoptera, Formicidae). - Soil Organisms, 92: 15-86.

Sharaf M.R., Taylor B., Klingenberg C., 2009 – Ants of the genus Solenopsis Westwood, 1840 (Hymenoptera: Formicidae) in Egypt with description of the worker caste of S. cooperi Donisthorpe, 1947. - Zootaxa, 2004: 49-58.

Social Insects Specialist Group, 1996 – Plagiolepis grassei. The IUCN Red List of Threatened Species 1996: e.T17464A7087398.

Steiner F.M., Csösz S., Markó B., Gamisch A., Rinnhofer L., Fölterbauer C., Hammerle S., Stauffer C., Athofer W., Schlick-Steiner B.C., 2018 – Turning one into five: integrative taxonomy uncovers complex evolution of cryptic species in the harvester ant Messor “structor”. - Molecular phylogenetics and evolution, 127: 387-404.

Stoch F., Vigna Taglianti A., 2005 – I corotipi della fauna italiana. Checklist e distribuzione della fauna italiana. - Memorie del Museo Civico di Storia Naturale di Verona, 2: 25-28.

Tinaut A., 2016 – Formicidos del Parque Natural de las sierras de Tejeda, Almijara y Alhamia (Andalucía, España) (Hymenoptera, Formicidae). - Boletín Asociación española Entomología, 40: 125-159.

Tohmé G., 1969 – Description d’espèces nouvelles de fourmis au Liban (Hymenoptera Formicoidea). – Publications de l’Université Libanaise, Section des Sciences Naturelles, 7: 1-15.

Tohmé H., Tohmé G., 1980 – Les fourmis du genre Solenopsis en Syrie. Description de deux nouvelles sous-espèces et d’ailés inédits. Notes biogéographiques et systématiques. - Revue Française d’Entomologie, 2: 129-137.

Verdinelli M., Sassu A., Molinu A., Fois X., 2007 – An updated list of Sardinia’s ants (Hymenoptera Formicidae). - Redia, 90: 61-66.

Vigna Taglianti A., Audisio P.A., Biondi M., Bologna M. A., Carpaneto G. M., De Biase A., Fattorini S., Piattella E., Sindaco R., Venchi A., Zapparoli M., 1999 – A proposal for a chorotype classification of the Near East fauna, in the framework of the Western Palaearctic region. - Biogeographia, 20: 31-59.

Vonshak M., Ionescu-Hirsch A., 2009 – A checklist of the ants of Israel (Hymenoptera: Formicidae). - Israel Journal of Entomology, 39: 33-55.

Wagner H.C., Athofer W., Seifert B., Muster C., Steiner F.M., Schlick-Steiner B.C., 2017 Light at the end of the tunnel: Integrative taxonomy delimits cryptic species in the Tetramorium caespitum complex (Hymenoptera: Formicidae). - Myrmecological News, 25: 95-129.

Zhang Y.M., Vitone T., Storer C.G., Payton A.C., Dunn R.R., Hulcr J., McDaniel S.F., Lucky A., 2019 - From Pavement to Population Genomics: Characterizing a Long-Established Non-native Ant in North America Through Citizen Science and ddRADseq. - Frontiers in Ecology and Evolution, 7: 453.